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Establishing a coordinated global framework for measuring demand-based material flows – Revised draft roadmap

Consultant report

This document presents a revised roadmap for establishing a coordinated global framework for measuring demand-based material flows (material footprints). It integrates comments received during a virtual OECD expert workshop organised on 24 March 2022 by WU Vienna – in cooperation with the Institute for Social Ecology, Vienna and CSIRO.

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The revised draft roadmap is submitted to WPEI Delegates for a second reading and a discussion on the priority topics and the options for a coordinated global framework, considering their country's experience.

Detailed written comments should be sent to the OECD Secretariat via the WPEI community site by Friday 20 January 2023 cob. The roadmap will subsequently be finalised by the OECD Secretariat in consultation with international partners and serve as basis for next steps in international work.

Action required: for discussion

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Updated roadmap for establishing a coordinated global framework for measuring demand-based material flows (material footprints)

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1. Preamble

1. This document builds on previous assessments by the OECD for the future of demand-based material flow indicators which are required for several international reporting processes, most notably the SEEA data initiative and the Sustainable Development Goals (SDG) indicators. The document summarises the process and main findings to date and lays out options for securing the future availability of the two main components for calculating demand-based material flow indicators, i.e. domestic material extraction accounts and global multi-regional input-output (MRIO) datasets. The aim is to enable countries world-wide to report demand-based material flow accounts and indicators within this decade.

2. The document needs to be read as input in particular for international organisations to further deliberation about the future capability development and capacity strengthening for these indicators and the role of key players in the data provision and policy support ecosystem.

2. Introduction

3. Successful promotion of resource efficiency requires a comprehensive quantification of the material basis of economies and their international linkages through trade. Based on this understanding, targeted measures to influence current patterns of resource use and increase resource efficiency can be designed (OECD, 2015). Comprehensive and internationally comparable datasets and indicators are a prerequisite for good decision making by the policy and business community. They assist in monitoring progress towards green growth (OECD, 2017) and the realisation of the Agenda 2030 as set out in the UN Sustainable Development Goals (UN, 2015), as well as in evaluating the effectiveness of policy programmes and business decisions.

4. To comprehensively assess the use of natural resources in the economy and to fully consider the role of international trade, “demand-based” or “footprint” indicators are necessary in addition to production-oriented indicators of material flows. Demand-based indicators quantify the sum of all resources required along the global supply chains of goods destined for final demand in a specific country. The “material footprint” (Wiedmann et al., 2015) applies this concept to the case of raw materials and is identified as one of the key indicators for SDG 8.4 and SDG 12.2 (UN, 2015).

5. As a response to the increasing demand for robust and reliable material footprint data, during the last 5-10 years, the OECD Environment Directorate established a process to provide guidance for calculating demand-based measures of material flows. This process consisted of investigating demand-based material flow measures, methodologies, and data by means of a sequence of studies (Lutter and Giljum, 2014; Giljum et al., 2015; Giljum et al., 2017; Lutter et al., 2019) as well as of holding several expert workshops (OECD, 2014, 2018). The studies can be understood, on the one hand, as an assessment of the state of scientific knowledge about the robustness and reliability of demand-based indicators of material flows. On the other hand, they evaluated the applicability of OECD’s own Inter-Country Input-Output database (ICIO) for material footprint analyses and identified areas where further development is needed to improve the accuracy of results.

6. One important aspect of the OECD process was discussing with relevant stakeholders whether and how a coordinated global framework for measuring demand-based material flows and further advancing the measurement agenda could be established. Such a framework is envisaged to have two main benefits: it would (1) bring together stakeholders such as statisticians, policy makers and scientists

to discuss the scientific and policy-oriented state of the art, and (2) achieve methodological advancements and robust and reliable footprint results to inform science-based policies.

7. Already in previous steps of the OECD process the necessary elements of such a framework, relevant stakeholders and potential timelines had been sketched. Meanwhile, progress has been achieved about both methodological and data advancements in academia and statistics as well as institutional developments. This document provides an update and revision of the roadmap for establishing a coordinated global framework for measuring demand-based material flows and for further advancing the measurement agenda in the coming years. The main target audience of this updated roadmap document are representatives of international organisations who aim at contributing to this institutional process.

8. The updated roadmap presented in this document builds on a series of OECD studies and assessments carried out between 2014 and 2019 and proposes methodological options to produce comparable indicators on demand-based material flows as part of the OECD's work on environmental and green growth indicators and on monitoring progress towards the SDGs.

9. In the following sections, this document elaborates on the following three aspects:

- **Priority elements to be addressed by the framework** (Section 3): Building upon the "MRIO guidance document" for measuring demand-based material flows (see separate document), this part of the report describes the steps and actions needed to ensure a high-quality measurement of demand-based material flows as well as necessary methodological advancements;
- **Main players that could implement the framework** (Section 4): Stakeholders whose contribution is key to achieve the framework's objectives are described, along with a summary of their past and current activities;
- **Specific roles and actions** (Section 5): An outline of options for the roles that could be taken by the different core players both in the field of material flow accounting and of developing input output databases.

3. Identifying priority topics

10. The 2018 OECD expert workshop on demand-based indicators for material flows (OECD, 2018) reached consensus on the principal measurement approach for international work at the OECD level and beyond. The workshop concluded that an approach based on multi-regional input-output (MRIO) analysis is best suited, as it ensures full coverage of supply chains of all product groups and thus enables to consider all indirect effects on material extraction. However, the experts also emphasised that shortcomings of current MRIO models needed to be addressed and more harmonised international databases were required to provide robust and consistent results.

11. In the following, the outcomes of previous workshops are updated to identify the core topics that should be addressed over the next 3-5 years.

3.1. Refinements of the MRIO calculation method

12. Several global MRIO databases are currently available for calculating demand-based material flows (see separate "MRIO guidance" document for a detailed comparison of these databases). One of these databases is the OECD Inter-Country Input-Output (ICIO) database that was first introduced in 2013 and has since been regularly expanded and improved. A key objective of the series of studies was to test,

whether the OECD ICIO database is suitable to calculate material footprints and whether any restrictions apply.

13. From the application of ICIO to the calculation of material footprints it became apparent that the ICIO database is generally apt to be used for the calculation of demand-based material flow indicators, as long as the analysis focuses on the very aggregated level. This means that derived indicators should remain on the level of the national economy and the material indicators should be disaggregated by a maximum of four main material categories. Based on the OECD series of studies, comparative analyses showed that for many economically important countries, ICIO delivers aggregated material footprint results in the range of 15% deviation from results generated with more detailed MRIO databases (Giljum et al., 2019).

14. However, when further detailing the results, for example to the level of economic sectors or product groups, substantial differences can be observed compared to other databases that discern a larger number of economic sectors. This illustrates that for improving the quality of estimates on demand-based material flows from the OECD ICIO database the availability of **more detailed data on primary activity sectors as well as material processing sectors is crucial**. This was emphasised in several OECD studies (Giljum et al., 2019; Lutter et al., 2019) and also confirmed by recent academic literature that identified minimal levels of sector disaggregation for proper material footprint assessments in an input-output framework (Schör et al., 2021; Weinzettel, 2021).

15. The latest release of the ICIO database (OECD, 2021) distinguishes 45 industries, of which four are primary sectors (i.e. 'Agriculture, hunting, forestry', 'Fishing and aquaculture', 'Mining and quarrying, energy producing products', and 'Mining and quarrying, non-energy producing products'). This is an improvement compared to earlier versions of ICIO that only contained two material extraction sectors (one for biomass and one for mining) that was also called for in earlier OECD studies (Giljum et al., 2015). However, this level is still far from delivering robust material footprint results. A recent assessment by EUROSTAT concluded that more than 10 biomass extraction sectors and more than 30 extraction sectors of non-renewable materials need to be disaggregated, in order to closely align with the results of the highly detailed EUROSTAT material footprint model (Schör et al., 2021).

16. Further increasing the suitability of MRIO databases for more detailed material footprint analyses can be achieved through three avenues. First, by further **disaggregating the monetary IOTs**, preferably in a standardised approach. Such a standardised approach would need to be developed by the MRIO research community in cooperation with OECD and other institutions compiling input-output data sets, such as Eurostat. More detailed MRIO databases and models already exist and include the IO database Global Resource Input-Output Assessment / GLORIA (with 97 industries) (Lenzen et al., 2021), which is used for the UNEP IRP work on material footprints, or EXIOBASE, which is the most detailed MRIO database currently available (163 industries and 200 product groups) (Stadler et al., 2018). While an increasing number of material-intensive sectors improve the accuracy of material footprint calculations, a drawback is that detailed breakdowns lead to very large input-output matrices whose handling requires substantial computer power and technical skills. This could put some technical restrictions on a broad application of these large input-output systems.

17. Second, existing IOTs could be complemented by so-called **physical use extensions**. In such an approach, material extraction is not allocated to the respective extraction sector supply raw materials (e.g. mining), but to the (domestic or foreign) sectors that use and further process the extracted materials (e.g. the steel industry or the construction industry). The calculation of material footprints using a highly aggregated input-output framework, such as the ICIO, would particularly benefit from such an approach. One advantage is that such a procedure follows a physical allocation logic, thus avoiding the standard assumption in input-output analysis of equal value-to-mass ratios (Weinzettel, 2021). Another advantage is that the structure of the IO table could be left unchanged. Use extensions are conceptually straight forward, but it should also be emphasised that compiling such detailed physical accounts for integration

into a global MRIO model is a complex and data intensive task. For some material categories, such global physical models have already been developed and tested, for example, for agriculture products (Bruckner et al., 2019), forestry products (Arto et al., 2022) and iron/steel products (Wieland et al., 2021).

18. A third option to improve the accuracy of material footprint results is to **replace monetary data by physical data in the inter-industry part of the MRIO matrix**, i.e. creating a mixed-unit matrix. This can particularly improve the results for sectors with significant differences in prices of products sold to different receiving sectors (energy carriers and electricity are a typical example) (Schör et al., 2021).

19. In addition to the topic of aggregation levels, other priority topics include:

- The **comparison** of results obtained from IO-based approaches **with national estimates** (benchmarking case studies often based upon very detailed single-region input-output (SRIO) models), allowing to get additional insights in the reliability of trends as well as of the meaningfulness of the applied sector (major industry groups) and material (major groups) breakdown.
- To allow for science-based policymaking, the **timeliness** of the data provided as well as the coverage of the **time series** are crucial. Currently, the new version of the OECD ICIO covers the years 1995-2018, the GLORIA database 1970-2019, and EXIOBASE 1995-2015 (with a now-casted version up to 2021).
- Finally, the **uncertainties** of the produced numbers need to quantified, reviewed and documented, to get a better understanding for the accuracy of results as well as for the necessity of specific policy user guidance.

3.2. Alignment of MRIO databases

20. During expert discussions in the OECD context, there was consensus that it would be very helpful if there existed one institutionalised international MRIO database that could serve as a common reference or “authoritative” database. It was concluded that the OECD ICIO database was best placed to serve that purpose, as it is the only MRIO database provided by an international organisation and as it is already aligned to some extent with other MRIOs, e.g. Eurostat’s FIGARO database (Eurostat, 2019b). The OECD is also playing an active coordination role in the development input-output tables in Asian countries (UNECA) and has observer/expert status in similar projects in UNECLAC and UNECE.

21. On the aggregated level, such a reference database should be harmonised to the extent possible with other, more detailed MRIO databases. For instance, the GLORIA database is directly using the ICIO tables as boundary condition for balancing the overall MRIO system. While the GLORIA database details many more sectors compared to ICIO, the sector aggregates are comparable.

22. A full alignment of existing MRIO databases to a one-fits-all model is neither technically feasible nor desirable from a methodological and policy application point of view. The various databases and models serve different purposes and applications and thus together offer a diverse perspective on resource use issues. However, a harmonisation with regard to main construction procedures and building blocks of MRIO frameworks is essential to improve quality, comparability, and interpretability of the results, to reduce uncertainties and to increase the applicability in policy contexts (Giljum et al., 2019).

23. Harmonisation is needed regarding the **classifications and data sources** that underlie input-output models and their extensions. Through ensuring that different MRIO databases are aligned with international classification systems like CPA, ISIC and HS (UNSD) and use the same database as basis for the material extension, comparability can be increased considerably (Koning et al., 2015). Especially with regard to the material extension using the official and very detailed UNEP IRP Global Material Flows Database (UNEP IRP, 2021) as standard data source is highly recommended (see the separate “MRIO guidance” document ENV/EPOC/WPEI(2022)7 for more details about the IRP database).

24. In addition, different MRIO databases should apply comparable **methods to integrate source data** into input-output models. Examples for this aspect are the conversion of supply-use tables into basic prices, or of supply-use tables into IOTs, as well as the alignment of bilateral merchandise and trade in services statistics with national and global supply-use tables.

25. Further alignment is needed for the **methods used to disaggregate** IOTs (by industry), as well as for the **concepts, definitions and calculation method used for the derived indicators**, and the way indicators are presented or communicated. For instance, Eurostat and the JRC are working on a method to disaggregate the 64 sectors of FIGARO into 182 industries.

26. Finally, also the way associated **metadata** are reported requires harmonisation. One suggestion in this regard was to use semantic standards such as those from the UNFCCC, as this could be useful to improve their quality and clarity.

3.3. Data provision and capacity building

27. Demand-based material flow indicators are used in the global monitoring of the SDGs and play an important role in regional and national policy strategies such as the European Green Deal (EC, 2019). It is hence of utmost importance that these indicators are based upon high-quality data and consistent methodologies, comparable among countries and accessible for all potential users. Thereby, it has to be considered that users have differing levels of expertise regarding environmental accounting, global modelling as well as the use and interpretation of available data and modelling results (see also the "MRIO guidance" document for user options with different priorities). Hence, for the design of a coordinated global framework for measuring material flows, the following elements need to be taken into consideration.

28. With regard to **data provision**, users without capacity to set up their own material flow accounts and/or run footprint calculations need access to an official data source providing them with the data and demand-based indicators relevant for SDG reporting and other types of policy applications. The most prominent example for the case of material flows is the UNEP Global Material Flows Database (www.resourcepanel.org/global-material-flows-database). Such a data source is also of value e.g. for statistical institutions maintaining their own footprint models, aiming to compare and benchmark their national results to international trends.

29. Users with expertise, who aim at performing their own calculations, need easy access to a reference MRIO database, including explanatory meta data. This reference database would also be of relevance for researchers maintaining their own MRIO database, as it would allow them to integrate the reference database into or align their own database with the reference database.

30. Ideally, in the future, the reference MRIO database and a reference MFA database would be fed directly by trained statisticians in the individual countries, and the resulting demand-based indicators would be used by policy designers with capacity to understand and interpret details and trends. To reach this goal, extensive **capacity building** is needed at different levels. This can be done via manuals such as Eurostat's "Economy-wide material flow accounts handbook" (Eurostat, 2018) or the "Global Manual on Economy Wide Material Flow Accounting" published by the UNEP, Eurostat and the OECD (UNEP, 2021), or by means of in-person trainings.

4. Main players within the framework

31. In the past, many international organisations and institutions have contributed to the development and use of analytical frameworks that allow to calculate demand-based material flow indicators. For a coordinated global framework for measuring demand-based material flows to be successful, the process would benefit from effective and cost-efficient cooperation and division of labour among the different international organisations and institutions. This would avoid duplication of efforts and make best use of available funding, and would ensure coherent reporting to be delivered to major international processes. Existing experience and collaboration such as those on material flow accounts (OECD, Eurostat, UNEP, UNSD), on SDG indicators (OECD, Eurostat, UNEP, UNSD), and on MRIOs (OECD, Eurostat/JRC) can be used when designing the framework. In the following, the main players and their activities will be briefly summarised.

4.1. OECD

32. The OECD is maintaining its own Inter-Country Input-Output database (ICIO). The most prominent regular application of this database is the TiVA – an analysis of trade in value added. The current version of ICIO (released in 2021) covers 67 countries (i.e. 38 OECD countries and 28 non-OECD economies), the Rest of the World and provides split tables for China and Mexico (differentiating between production for the domestic market versus exports). The OECD has also been playing a key role in the development of standards and the promotion of the application of Material Flow Accounting (MFA) and the use of MFA in policy (OECD, 2007), with a particular focus on promoting the development of robust demand-based indicators for material flows since 2014. OECD was also a core player in the process of the Inter-Agency Expert Group developing the SDG indicators set.

4.2. Eurostat / JRC

33. The European Union, especially its statistical office Eurostat and the Joint Research Centre (JRC) have been playing a major role in the development of a harmonised material flow accounting methodology since about 2001. Eurostat's ground-breaking work has enabled international agreement of accounting standards for MFA (Eurostat, 2018). Eurostat provides training for EU Member States for the compilation of material flows accounts. In addition, in recent years, significant effort to develop methodologies and tools to calculate demand-based indicators for the EU as a whole, and for the Member States has occurred. Eurostat has developed and maintains a material footprint calculation model based on a single-region input-output (SRIO) framework (Eurostat, 2019a). In addition, together with the JRC, an MRIO-based approach for calculating demand-based indicators has been developed (FIGARO) in recent years (Eurostat, 2019b). The FIGARO approach was meant to be closely aligned with the OECD ICIO initiative, i.e., FIGARO was expected to deliver data for European countries to ICIO. However, recently, collaborations have been less intense, resulting in two parallel MRIO products. Also Eurostat has played a key role in the process of the Inter-Agency Expert Group developing the SDG indicators set.

4.3. UNEP

34. The United Nations Environment Program is the UN authority responsible for establishing a global environmental agenda and to support the implementation of the environmental aspects of the 2030 development agenda and has a specific focus on Africa, Asia and the Pacific and Latin America and the Caribbean. UNEP has adopted demand-based material flow indicators since 2015 and has played a key role in establishing sustainable consumption and production as a standalone goal of the SDGs and

contributed to datasets allowing material flow indicators to be selected for SDG 8.4 and 12.2. UNEP is also a key player in the SEEA data process jointly with the OECD and Eurostat. In 2022, it initiated the collection of material flow data from countries to populate the related SDG indicators. This is complemented with the development of online training materials for material flow accounting for statistical offices in Africa, Asia and the Pacific and Latin America and the Caribbean.

35. In 2021, UNEP and the International Resource Panel (IRP) published "The use of natural resources in the economy: A global manual on economy wide material flow accounting" jointly with Eurostat and the OECD (UNEP, 2021). This global manual establishes a globally accepted methodology and can be used for providing capacity building to national statistical offices world-wide to develop MFA capability of countries. The global manual caters for different levels of expertise, data availability and ecological-economic settings.

4.4. UNEP IRP

36. The International Resource Panel was established by UNEP in 2007 to inform policy makers to shift to sustainable consumption and production and to decouple economic growth form environmental pressures and impacts. In the context of this mandate, the UNEP IRP since 2015 hosts the Global Material Flow and Resource Productivity Database, which provides data to help governments, policy researchers and interested stakeholders understand and trace the linkages between economic growth and raw material usage (UNEP IRP, 2021). The database is based on authoritative, publicly accessible international data sources assembled employing the most recent methodologies to establish material flow accounts. It covers the period 1970-2019, for more than 200 countries, and reports extraction and direct trade of raw materials, indirect trade flows (including material footprints), as well as material efficiency data. This online database has since filled an information gap and provided material flow indicators (domestic material consumption, material footprint) for measuring SDG progress in the absence of national reporting.

37. The IRP publishes a regular report, the Global Resource Outlook, to provide information about the pressures and impacts of growing material use, and to develop coherent scenario projections for resource efficiency and sustainable production and consumption that decouple economic growth from environmental degradation (UNEP IRP, 2019).

38. The database is also used in the web-based Sustainable Consumption and Production Hotspots Analysis Tool (SCP-HAT, scp-hat.lifecycleinitiative.org) jointly commissioned by the UN Lifecycle Initiative, the UNEP IRP and the One Planet Network. The SCP-HAT is an entry level tool providing science -based evidence for SCP policy priorities in countries world-wide.

4.5. UNSD

39. The UN Statistics Division (UNSD) is charged to support the development of the global statistical system and plays a key role for the development and implementation of the System of Integrated Environmental and Economic Accounts (SEEA) and the establishment of global SEEA databases. This includes responsibility for the development of statistical standards and providing capacity building for environmental-economic accounting (UNSD, 2017) as well as the compilation of supply, use and input-output tables and analysis (UN, 2018). UNSD is also providing a wide range of global data sets that can be used to compile MFA accounts – such as mining data, data for energy production, etc. – as well as to construct IO tables (e.g., monetary production and trade data).

4.6. UN regional commissions

40. The UN economic commissions for Africa (ECA) and Latin America and the Caribbean (ECLAC) and the Economic and Social Commission for Asia and the Pacific (ESCAP) have a strong human development agenda and can play a key role in supporting the integration of economic, environmental and social policy goals and will be a key partner in creating the regional knowledgebase for demand-based material flow indictors and their use to inform policy.

4.7. National Statistical Offices (NSOs)

41. NSOs play a critical role for developing the knowledgebase for material flows and resource productivity in their respective countries. Many NSOs already report national material flow accounts and indicators and there have been capacity building activities for middle- and low-income countries that will be further strengthened now that a global manual for material flow accounting has become available. Ideally, in the future every NSO in the World would have the capacity to compile its own MFA dataset, so that the global material extension would consist solely of national statistical data.

42. Some NSOs have also invested in in the development of their own material footprint model, often using SRIOs or trade coefficients as a methodological basis (Lutter et al., 2016). These models can provide meaningful results but for the majority of products assume that domestic production technologies are identical to international ones when employing an SRIO. Examples are the SRIO-based models of Austria, Germany or the United States, or the coefficient-based approach developed by Switzerland. A key question for the development of demand-based indicators for material flows is how to make a global MRIO facility available for NSOs that satisfies the quality assurance standards of national statistics.

4.8. Research institutions

43. Methodological progress in the field of environmental footprinting and MRIO modelling has been advanced by research institutions, who have developed several global MRIO databases and have engaged in comparing the validity of results across MRIO models. The most prominent global MRIO databases developed by academic institutions currently are EXIOBASE, Eora/GLORIA, WIOD and GTAP. The UNEP IRP online database reports global material footprints employing a novel MRIO table, GLORIA, developed for the IRP in 2021.

44. Through these various approaches extensive technical expertise was developed which includes the compilation of SUTs/IOTs, disaggregation, trade linking, compilation of extensions, uncertainty assessments, etc. The advantage of a scientific setting is the ability to develop methodological detail and to advance the methodological apparatus for demand-based indicators. In many countries, the division of labour between academia, environment departments and national statistical offices has been a successful model to develop the scientific and statistical knowledge base for policy making. Research can also play a crucial role when developing harmonised standard procedures for the setup of global MRIO databases.

5. Implementation of the framework

45. The overall aim of establishing an international framework is to enable countries world-wide still within this decade to report demand-based material flow accounts and indicators. Two components are needed for establishing demand-based material flow indicators at the national level for most countries globally and for satisfying the reporting needs of the SEEA data initiative and the SDGs. First, a material extraction satellite account with a sufficient level of detail and second, an input-output table that allows attributing primary materials extraction to final demand. Integrating global supply chains in the assessment demands that the material extraction satellite account needs to have global coverage and sufficient regional (country) detail. Also the input-output table needs to be a global table with regional (country) detail and with sufficient sector detail, in order to produce robust material footprint results. The roadmap therefore needs to address both aspects:

- Development of national capability for material flow accounting
- Availability of a global multi-regional input output dataset.

46. In the following, we outline required steps to build up capabilities for national material flow accounting in different countries (Section 5.1) and options to move forward towards the availability of a reference global multi-regional input output dataset (Section 5.2). In both sections key players are marked in bold to highlight their roles in the implementation of the different tasks.

5.1. Developing national capability for material flow accounting

47. The UNEP IRP global material flow dataset (UNEP IRP, 2021) has developed into the core source of domestic extraction data with global coverage and detail for about 200 countries. This allows UNEP to play its role as custodian for reporting global data for SDG's 8.4 and 12.2 and to contribute to the SEEA data initiative.

48. However, to integrate larger amounts of national MFA data from statistical sources, technical capacities need to be developed, in particular in non-OECD countries. Here, we outline a vision how MFA capabilities could be set up, and describe key steps that would need to be taken in the short- (1-3 years), medium- (3-5 years) and longer (5-10 years) term. Note that depending on the existing national expertise and statistical procedures in place, capacity building in the short- and medium-term will possibly focus on compiling accounts for direct material flows (domestic extraction, direct imports and exports). Indicators including indirect flows, such as demand-based indicators, might then be integrated into the national reporting at a later stage.

1-3 years

49. In the short term, the UNEP IRP dataset will continue to be the most important international source for domestic material extraction data. **UNEP IRP** should finance regular updates and improvements of the database as a basis for deriving the material extension (satellite) for ready use in MRIO models.

50. However, as many countries already compile national material flow accounts, a procedure for integrating official statistical MFA data into the UNEP dataset should be developed and pursued. A first pilot step that has already started tests how MFA data reported by **Eurostat** can be incorporated into upcoming versions of the global dataset. Data from other countries shall follow.

51. In parallel, **UNEP** should further develop online training material, based on the global material flow accounting manual (UNEP, 2021), for national statistical offices to build capacity at national level. Various

models for training and capacity building may exist and different organisations, such as the **UN regional committees** mentioned above, should play important roles in implementing them at the regional level.

3-5 years

52. Based on the intensified efforts for capacity building in countries world-wide, the number of countries that report material flow accounts as part of their official statistical system has grown substantially. Training and capacity building material and formats should be further standardised by **UNEP**, including live and pre-recorded online trainings. Financial resources should be provided to set up and maintain a permanent expert group to which questions by national officials can be addressed and issues resolved.

53. Because of the increasing amount of national data being available and integrated, the IRP database will pivot from a reporting process to a data assurance and data repository facility. This transition needs to be supported by **UNEP** and its **IRP**, including clarification of changing roles between scientific experts and UNEP staff.

5-10 years

54. In the longer-term, the ambition should be that every country is enabled to report material flow accounts by 2030 and has established yearly reporting as part of the statistical system. Supported by **UNEP** and **UNEP IRP**, the global material flow database has then developed into a data product that is populated almost entirely by official national data and is being updated on an annual basis.

55. A global material satellite for integration with a MRIO database with world-wide coverage can then be derived from this database with national statistical data included for most countries.

5.2. Availability of a global multi-regional input output dataset

56. There are several options for building capability towards global multi-region input output tables in sufficient detail to calculate demand-based material flows that could be made accessible to the statistical community. In this section, we outline three options which should be seen as examples of possible pathways. Which of the options to pursue depends on the interest and resources of key involved institutions and stakeholders to lead or contribute to its implementation.

Option 1: Develop ICIO/FIGARO into a global reference system

57. Option 1 would build on existing capability at the OECD and the European Community and would develop the existing official MRIO datasets from OECD (ICIO) and Eurostat/JRC (FIGARO) into a harmonised, global reference MRIO system. For this to work it would be necessary that the collaboration between the **OECD** and **Eurostat/JRC** is intensified, to allow aligning efforts and avoid duplication of effort that results in competing MRIO products. The ongoing ‘Regional-Global Trade in Value-added Initiatives’ by OECD, including e.g. a OECD-EUROSTAT-JRC TiVA Webinar Series, could provide valuable platforms for deepening cooperation. This global reference MRIO table could be hosted by the OECD and made available to national statistical offices.

58. To service the need of the global community the MRIO system would need to be further developed. The MRIO dataset would need to be extended to grow the number of countries that are covered, in particular countries of the global South, where a significant share of the global supply of some raw materials, for example of metal ores, originates. To achieve this, the involved international and European organisations should engage with the **academic MRIO community** and rely on input from other

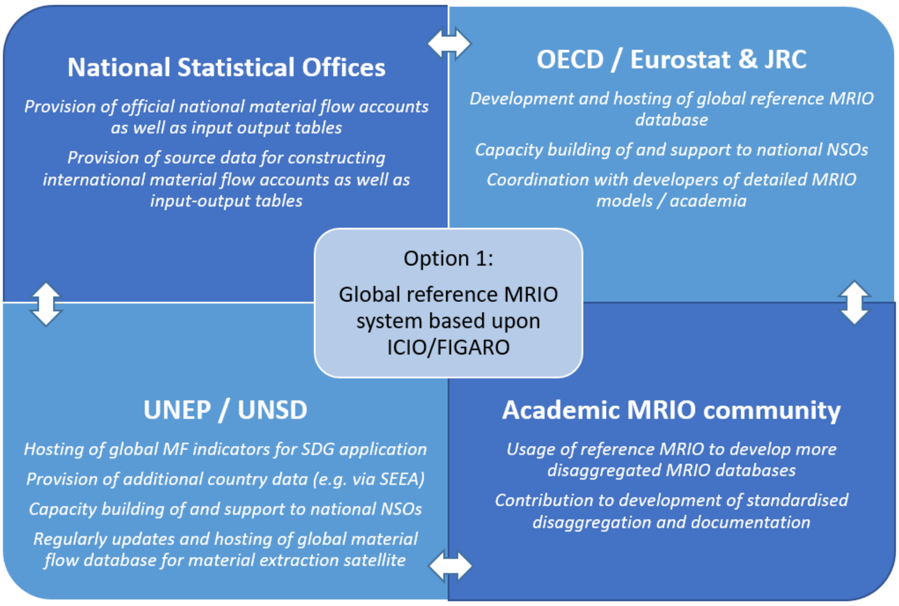
frameworks that can provide additional country data, such as the SEEA global database initiative (**OECD, UNEP**, **UNSD**).

59. In addition, the **OECD**, **Eurostat** and the **UN regional commissions** need to engage in capacity building and support to **national NSOs** world-wide to compile official input output tables that do not yet exist for many countries, but at some point need to be made available to the OECD/FIGARO MRIO database. As a first step, capacity building activities could focus on the provision of the data needed to compile the IO tables.

60. In addition to expanding country coverage, this option would require significant investment in a more detailed MRIO framework for the specific application to the case of material flows. An aggregated harmonised reference database could be used as a starting point for **academic institutions** to develop more disaggregated MRIO databases and model variations that provide the required detail for primary material extraction sectors as well as processing sectors with high material intensities. **OECD** and **Eurostat** could foster exchange with scientific institutions involved in the further development of input-output databases and MRIO construction principles, for example through facilitating a process for developing standardised procedures for disaggregation and for documentation of implementation steps.

61. Finally, the resulting global MF indicators should be hosted by the **UNEP** for SDG application. In general, UNEP can play an important role through providing additional country data, e.g. via the SEEA initiative but also through regular updates of its global material flow database. These data can be used for the material extraction satellite of the reference MRIO system. Figure 1 provides a summary of the roles of different players in Option 1.

Figure 1. Distribution of roles between different organisations (option 1)



62. **Advantages and limitations**: OECD and Eurostat in partnership and individually have ample experience in environmental economic accounting and for material flow accounting which can be brought to bear a significant policy clout. However, at least in the short term, data would be limited to a restricted set of countries and extending country coverage would need significant time and investment.

Option 2: Utilise the UNEP IRP MRIO data set

63. Option 2 builds on previous investments by the UNEP IRP and the UN Life Cycle Initiative resulting in a detailed global MRIO called GLORIA (Global Resource Input-Output Assessment). Since 2015, the **UNEP IRP** has set up a process to calculate material footprints for most countries world-wide as part of their regular reporting routine. Option 2 is hence that a suitable UN organisation such as **UNEP** or **UNSD** hosts a global MRIO database and makes it available to national statistical offices.

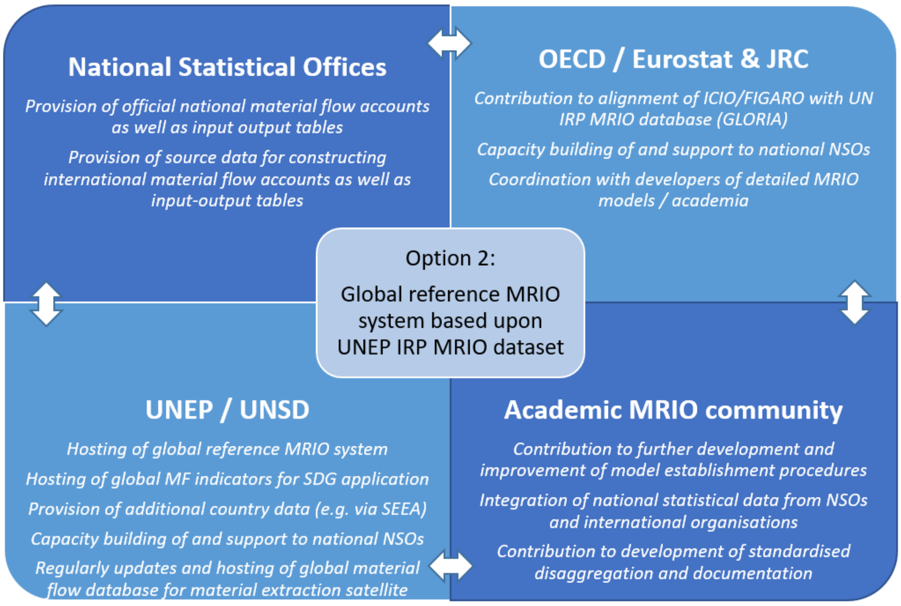
64. The IRP has supported the development of the global MRIO database GLORIA that is specifically designed for providing high sector detail in material extraction and processing sectors. GLORIA thus provides sector detail similar to EXIOBASE, another highly disaggregated database for environmental assessments (see separate "MRIO guidance" document for more details on available MRIO databases).

65. The GLORIA model relies on UN statistics such as the UN main aggregates, UN country information, COMTRADE, and UNIDO datasets for industrial production. It already uses the ICIO database as a reference system for the aggregated level, hence achieving a high level of consistency with the ICIO data, but providing further detail for key sectors important for calculating robust material footprints (e.g. agriculture, mining, metal processing, etc.). However, all MRIO models with a high country detail require approximation of input-output tables for all countries, for which no national table is yet available from NSOs.

66. A UN host organisation would need to work closely with **academic institutions**, in order to further develop and improve model establishment procedures. Model developers should also strive for integrating increasing amounts of national statistical data from **NSOs** and **international organisations**, as they become available (for example, national material flow accounts or input output tables).

67. **OECD's and Eurostat's roles** in this option is to contribute to the alignment of the ICIO/FIGARO databases with GLORIA and to coordinate with developers of detailed MRIO models (academia) in the context of database development and disaggregation. The two institutions should also engage in capacity building of and support to national **NSOs** in the fields of **IO-table development and environmental accounting**. A summary of Option 2 is illustrated in Figure 2.

Figure 2. Distribution of roles between different organisations (option 2)



68. **Advantages and limitations**: Full coverage of most countries is immediately available through employing data modelling procedures and the tables are characterised by a high sector detail. However,

the UN-based funding model would require significant donor commitment to ensure regular maintenance, improvement and expansion of the MRIO database.

Option 3: Develop regional MRIO databases

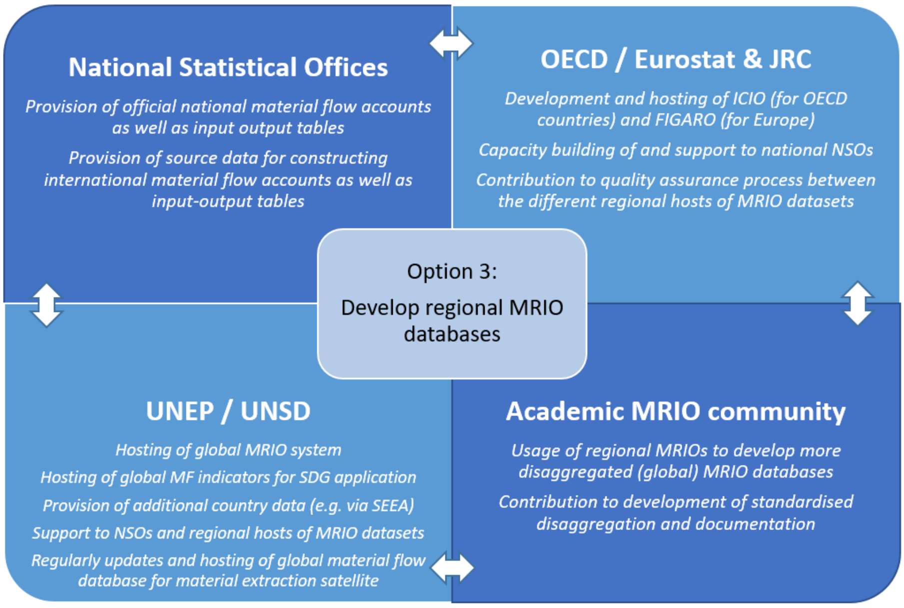
69. Option 3 focuses on a more decentralised approach and relies on regional nodes that utilise various MRIO databases with specific regional coverage for different world regions. This could result in specific models for the OECD, Europe, and various parts of the Southern Hemisphere and would perpetuate the status quo. To avoid contradicting results, a quality assurance process needs to be established between the different regional institutions hosting such MRIO datasets.

70. In this option, OECD and Eurostat develop and host the ICIO (for OECD countries) and FIGARO (for Europe) respectively. The two institutions also engage in capacity building of and support to national **NSOs** in the fields of **IO-table development and environmental accounting**. Very importantly, they contribute to the above mentioned quality assurance process between the different regional hosts of the MRIO datasets.

71. The **UNEP** and/or **UNSD** are the host of the global MRIO system, the IRP Global Material Flows Database as well as of the global MF indicators for SDG application and provide regular updates. As their European and OECD counterparts, they contribute to the above mentioned quality assurance process between the different regional hosts of the MRIO datasets aiming at integrating the different datasets into the global system. Further, they provide additional country data (e.g. via the SEEA initiative) and provide support to NSOs and regional MRIO hosts.

72. Finally, the academic MRIO community engages in using the regional and global MRIOs to develop more disaggregated MRIO databases to allow for tailored policy analysis of specific policy areas. Researchers contribute to the development of standardised methods for disaggregation and documentation of model developments. Figure 3 illustrates the role of players according to Option 3.

Figure 3. Distribution of roles between different organisations (option 3)



73. **Advantages and limitations**: Most existing regional models can produce data immediately but the coordination of diverting results and interpretation of the root cause of differences in results can be time consuming. Duplication of effort and investment is almost certain.

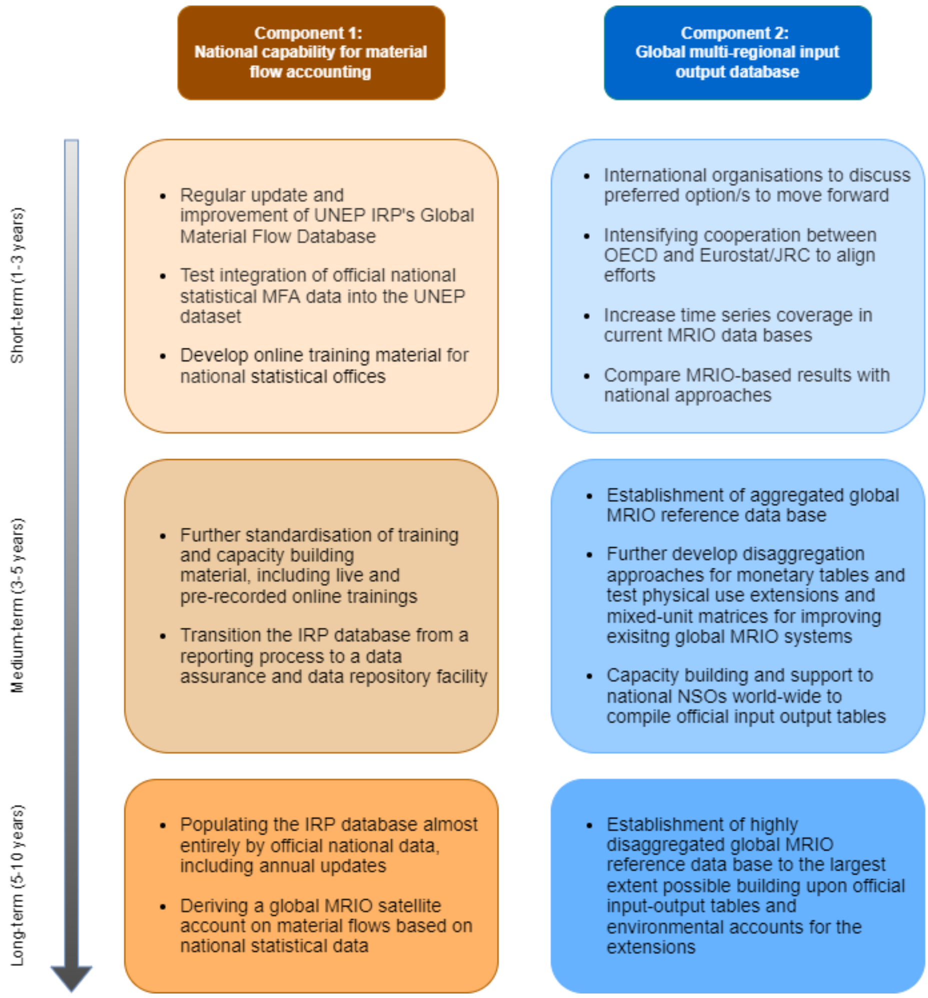
74. An important issue for any solution is the question of maintenance of the MRIO database to ensure new data is integrated on a regular basis. Experiences gained in the past few years with the development of highly detailed, global MRIO datasets suggest that employing advanced mathematical, computing and coding techniques to create an automated data workflow supported by quality assurance procedures can reduce updating costs significantly.

5.3. Summary of framework and actions

75. Figure 4 summarises the main development and improvement needs discussed in sections 5.1 and 5.2, structured into short-term (1-3 years), medium-term (3-5) and long-term (5-10 years) actions and covering both the MFA capacity building track as well as the further development and refinement of the MRIO approach.

76. Note that other actions are required in addition to those listed below, addressing issues that reach beyond demand-based indicators of material flows. One issue is the ***consistency between production- and consumption-based indicators*** regarding the use of physical versus monetary data to derive the indicators. Another topic is the ***coherence between various demand-based measures***, for example between material, energy and carbon footprints.

Figure 4. Overview of proposed framework and actions



6. Conclusions

77. Over the last two decades, the work of key organisations has enabled significant contributions to the knowledge base for demand-based material flow indicators. This has resulted in an adoption of the material footprint indicator by the UNEP, the OECD, Eurostat and many countries as well as in the context of the SEEA and the SDGs. The global community has also settled on environmentally extended input output analysis as the most suitable tool for the calculation of demand-based material flow indicators.

78. One advantage of the input output approach is that it is rooted in economic theory and its conceptual framework and methodological apparatus is part of the system of national accounting methodology. This facilitates adoption of a globally accepted standard for how to establish the accounting procedures.

79. Nevertheless, various global MRIO datasets have been developed over time from both international and statistical institutions as well as from academia, which has suited the intellectual progress in refining the approach. The availability of global data for demand-based material flow indicators has also increased the political acceptance and use in decision making and target setting.

80. This report has documented the institutional state of play in the area of calculating demand-based material flow indicators and has outlined the main methodological and procedural areas where further improvements are required. It has also outlined the way forward for the material satellite account needed for the calculation of material footprints as well as provided three options for progressing the MRIO development. All outlined options have certain advantages and limitations that shall be further explored in upcoming events. Whichever option is deemed most beneficial it would still require a certain level of international coordination to avoid contradicting results.

81. The process has now come to a point where further harmonisation and institutionalisation of a global approach for calculating material footprints have become an obvious advantage and perhaps a necessity to ensure high consistency of results. It is up to the international policy and science community to decide which future pathway for instituting demand-based indicators and supporting countries’ reporting needs is taken.

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