CIRCLE ECONOMY

The CIRCULARITY GAP Report
Norway

Methodology Document

CIRCLE ECONOMY

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Summary

This methodology document is meant to provide all the technical details behind our assessment of the circular state of the Norwegian economy. The document is structured around the 4 key analytical elements (deliverables) of the National Circularity Gap Report (CGR), namely:

1. Material Flow Accounting (MFA)
2. National Circularity Index (NCI)
3. Scenario modelling through Input/Output Analysis (IOA)
4. Visualizations - Sankey Diagram (SD) and Mass-Carbon-Value nexus (MCV)

Figure 1 shows a schematic depiction of the link between data sources and project deliverables.

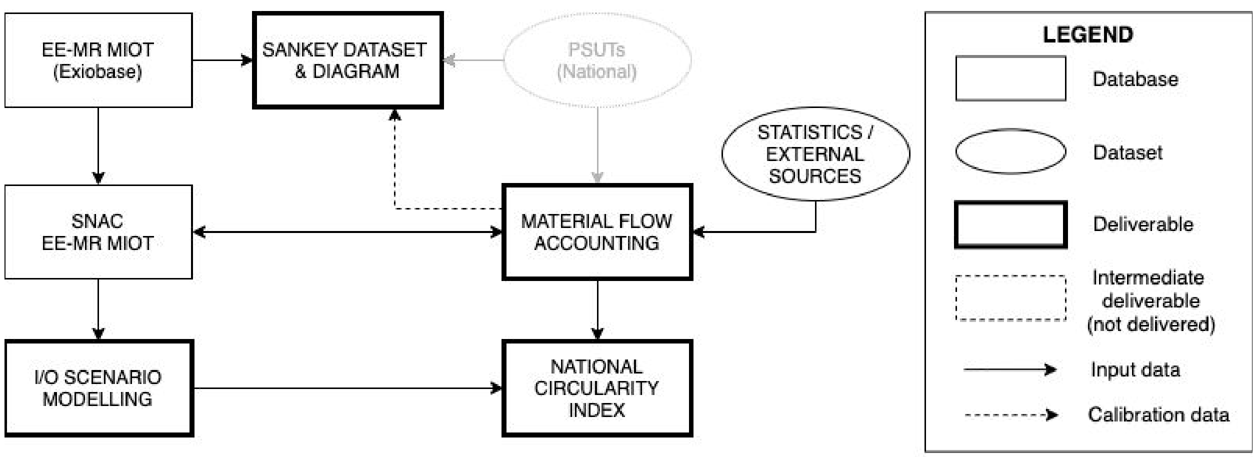


Figure 1. *Flowchart of data and deliverables*

In short, the analytical scope of the report is to provide a good understanding of flows and stocks of raw materials in Norway for 2017 as well as insights into how they can be made more circular. The ***accounting*** (MFA) and ***mapping*** (Sankey Diagram) efforts form the basis for the ***measuring*** step which is expressed by a single headline indicator termed "National Circularity Index" (NCI). This indicator reveals the degree of circularity of a region from a consumption and life-cycle perspective. The MFA balance is closed in respect to each resource group and resource-specific circularity indices are estimated. Flows in Raw Material Equivalents (RMEs) are estimated using a novel custom model and validated by a cross-comparison with IRP and Eurostat estimates. Accounting and mapping also form the basis for the scenario ***modelling*** step, which results are in turn reflected on the NCI providing new inputs for measuring.

1. Material Flow Accounting

The Economy-Wide Material Flow Accounting (EW-MFA) technique is an effective tool to provide an high-level overview and understanding of the socioeconomic metabolism of the system under analysis. We perform a simplified EW-MFA of Norway for the year 2017 following key guidelines from the Eurostat manual[1], focusing on 4 key resource groups (biomass, fossil fuels, metal ores and non-metallic minerals) and excluding O_2 and H_2O. We integrate the standard practice of looking at direct flows of products with the inclusion of indirect (or hidden) flows of raw materials derived through IO techniques. This involves gathering and processing a vast amount of physical flow data such as imports of product, emissions and stock additions, among the others. Whenever available, Physical Supply and Use Tables (PSUTs) are used, almost all data used in the MFA was retrieved from the Norwegian statistical bureau (SSB). Below, an exhaustive list of the datasets employed is provided together with their source:

- Economy-wide material flow accounts. Domestic extraction (1 000 tonnes), by type of material, contents and year (10221)
- Economy-wide material flow accounts. Natural resources, products and waste, by import/export and product classification (1 000 tonnes) 1990 - 2018 (10321)
- Treatment of waste from construction, rehabilitation and demolition of buildings, by material and treatment (tonnes) 2013 - 2018 (09781)
- Household waste, by material and treatment (M) 2015 – 2019 (12313)
- Waste in the manufacturing industries, by industry (SIC2007), material and treatment (1 000 tonnes) 2008 – 2015 (08604)
- Waste from service industries, by section (SIC2007) and material (tonnes) (07355)
- Imports and exports of waste by trading partner https://miljostatus.miljodirektoratet.no/Tema/Avfall/Import-og-eksport-av-avfall
- Transboundary shipments of notified waste by partner, hazardousness and waste management operations [env_wasship]
- Material flows for circular economy – Sankey diagram data [env_ac_sd]

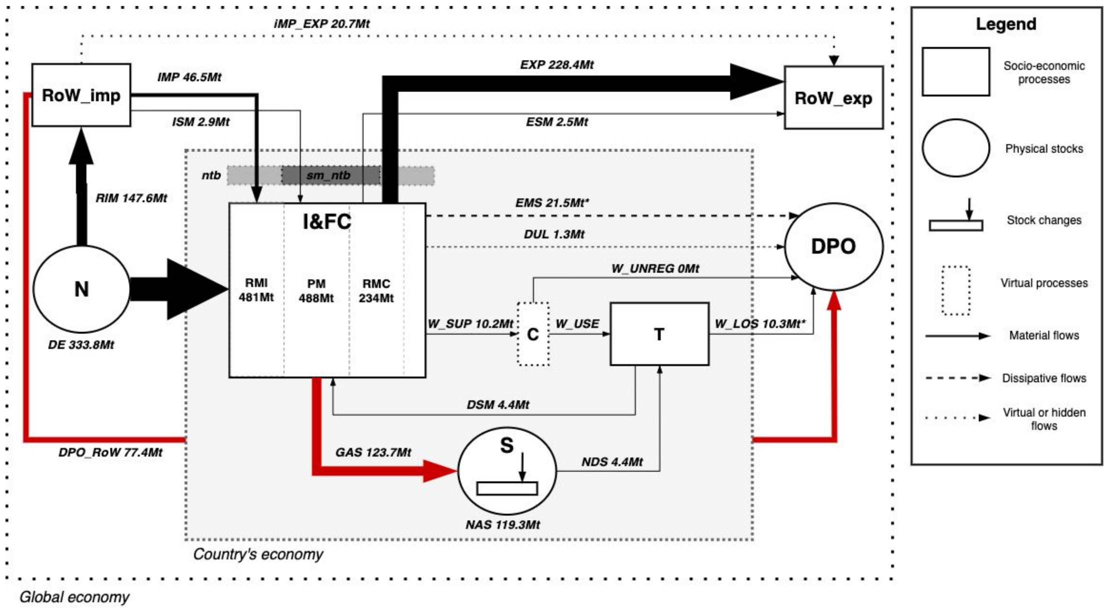
[1] Eurostat (2001). Economy-wide Material Flow Accounts and Derived Indicators – A Methodological Guide. Luxembourg - https://bit.ly/2TSMYHJ;

- Greenhouse gases from Norwegian economic activity, by pollutant, year, industry and contents (09288)
- Average composition of European Domestic Processed Output [env_ac_mfa]

Flows in Raw Material Equivalents (RMEs) are obtained from Circle Economy's novel Single-country National Account Consistent (SNAC) Exiobase model which is described in detail in **Chapter 3**.

Building upon the system definition laid out in the document *"Measuring & Mapping Circularity - Technical methodology document"*, **Figure 2** presents an updated version of the flowchart displaying aggregated material flows (in million tonnes) and stocks in Norway (the numbers may not add up due to rounding). Two new "virtual" flows termed "DPO_RoW" (Domestic Processed Output Rest of the World") and "IMP_EXP" (imports used in the production of exports) were introduced to more accurately account for processes occuring in foreign countries as a result of Norwegian demand. The mass balancing is performed largely according to the formulas presented in the same methodology document, with the only difference being that the balance is closed in respect to Net Addition to Stock (NAS) rather than "Dissipative Uses and Losses" (DUL). This change was implemented due to the scarce and uncertain data on Norwegian material stocks and entailed the estimation of dissipative uses and losses based on external data. The EU28 average share of "dissipative use of products" and "dissipative losses" in the Domestic Processed Output (DPO) was taken as reference for such estimation.

Figure 2. *System definition of national material inflows, outflows and stocks, own elaboration based on Aguilar-Hernandez et al. (2019)[2]*



Flows *- **DE**: Extraction of natural resources, **IMP**: Imports, **EXP**: Exports, **IMP_EXP**: Imports used in production of exports, **EMS**: Emissions, **DUL**: Dissipative Uses and Losses, **GAS**: Gross Additions to Stock, **NDS**: Net Depletions from Stock, **W_SUP**: Supplied or generated waste, **W_USE**: Treated waste, **DSM**: Domestic Secondary Materials (recovered waste), **ISM**: Imported Secondary Materials, **ESM**: Exported Secondary Materials, **W_LOS**: Lost waste, **W_UNREG**: Unregistered waste, **DPO_RoW**: Domestic Processed Output abroad*

Socio-economic processes *– **RoW_Imp**: Economies of import, **RoW_Exp**: Economies of export, **I&FC**: Intermediate and final consumption, **T**: Waste treatment sectors*

Virtual flows and processes *- **RIM**: Raw Materials Equivalents of imports, **REXP**: Raw Materials Equivalents of exports, **ntb**: Net trade balance, **sm_ntb**: Net trade balance of secondary materials, **C**: Waste collection*

Physical stocks *– **N**: Natural stocks of resources, **S**: Socio-economic stocks of products, **DPO**: Domestic Processed Output*

[2] Aguilar-Hernandez, G. A., Sigüenza-Sanchez, C. P., Donati, F., Merciai, S., Schmidt, J., Rodrigues, J. F., & Tukker, A. (2019). The circularity gap of nations: A multiregional analysis of waste generation, recovery, and stock depletion in 2011. Resources, Conservation and Recycling, 151, 104452.

Table 1. *List of particular material flows accounted and their inclusion/exclusion from the metric*

Material flow	Accounted	Included	Description
Water (H_2O)	✓	X	All flows expressed in dry matter content
Oxygen (O_2) and Nitrogen (N_2) in air	✓	X	No oxygen intake from the input side and calculation of combustion flows (e.g. CO_2) back to their elemental weights (C) on the output side
Dredging spoils (excavated soil)	✓	X	Unused domestic extraction excluded
Mining waste (waste rocks)	✓	✓	Run-of-Mine (RoM) concept, metals in gross ore content
Sewage (general wastewater treatment)	✓	X	General WWT not accounted as “circular”, only biogasification of sewage
Manure (land application and biogasification)	✓	✓	Feedback to economy and not to environment (suggested)
Backfilling materials (sand, rubble, aggregates, etc.)	✓	✓	–
Landfilled materials	✓	✓	Flow to DPO and not to stock (suggested)
Materials to energy recovery	✓	✓	Count as “cycled materials” as long as CHP efficiency >65%

2. National Circularity Index

This section is an extract from the position paper co-published by PBL, CBS and CE entitled “Circulair materiaalgebruik in Nederland”[3]. There are 4 key methodological choices in the calculation of the National Circularity Metric (NCI):

1. Which materials are counted?
2. Is the indicator based on a production or consumption perspective?
3. Is the indirect use of raw materials included?
4. What is included in the input of secondary materials?

Depending on how these issues are dealt with, the final figure will change considerably. **Table 2** and **Table 3** summarise the positioning of the NCI in relation to these choices and the scores under some of the combinations, respectively. For some of them, a more detailed discussion is given below.

Table 2. *NCI core traits*

	NCI
1) Which materials are counted?	
- All materials	Dark green
- Without biomass and fossil fuels	Light green
- One indicator for each resource group	Dark green
2) Is the indicator based on a production or consumption?	
- Production	Light green
- Consumption	Dark green
3) Is indirect use of raw materials included?	
- Direct use	Light green
- Chain (or life-cycle) approach	Dark green
4) What is included in the input of secondary materials?	
- Waste imports for recycling	Dark green
- Waste exports for recycling	Red
- Share of secondary materials embodied in imports	Dark green

Dark green: Fully included
Light green: Calculated but not included
Red: Not included

[3] For the integral report visit: https://www.cbs.nl/nl-nl/achtergrond/2020/23/notitie-circulair-materiaalgebruik-in-nederland

Table 3. *NCI results under different variants*

	Consumption perspective, all materials	Consumption perspective, except biomass and fossil fuels	Production perspective, all materials	Production perspective, except biomass and fossil fuels
Biomass	**4.9%**	-	4.9%	-
Fossil Fuels	**0.2%**	-	0.2%	-
Metal Ores	**5.8%**	5.8%	5.8%	5.8%
Nonmetallic Minerals	**1.6%**	1.6%	1.5%	1.5%
Weighted average	**2.4%**	2.3%	1.5%	2.1%

The headline NCI (in bold) is calculated taking into account all materials, including those that are not fully cyclable such as biomass and fossil fuels. The NCI is based on a “chain” or “life-cycle” approach (indirect RME flows are also included) and on a consumption-based accounting (exports are subtracted from total input). In the trade dynamic, we allocate the imports and exports of waste destined for recycling to the importing country, thereby putting emphasis to the recycling process within the national economy. We also strive to account for the share of secondary materials in imported products in the total amount of consumed secondary materials.

Due to the absence of extensive data on the trade and consumption of secondary materials we estimate them by introducing 2 assumptions:

1. For estimating the volume of secondary materials imported, we apply the average Global Circularity Index (GCI) calculated per resource group to the net direct imports of the country (aggregated by resource group). Because the GCI includes waste for recycling and partially also secondary materials, we assume that this is a good proxy for the estimation of the total amount of secondary materials in the system.
2. In order to understand the amount of secondary materials that are consumed domestically, rather than exported, we assumed that the share of secondary materials in the total consumption of raw materials is equal to the share of imported and domestically cycled secondary materials in the total input of raw materials.[4]

[4] This assumption is applied at the level of single resource group (biomass, metals, minerals and fossil fuels), that is: If the share of secondary biomass, say recycled paper, in the total input of biomass is 1%, then also the share of consumed recycled paper in the total consumption of biomass will be 1%

In mathematical terms, the metric and the assumptions behind it are condensed in the following equations set, with the variable definitions listed in **Table 5**:

$$NCI_i = \frac{smc_i + wu_i}{RMC_i + smc_i + wu_i}$$

$$\text{with } \frac{smc_i}{RMC_i} = \frac{smi_i}{RMI_i}$$

$$smc_i = \frac{RMC_i}{RMI_i} * smi_i$$

$$smi_i = sm_i + (imp_i * GCI_i)$$

Table 5. *NCI-related variable definitions*

Variable	Definition
sm_i	Secondary materials of resource group *i* deployed domestically
smi_i	Secondary materials of resource group *i* deployed domestically and imported (the latter include imported waste for recycling and share of secondary materials in imported products)
smc_i	Secondary materials of resource group *i* consumed domestically
wu_i	Waste of resource group *i* reused domestically without (or with minimal) pre-processing
imp_i	Net direct imports of physical products of resource group *i*
RMI_i	Raw Material Input of resource group *i*
RMC_i	Raw Material Consumption of resource group *i*
GCI_i	Global Circularity Index of resource group *i*
NCI_i	National CIrcularity Index of resource group *i*

3. Scenario Modelling - SNAC Exiobase

Scenarios are implemented in the form of "what-if" and "static" counterfactual representations of reality. Their rationale is not to develop accurate projections, but to explore the potential effects on the NCI (circularity rate) and RMC (material footprint) of drastically deploying radical circular strategies. They are focused on key focus areas for the development of a Circular Economy in Norway which were selected based on Mass-Carbon-Value (MCV) scorecards (Chapter 4.3). Environmentally Extended Multi-Regional Input-Output Analysis (EE-MRIOA) represents a powerful tool for modelling economic and environmental interventions related to the Circular Economy. Improving upon the method used in the CGR Netherlands, a custom SNAC Exiobase version was developed for this study. The rationale behind the selection of such approach is expressed by Giljum and colleagues (2017)[5] in the context of an expert workshop on "Demand-based measures of materials flows" organised by the OECD, UNEP and its IRP:

"Countries that aim to take leadership in the process of establishing material footprint indicators could test "single-country national accounts consistent" or "SNAC models" (Edens et al., 2015)[6]. Applying an international accounting approach using international data sources entails the risk of discrepancies with national statistical data. This problem can be overcome by replacing data for a specific country with data from official national trade and extraction statistics, thus building a single-country national accounts consistent (SNAC) footprint accounting model. This step is highly recommended when implementing a top-down trade and footprint model for monitoring or target setting purposes at the national level. SNAC models should improve the robustness of national calculations and remove uncertainties that originate from necessary manipulation of national data in the process of constructing an MRIO database".

Scholars and practitioners have extensively discussed the merits and drawbacks of different input-output database structures, compilation and manipulation

[5] Giljum, S., Lutter, S., Bruckner, M., Wieland, H., Eisenmenger, N., Wiedenhofer, D., & Schandl, H. (2017). Empirical assessment of the OECD inter-country input/output database to calculate demand-based material flows. Paris: Organisation for Economic Co-operation and Development.

[6] Edens, B., Hoekstra, R., Zult, D., Lemmers, O., Wilting, H., & Wu, R. (2015). A method to create carbon footprint estimates consistent with national accounts. Economic Systems Research, 27(4), 440-457.

techniques (Choer et al. 2013, [7]Giljum et a. 2015[8], Bruckner et al. 2015[9], Kovanda et al. 2018[10], Giljum et al. 2019[11]). According to Tukker and colleagues (2018a[12], 2018b[13]), there are several approaches to the calculation of footprints and the one employed in this study is regarded as a slight variation of method 6 (SNAC method). The key difference lies in the fact that our input-output database is not rebalanced after the modifications. This way, we guarantee full consistency of the single-country account with its SNI data at the cost of not fully respecting the market balance. For an exhaustive explanation of the SNAC procedure please refer to Edens et al. (2015).

The SNAC model used in this study is based on the latest version of Exiobase (v3.7) which features updated economic data for the year 2016 and environmental data for different years[14]. Since the model's focus is the calculations of material footprints, the resource extensions are updated for every country based on the Global Material Flows Database (GMFD) by IRP[15]. We developed a specific script and concordance tables to match the GMFD to Exiobase. Only for Norway, country specific data from the national statistical office were used. In the absence of Supply and Use Tables (SUTs) for Exiobase 3.7, the SNAC procedure was implemented at the IOT level. The

[7] Schoer, K., Wood, R., Arto, I., & Weinzettel, J. (2013). Estimating raw material equivalents on a macro-level: comparison of multi-regional input–output analysis and hybrid LCI-IO. Environmental science & technology, 47(24), 14282-14289.

[8] Giljum, S., Lutter, S., Wieland, H., Eisenmenger, N., Wiedenhofer, D., Schaffartzik, A., & West, J. (2015). An empirical assessment comparing input-output based and hybrid methodologies to measure demand-based material flows. Paris: Organisation for Economic Co-operation and Development.

[9] Bruckner, M., Fischer, G., Tramberend, S., Giljum, S., 2015. Measuring telecouplings in the global land system: A review and comparative evaluation of land footprint accounting methods. Ecological Economics 114, 11-21.

[10] Kovanda, J., Weinzettel, J., & Schoer, K. (2018). What Makes the Difference in Raw Material Equivalents Calculation Through Environmentally Extended Input-Output Analysis?. Ecological economics, 149, 80-87.

[11] Giljum, S., Wieland, H., Lutter, S., Eisenmenger, N., Schandl, H., & Owen, A. (2019). The impacts of data deviations between MRIO models on material footprints: A comparison of EXIOBASE, Eora, and ICIO. Journal of industrial ecology, 23(4), 946-958.

[12] Tukker, A., de Koning, A., Owen, A., Lutter, S., Bruckner, M., Giljum, S., ... & Hoekstra, R. (2018a). Towards robust, authoritative assessments of environmental impacts embodied in trade: Current state and recommendations. Journal of Industrial Ecology, 22(3), 585-598.

[13] Tukker, A., Giljum, S., & Wood, R. (2018b). Recent progress in assessment of resource efficiency and environmental impacts embodied in trade: An introduction to this special issue. Journal of Industrial Ecology, 22(3), 489-501.

[14] As of v3.7 (doi: 10.5281/zenodo.3583071), the end year is: 2015 energy, 2016 all GHG (non fuel, non-CO2 are nowcasted from 2015, CO2 fuel combustion is based on data points (see below)), 2013 material, 2011 most others, land, water.

[15] https://www.resourcepanel.org/global-material-flows-database

ESA Questionnaires 1850 (symmetric IOT for domestic production) and 1950 (symmetric IOT for imports) were used to create the building blocks of the model: a 2 regions IOT based on data from National Statistical Institutes and matched to the Exiobase classification and currency. In the next step, the exports vector and imports matrix are disaggregated to 49 regions based on country-specific multiregional trade shares from Exiobase to obtain the multiregional SNAC Exiobase blocks. This is done for both intermediate and final demand. In the last step, the BACI database[16] is used to obtain the most updated and globally-consistent trade data in the form of vectors of total imports/exports by product and trading partner. These are then used to scale the multiregional SNAC Exiobase blocks. This step is important because it guarantees that the trade data is consistent in that the BACI database implements a reconciliation procedure over COMTRADE data. This also ensures that valuation (transport margins) between Exiobase and the new trade data is the same in that BACI is the very same database used in the original compilation of Exiobase. It should be noted that while Exiobase data is from 2016, the data from BACI is from 2017. However, due to the complexity involved in deflating an IO database, it was regarded as a safer option not to implement it. **Figure 3** summarizes the different data sources used throughout the update process.

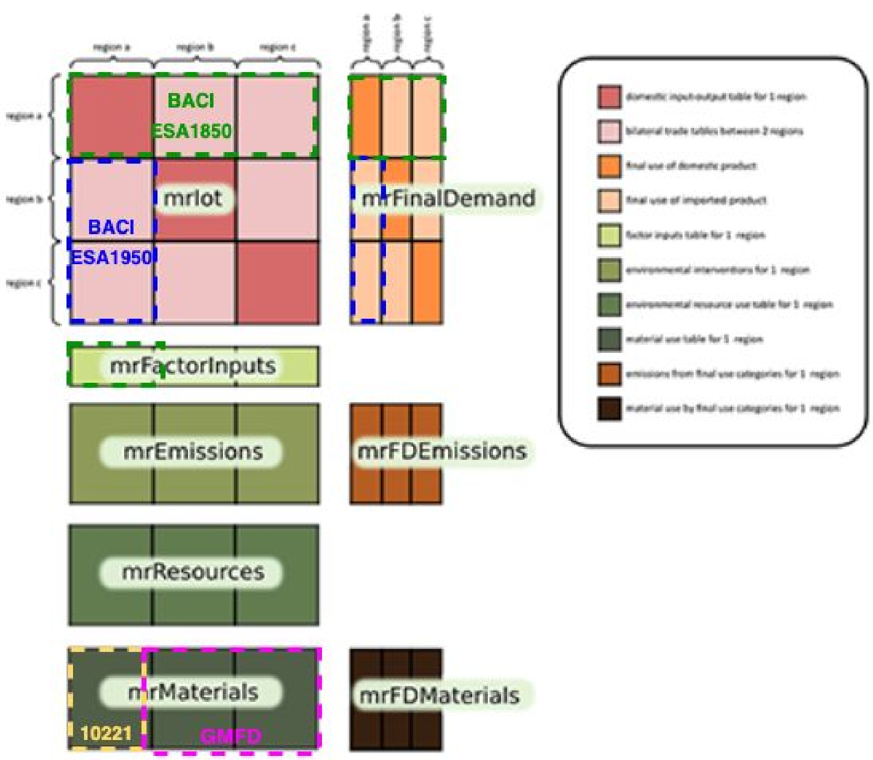


Figure 3.

[16] http://www.cepii.fr/cepii/en/bdd_modele/presentation.asp?id=37

Overall, SNAC Exiobase presents economic and material flows for Norway updated to 2017 and economic and environmental flows for all the other regions (excluded imports and exports from and to Norway) updated to 2016 and 2017, respectively. **Figure 4** shows a cross-database comparison of RME accounts per resource group.

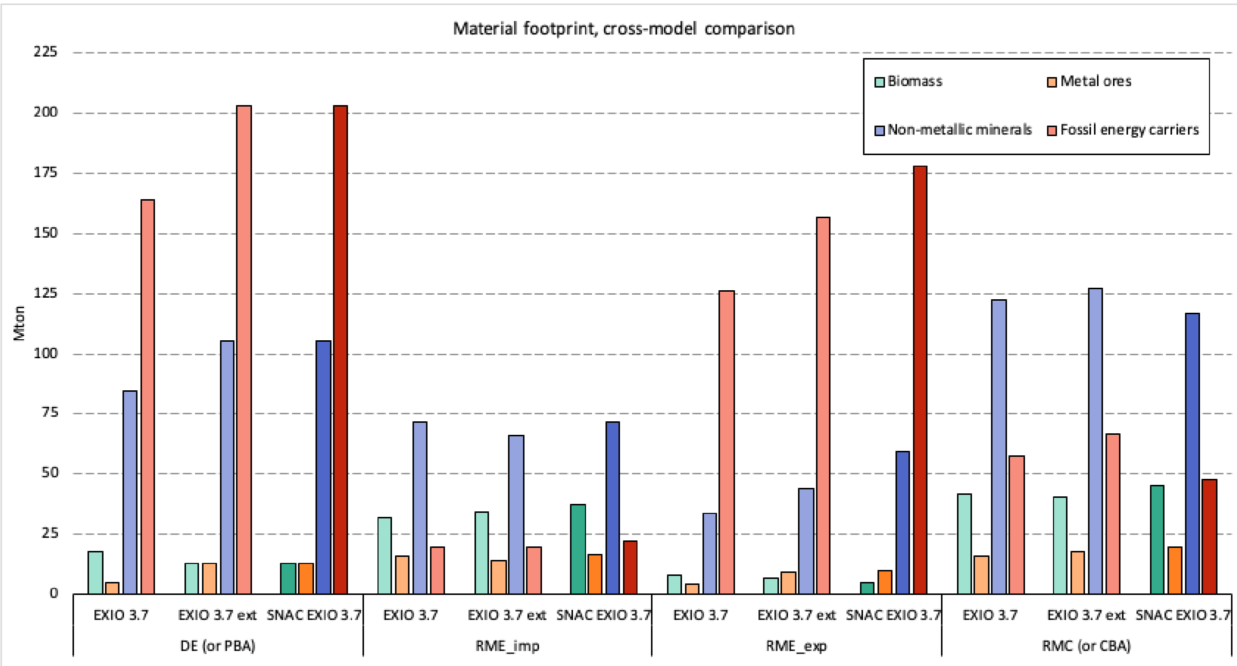


Figure 4. *Resource footprint of consumption categories (own calculations based on Exiobase v3.7)*

The three databases compared are the original Exiobase v3.7, the version of Exiobase v3.7 with only material extensions updated and the complete SNAC Exiobase. All the calculations are performed using the open source tool for analysing global EE-MRIOTs, **pymrio**[17].

The SNAC Exiobase is then used for the calculation of counterfactual scenarios using a modified version of the Python package for modeling circular economy policy and technological interventions in EE-MRIOs named **pycirk**[18]. The modelling logic follows closely the blueprints developed by Donati et al. (2018)[19].

[17] https://pymrio.readthedocs.io/en/latest/index.html

[18] https://pycirk.readthedocs.io/en/latest/readme.html

[19] Donati, F., Aguilar-Hernandez, G. A., Sigüenza-Sánchez, C. P., de Koning, A., Rodrigues, J. F., & Tukker, A. (2020). Modeling the circular economy in environmentally extended input-output tables: Methods, software and case study. Resources, Conservation and Recycling, 152, 104508.

4. Visualizations

4.1 Sankey Diagram

The Sankey dataset and diagram for Norway were generated using the hybrid version of Exiobase (v3.3.17). For an explanation of the logic behind the development of the Sankey dataset and diagram refer to the document *"Measuring & Mapping Circularity - Technical methodology document"*.

4.2 Material Footprint of Consumption Categories

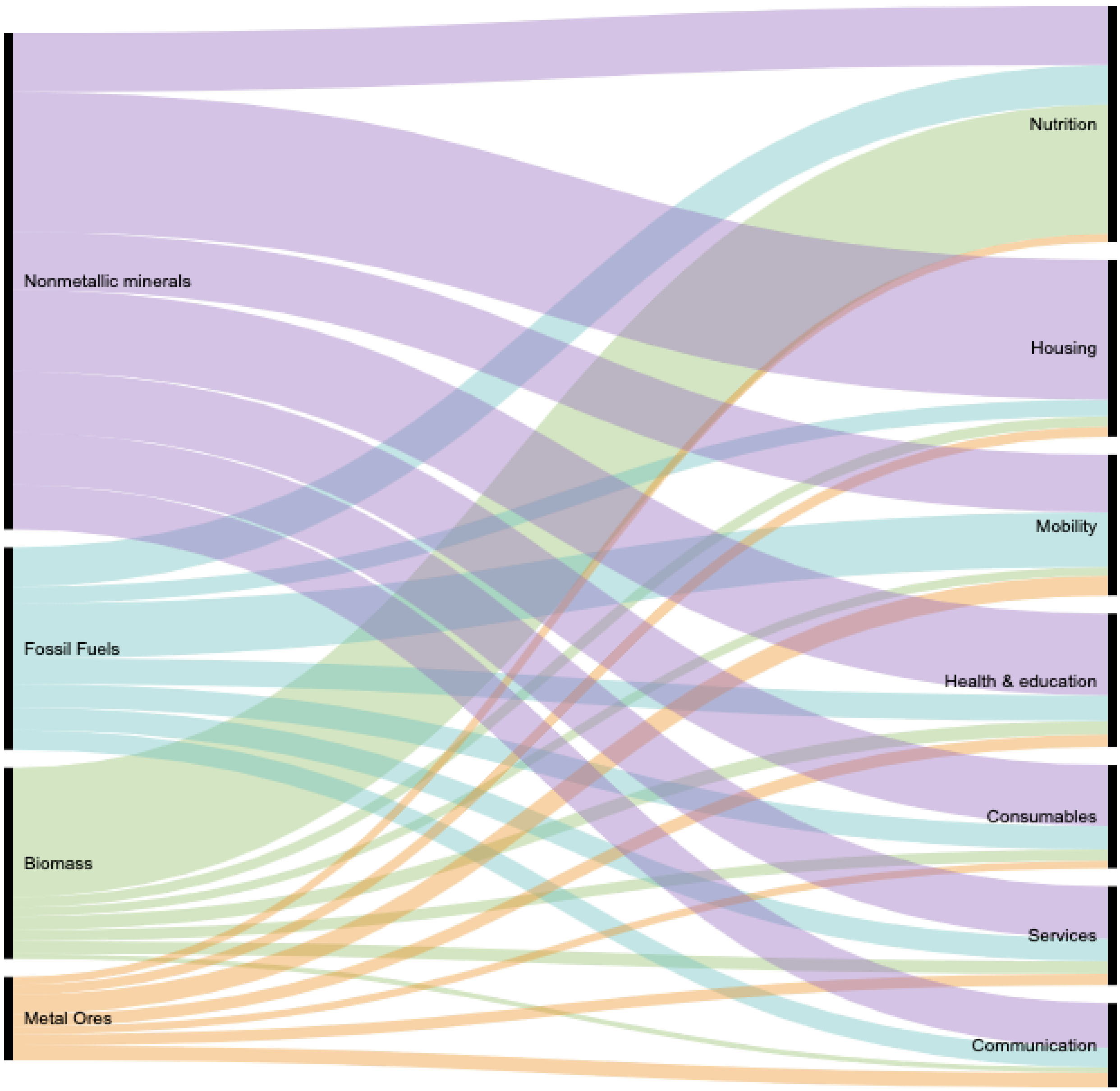
This section explains instead how the monetary version of Exiobase was used to calibrate the material footprint of consumption categories (or societal needs) originally derived from the hybrid version of Exiobase.

Building upon the work by Ivanova et al. (2017)[20], we applied a similar classification to final demand items belonging to 9 consumption groups: Nutrition, Housing, Energy, Capital Equipment, Consumables, Communication, Services, Mobility and Healthcare. Differently from Ivanova et al. (2017), we assigned a classification to all products and not only those for which there was a final demand. We then calculated the consumption-based footprint for the 4 resource groups and performed a contribution analysis to reveal how the key consumption groups contributed the resource footprint. Finally, we narrowed down the number of the groups to 7 keys societal needs by re-allocating Energy and Capital Equipment to the other groups. This step was carried out by using the structure of the total requirement matrix to find out how much of Capital Equipment and Energy (the total input requirement per unit of total output) would feed into every other consumption group. We used these shares calculated from the total requirement matrix to re-distribute the Energy and Capital Equipment footprint to the other 7 consumption categories and disregarded the rest of their footprint (i.e. Energy to Energy and Capital Equipment to Capital Equipment). We applied the same principle to split the housing footprint into the actual housing part (total input requirement per unit of output of housing to housing) and the infrastructure and non-residential part (total input requirement per unit of output of housing to other consumption groups) and re-allocated it to the other consumption groups. **Figure 5** shows the use of resource groups by different societal needs estimated in such a way. These shares were used to further calibrate

[20] Ivanova, D., Vita, G., Steen-Olsen, K., Stadler, K., Melo, P. C., Wood, R., & Hertwich, E. G. (2017). Mapping the carbon footprint of EU regions. Environmental Research Letters, 12(5), 054013.

the Sankey dataset. All the operations were done using EXIOBASE v3.7 and the open source tool for analysing global EE-MRIOTs, **pymrio**.

Figure 5. *Resource footprint of consumption categories (own calculations based on Exiobase v3.7)*



4.3 MCV Scorecards

The MCV Scorecards are used to single-out the key sectors for deployment of Circular Economy strategies in a region. Data on mass is taken from the SNAC Exiobase model. Data on carbon emissions are taken from the “Greenhouse gases from Norwegian economic activity, by industry and pollutant” dataset by the Central statistics bureau Norway (SSB). Data on value is taken from the “Production account and income generation, by industry, contents and quarter” dataset by the Central Statistics Bureau Norway (SSB).

5. Limitations

- Practical limitations in closing material balance due to re-allocation of resource extraction in RME flows
- Rough re-calculation of direct flows of traded products based on changes in their footprint → need for a more integrated physical/monetary model
- Rough “conceptual” estimation of “transit flows” (e.g. IMP_EXP and DPO_ROW) → to be improved based on IO calculations according to Giljum et al.