Producing environmental accounts with environmentally extended input output analysis

NILS BROWN (ED.), MÅRTEN BERGLUND, MIA BIVERED,
MALCOLM GRAY, SHINICHIRO NAKAMURA

2021 edition

STATISTICAL
WORKING PAPERS

eurostat

Producing environmental accounts with environmentally extended input output analysis

NILS BROWN (ed.), MÅRTEN BERGLUND, MIA BIVERED,
MALCOLM GRAY, SHINICHIRO NAKAMURA

2021 edition

Manuscript completed in February 2021

Luxembourg: Publications Office of the European Union, 2021

Theme: Environment and energy statistics
Collection: Statistical working papers

PDF: ISBN 978-92-76-30150-9 ISSN 2315-0807 doi: 10.2785/172888 KS-TC-21-001-EN-N

Abstract

Environmentally extended input output (EEIO) analysis has developed significantly in the last two decades. The method is presented in the *Applications and Extensions* for the System of Environmental-Economic Accounting (SEEA) and there are many national statistical offices (NSOs) using it produce for example statistics on greenhouse gas emissions with a consumption perspective. Building on this interest from NSOs, an EEIO subgroup to the London Group on environmental accounting was formed in 2019. This report builds on the highly-detailed technical presentation of EEIO in the *SEEA Applications and Extensions* and aims to demonstrate the potential of EEIO in the SEEA context by presenting practical examples of statistical offices' production, publication and communication of data produced with EEIO methods. The report also aims to provide examples of how EEIO data can be visualised and what types of analysis it can be used for. The examples presented are based on information compiled by statistical offices specifically for this report and other published information about the data and its production.

The examples included in the report cover greenhouse gas emissions (Statistics New Zealand, Eurostat and Statistics Sweden), domestic energy use (Eurostat) and waste (research results for Japan). Statistical offices in general publish their EEIO-data for a multitude of variables that can be suited to users' needs. Variables include for example product groups (in general for 50 to 60 categories covering the entire economy), time series of ten years or more, macroeconomic aggregates, and categories of final consumption. One key presentation for EEIO-data is according to macroeconomic aggregates reflecting the national accounts balancing equation. This presents environmental pressures (for example greenhouse gas emissions) for supply to the economy (domestic production and imports) on one side with total final demand (private consumption, government consumption, gross capital formation and exports) on the other. Such data can be powerfully visualised in a Sankey diagram. Another key presentation is for the environmental pressures (e.g. waste) generated due to the entire supply chain for consumed products which can be much higher than the environmental pressures arising directly from a single production process.

Communicating EEIO data presents unique challenges. The term "consumption perspective" is often used as the direct opposite to "production perspective". At the same time, "consumption" represents only one component in domestic final demand according to the national accounts where capital formation represents another. The term "footprint" is also commonly used. Whereas statistical analysts and other experts may require highly detailed and specific terminology, policy makers and the general public may be more comfortable with general terms.

The examples demonstrate two main approaches to accounting for imported products in EEIO - to use data that models the economic structure and environmental pressures of exporting countries explicitly (e.g. Statistics Sweden), or to assume that imported products are produced in the same way as domestic products (e.g. Eurostat). It is most important that the decision of which method to use is given due consideration, and that the choice is communicated transparently. Eurostat's FIGARO (Full International and Global Accounts for Research in input-Output) project in collaboration with the Joint Research Centre has an ultimate goal to produce input-output tables with global coverage. The outcomes of FIGARO are therefore highly relevant for statistical offices work with EEIO going forward.

The EEIO subgroup will continue to be an important forum and community of practice facilitating knowledge sharing and discussion about EEIO and SEEA-related issues such as those raised in this report.

Keywords: environmentally-extended input-output analysis, system of environmental-economic accounting, greenhouse gas emissions, material flow accounts, waste

Foreword

Statistics Sweden has had the opportunity to coordinate the work of writing this report in part due to funding from Eurostat through the 2019 Grants call ESTAT-2019-PA5-E-ENVECO. Statistics New Zealand, Eurostat and Prof. Shinichiro Nakamura (Waseda University, Japan) have made valuable text contributions to the work.

The authors are grateful to the continued engagement of other participants in the London Group subgroup on environmentally-extended input output analysis who have attended meetings throughout 2020. We are further grateful to members of the London Group on environmental accounting who discussed an early draft of Chapter 2 of this report that was submitted the 26th Meeting of the London Group (online). Ole Gravgård Pedersen (Statistics Denmark) is worthy of special thanks for leading the discussion of the paper at the meeting.

Nils Brown, Bagarmossen, December 2020

Contents

Abbreviations

ADTA-IO adapted domestic technology assumption input-output

CPA – classification of products by activity

DTA - domestic technology assumption

EEIO – Environmentally extended input-output

FIGARO - Full International and Global Accounts for Research in input-Output

GHG – greenhouse gas

EU-ICIO – EU – Inter-country input-output

IFEU – Insitut fur Energie- und Umweltsforschung, Heidelberg, Germany (Institute for Energy and Environmental Research)

IO – input-output

MFA-RME material flow accounts in raw material equivalents

MOE - Ministry of the Environment

MRIO – multi-regional input output

NPISH – non-profit institutions service households

NSO – National statistical office

RME – Raw material equivalents

RMC - Raw material consumption

SDG – sustainable development goal

SEEA – System of Environmental-Economic Accounting

SNAC - single country national accounts consistent

SRIO – single region input-output

WIO - Waste input-output

WIO-WWW – web-based waste input-output table for Japan

1 Introduction

Environmentally extended input-output (EEIO) tables combine information from standard economic input-output tables and information on environmental flows into an integrated data set. EEIO analysis has been used to produce data on for example GHG emissions from a consumption perspective. Other output examples include land, water, material and waste footprints.

EEIO can be a powerful tool for analysing the relation between economic and environmental flows. It is a method that national statistical offices (NSOs) are beginning to adopt as a complement to other data produced in the System of Environmental-Economic Accounting (SEEA). EEIO analysis can be used to produce policy relevant data. For example, statistics on GHG emissions from a consumption perspective and material flows are relevant for several national and EU policies as well as for the Sustainable Development Goals (SDGs).

This report aims to demonstrate the potentials of EEIO analysis for producing statistics, by presenting practical examples of key extensions of the SEEA with EEIO for data production in statistical offices in more detail. The London Group EEIO sub-group, formed at the meeting in Melbourne in 2019, has acted as a reference group for this report. Four of its members have also contributed to this report by submitting material about their experiences with EEIO, namely Statistics New Zealand, Eurostat, Professor Shinichiro Nakamura and Statistics Sweden. The EEIO sub-group has also participated in discussions focusing on the way forward for EEIO analysis in SEEA.

1.1. Research background

The theory for the economic core of input-output modelling was developed by Wassily Leontief in the 1940s (see Leontief, 1936 and Leontief, 1977). Interest in environmental extensions first arose in the late 1960s with for example Ayres and Kneese (1969) paper, which presented a formal mathematical framework for tracing residual flows in the economy using a general equilibrium model. Leontief also worked with EEIO at this time, and published a paper in 1970 incorporating pollution into an input-output model of a national economy (Leontief, 1970).

Research interest in EEIO has grown significantly since the late 1990s (Hoekstra, 2010). An early and still key application has been the calculation of greenhouse gas (GHG) emission footprints from a consumption perspective (Wiedmann, 2009). There is also a growing body of research applying EEIO for other highly relevant environmental pressures such as land use (Weinzettel et al. 2013), water use (Hoekstra and Mekonnen, 2012) and material demand (Wiedmann et al., 2015). Beyond the growing body of scientific literature in EEIO, recent research efforts have further produced a number of multiregional input-output (MRIO) databases, for example GTAP[1], EXIOBASE[2], WIOD[3]

[1] GTAP: https://www.gtap.agecon.purdue.edu/

[2] EXIOBASE: https://www.exiobase.eu/

[3] WIOD: http://www.wiod.org/home

and EORA[4]. These databases have facilitated further research. Researchers have for example estimated footprints for several types of environmental pressures across many countries using EXIOBASE (Wood et al., 2018).

1.2 EEIO in the SEEA

Meanwhile, when the *SEEA Central Framework*[5] was adopted by the United Nations Statistical Commission in 2012, EEIO was included in the companion document *SEEA Applications and Extensions*[6]. The *SEEA Applications and Extensions* presents the background to a number of valuable theoretical approaches for using EEIO to extend the coverage of the environmental accounts as considered in the Central Framework.

These presentations include theoretical descriptions of the main methodological EEIO approaches: SRIO, MRIO and the hybrid IO approach. The single-region input-output (SRIO) approach is based on supply-and-use tables that are combined into input-output tables. These can be structured as a product-by-product or an industry-by-industry matrix. SEEA data on environmental flows can then be integrated into the model. Hybrid input-output tables are similar to SRIO tables, but combine monetary and physical units and incorporates elements of life cycle assessment and process analysis. Multiregional input-output (MRIO) tables have a similar accounting structure to SRIO but also take into account international differences by including several countries' production, consumption, import and export. The *SEEA Applications and Extensions* further presents theoretical explanations of available techniques for analysing EEIO data, including multiplier analysis, attribution of environmental flows to final demand (e.g. footprint calculations, production versus consumption perspectives, environmental trade balance), decomposition analysis and computable general equilibrium modelling[7].

The *SEEA Applications and Extensions* thus provides a valuable introduction to EEIO in the SEEA context. However, it does not provide examples of recent applications or examples of how EEIO can be practically implemented in NSOs to produce and publish data. A growing number of NSOs and international organisations now use EEIO analysis to produce statistics, as presented in the next section. In the next section, results from a recent survey about the use of EEIO among statistical institutions and researchers within the London Group network are presented, which gives an overview over current use, communication of results and improvement needs.

1.3 Current use of EEIO analysis amongst NSOs and international organisations

Arising from the ongoing interest amongst London Group members in the use of EEIO in the SEEA, in 2019 an online survey of NSOs and international organisations with an interest in EEIO was carried out[8]. It was implemented in a collaboration between Statistics Sweden, Eurostat and the OECD. The aim of the survey was to gather knowledge about which organisations are doing work on EEIO within the London Group network and in what form, rather than to make a full inventory of EEIO at NSOs. The survey investigated issues such as the current use of EEIO analysis, coverage (in terms of environmental indicators), sub-national regionalization of analyses, types of data used,

[4] EORA: https://worldmrio.com/

[5] seea_cf_final_en.pdf (un.org)

[6] https://seea.un.org/sites/seea.un.org/files/ae_final_en.pdf

[7] See chapter 3.3 in https://seea.un.org/sites/seea.un.org/files/ae_final_en.pdf

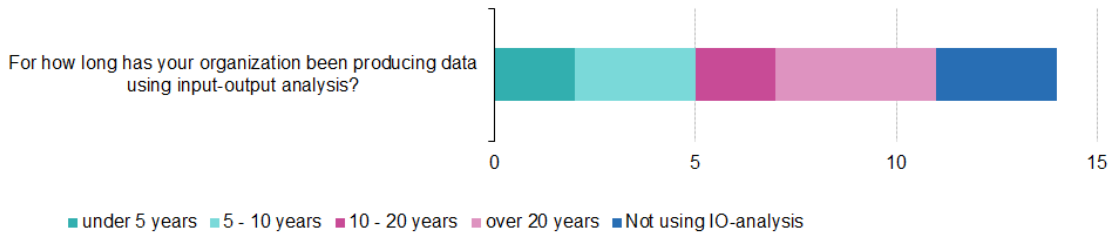
[8] The survey results were presented at the 25th London Group meeting in Melbourne in 2019. https://seea.un.org/sites/seea.un.org/files/190923_survey_report.pdf

communication of results and areas of improvement for communication.

The target group for the survey was statistical offices and international organizations working with environmental economic accounts through the London Group. The survey was also sent to members of the research community working with EEIO and connected to the London Group.

Fourteen organisations answered the survey, of which eleven use EEIO analyses to produce data as shown in Figure 1. Four organisations reported more than 20 years of experience of EEIO analysis. Three organisations answered that they did not yet use EEIO analysis, and one of the main reasons organisations have not started using EEIO analysis appears to be lack of funding. The respondents are listed in Table 1 below. The survey did not attempt to compile an exhaustive list of countries producing and publishing EEIO data. The UK and Denmark for example do not feature in Figure 1 and Table 1 but do produce and publish EEIO-based data. Eurostat publishes material flow accounts in raw material equivalents (MFA-RME) for a number of member states that voluntarily report data produced with an EEIO approach.

Figure 1: Number of respondents using EEIO analysis to produce data and the length of time they have been doing it



Source: https://seea.un.org/sites/seea.un.org/files/190923_survey_report.pdf

Table 1: List of survey respondents

Central Bank of Costa Rica
European Environment Agency
Eurostat
Inter-American Development Bank
Istat
Ministry for an ecological and solidary transition Office of the Commissioner-General for Sustainable Development Data and Statistical Studies Department
National Bureau of Statistics, P.R.China
Statistics Canada
Statistics Finland
Statistics Netherlands
Statistics Sweden
Stats NZ
UNSW Sydney (The University of New South Wales, Sydney, Australia)
World Bank

Source: https://seea.un.org/sites/seea.un.org/files/190923_survey_report.pdf

Respondents identify data sources for EEIO analysis such as national statistics (IO tables from the national accounts and data from the environmental accounts), Eurostat and EXIOBASE. The data produced using EEIO is considered official statistics in the case of three of the respondents. Five of the eleven respondents compile regional (sub-national) data and others mention they intend to do so. Seven of the respondents cover both domestic final consumption and international trade. All three types of methodological approaches presented in the SEEA *Applications and Extensions* are used: MRIO approach (three respondents), hybrid approach (three respondents) and SRIO approach (two respondents).

According to the survey, EEIO analysis is most commonly used to produce data on GHG emissions, with five respondents specifically mentioning it and others mentioning air emissions (presumably also covering GHG emissions). Several respondents also produce land-, water-, material- and forest-related data using EEIO analyses as shown in Table 2.

Table 2: Areas covered by NSOs and others producing EEIO-based data

	Total respondents	...of which planned/pilot	Respondent (if only one)
GHG emissions	5	1	
Air emissions	3		
Land use, land cover	4	2	
Water (water footprint, water use etc.)	4	1	
Material	4		
Energy	2	1	
Forest	2		
Tourism	2	1	
Agriculture	1		IADB
Environmental pressures and impacts	1		EEA
Marine economy	1		Stats NZ
Indirect contribution to GDP	1		Stats NZ
Social accounting matrix	1		CB of Costa Rica

Source: https://seea.un.org/sites/seea.un.org/files/190923_survey_report.pdf

Most of the respondents who use EEIO analysis reported that the produced data communicates strengths of the SEEA in general. One respondent highlighted that it makes it possible to analyse "environmental and economic interlinkages and understanding of the structure and drivers of environmental pressures". The main forms of publishing EEIO data according to the survey responses is in public reports, databases and/or tables.

Respondents also raised a number of issues to be addressed going forward; e.g. how much harmonisation to aim for and how to improve the communication of results.

1.4 Aim

This report builds on the highly-detailed technical presentation of EEIO in the *SEEA Applications and Extensions* and the London Group EEIO sub-group's survey. This report aims to demonstrate the potential of EEIO in the SEEA context by presenting practical examples of statistical offices' data production with EEIO. The report also aims to provide examples of how EEIO data can be visualised and what types of analysis it can be used for.

1.5 Work process

The work process for the production of the report has been as follows:

Statistics Sweden produced a document template with a structure for EEIO subgroup participants to fill in with information about their work with EEIO as a contribution to the report.

The template was sent out to participants in the EEIO subgroup spring 2020, and contributions were sent to Statistics Sweden between August and November 2020.

Statistics Sweden compiled a draft report chapter focussing on GHG emissions with a consumption perspective which was submitted to the 26th Meeting of the London Group on environmental accounting (held online) in September 2020. The chapter comprised a synthesis of relevant material received up to that point from subgroup participants supplemented in particular cases with additional information gathered from supporting documents online. The draft chapter noted above was presented and discussed at the London Group meeting.

In December 2020 a full draft of the report was shared with members of the London Group EEIO subgroup with the invitation to comment. The final draft of the report expands from the draft chapter by including another chapter covering other environmental applications (waste and MFA-RME) based on further contributions from subgroup participants, also supplemented with additional information from supporting documents online. The final draft also includes a discussion of major points arising in the previous chapters as well as discussions with the EEIO subgroup held during the course of the work (see below).

1.6 Engagement with the EEIO subgroup

EEIO subgroup participants were invited to engage in the production process of the report by:

- Contributing written information about their work with EEIO through the template
- Presenting their work to other members of the subgroup at subgroup meetings
- Commenting on presentations from other subgroup participants
- Participating in the 26th London Group Meeting and commenting on the presentation and draft chapter of the report
- Contributing to the discussion of next steps for international collaboration
- Commenting on a draft of the final report

The following London Group EEIO subgroup meetings have been held:

- April 2020: Start-up meeting:
    - Presentation of template for participant contributions to report
    - Discussion of format for the report
- August 14th, 2020 - late timezones meeting:
    - Presentation by Prof. Shinichiro Nakamura, Waseda University on endogenous calculation of GHG emissions using EEIO and Waste IO
    - Presentation by Statistics Sweden about producing statistics on GHG emissions with a consumption perspective
    - Tour-de-table discussion of presented material
- August 25th, 2020 - early timezones meeting:
    - Presentation by Statistics Sweden about producing statistics on GHG emissions with a consumption perspective
    - Tour-de-table discussion of presented material

- November 11th 2020: Discussion of next steps for international EEIO collaboration (early timezones):
  - Tour-de-table of participants
  - Opportunity for further feedback on the EEIO presentation at the 26th London Group meeting (online)

- November 12th 2020: Discussion of next steps for international EEIO collaboration (late timezones):
  - Tour-de-table of participants
  - Opportunity for further feedback on the EEIO presentation at the 26th London Group meeting (online)

In addition to the dedicated meetings noted above, all members of the London Group were given the opportunity to comment on the draft chapter presented the group's 26th Meeting, online in October 2020. One outcome from the presentation was that Istat (Italy) and the Office of National Statistics (UK) expressed their interest in joining the EEIO subgroup.

1.7 Report outline

The structure of the subsequent sections of the report is as follows:

Chapter 2 presents EEIO-based data on GHG emissions and domestic energy use. The Chapter makes use of material contributed by Statistics New Zealand and Statistics Sweden (GHG emissions) and Eurostat (GHG emissions and domestic energy use).

Chapter 3 presents EEIO-based data on waste and material flow accounts in raw material equivalent (MFA-RME), making use of material contributed by Eurostat (MFA-RME) and Prof. Shinichiro Nakamura (Waseda University, Japan).

Chapter 4 is a concluding discussion encompassing significant issues arising from the material in previous chapters and issues raised in subgroup participants written contributions and meeting discussions.

2 EEIO analysis for GHG emissions and domestic energy use with a consumption perspective

2.1 Background

GHG emissions from a consumption perspective are policy relevant from multiple perspectives and governance levels. For example they are relevant for EU policies such as the Sustainable Consumption and Production and Sustainable Industrial Policy Action Plan[9], resource efficiency (as addressed in the Roadmap to a resource efficient Europe[10]) and for the border carbon adjustment proposed in the European Green Deal[11]. Such policy issues are also relevant for Eurostat's data on domestic energy use with a consumption perspective

Statistics New Zealand developed initial estimates of consumption-based GHG emissions as part of a response to recommendations from a New Zealand Productivity Commission report[12] on transitioning to a low emissions economy. It adds to New Zealand's suite of emissions data providing an important additional lens on the climate change mitigation challenge and fills an important data gap in New Zealand's new well-being indicator framework.

In Sweden, the generational goal of the Swedish environmental quality objectives aims to "hand over to the next generation a society in which the major environmental problems have been solved without increasing environmental and health problems outside Sweden's borders"[13]. GHG emissions with a consumption perspective are one of eight indicators used to follow progress towards this goal, and notably the only one which measures environmental pressures outside of Sweden. An increasing number of regional and local government authorities in Sweden are establishing consumption-based emissions targets complementing existing territorial GHG emissions targets.

At the international level, GHG emissions from a consumption perspective is relevant for the Sustainable Development Goals (SDGs). Goal 12 is to "Ensure sustainable consumption and production patterns", which calls for introduction of sustainable consumption and production (SCP) national action plans or making SCP a national policy priority or target[14]. EEIO-based data on domestic energy use is relevant for tracking progress towards SDG8 – Affordable and clean energy. Countries are allowed to track additional SDG indicators and Sweden for example has chosen to

[9] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52008DC0397&from=EN

[10] https://ec.europa.eu/environment/resource_efficiency/about/roadmap/index_en.htm

[11] https://ec.europa.eu/info/sites/info/files/european-green-deal-communication_en.pdf

[12] https://www.productivity.govt.nz/assets/Documents/4e01d69a83/Productivity-Commission_Low-emissions-economy_Final-Report.pdf

[13] http://www.swedishepa.se/Environmental-objectives-and-cooperation/Swedens-environmental-objectives/The-generational-goal/

[14] https://sdgs.un.org/goals/goal12

track a national indicator on GHG emissions from consumption (indicator 12.1.2(N))[15], which more countries could do by using EEIO analysis.

2.2 Methodologies

2.2.1 Calculation procedures

EEIO incorporates a family of closely related methods. Statistics New Zealand and Eurostat both use a single region input-output (SRIO) method, assuming domestic technology for imports. Statistics Sweden applies a simplified single country national accounts consistent (SNAC) method.[16] These two approaches use the same method for the calculation of domestic environmental pressures, but differ in the calculation of environmental pressures arising due to imported products.

In both methods, the environmental pressures arising from final demand in the economy S_{tot} can be expressed as the sum of those arising domestically, S_{dom} and those arising abroad (due to imports) S_{imp}:

$$S_{tot} = S_{dom} + S_{imp}$$

Equation 1

In both methods, domestic environmental pressures as given in Equation 1 are calculated according to

$$S_{dom} = e_{dom}(I - A_{dom})^{-1}Y_{dom} + H_{dom}$$

Equation 2

where e_{dom} is the environmental pressure per unit gross output, A_{dom} is the domestic intermediate demand, Y_{dom} is the final demand for domestically produced products in the economy and H_{dom} are direct environmental pressures from households. Eurostat uses the same method to calculate domestic energy use.

In the SRIO with DTA, emissions arising in total, both domestically and abroad can be calculated as

$$S_{tot} = e_{dom}(I - A_{tot})^{-1}Y_{tot} + H_{dom}$$

Equation 3

where A_{tot} is the total intermediate demand ($A_{tot} = A_{dom} + A_{imp}$) and Y_{tot} is the final demand of both domestic and imported products. Emissions arising abroad only, can then be calculated as the residual through

$$S_{imp} = S_{tot} - S_{dom}.$$

Equation 4

Here, S can be interpreted as either a scalar (total environmental pressure), a vector (environmental pressure per product consumed) or a matrix (environmental pressure per product consumed and per component of final demand, of which one of the components could also be exports).

The environmental pressures of imports are thus calculated as if the imports had been produced in the economy in question. One interpretation of this method is that these environmental pressures

15 https://scb.se/en/finding-statistics/statistics-by-subject-area/environment/environmental-accounts-and-sustainable-development/sustainable-development-indicators/

16 Description in journal article: https://www.sciencedirect.com/science/article/abs/pii/S0959652619312600

represent those avoided domestically by importing the products. Eurostat does not aim to include imports when calculating domestic energy use with EEIO.

In the simplified SNAC, the environmental intensity for imported products is calculated using a global multi-regional input output (MRIO) table. In a first step, production intensities around the globe are calculated:

$$e_{world} = e_{GMRIO}(I - A_{GMRIO})^{-1}$$

Equation 5

Where e_{world} is the environmental intensity per product and country/region included in the MRIO. e_{GMRIO} is the environmental intensity of gross output in the MRIO and A_{GMRIO} is intermediate demand per unit of gross output in the MRIO. Note that matrices in Equation 5 are disaggregated both by product type and geographical area (in single countries or groups of countries). In order to derive import intensities for the importing nation, the following calculation is performed:

$$e_{imp} = B \circ e_{GMRIO} a$$

Equation 6

Where B is a matrix of import shares from each geographical area in the MRIO by product group for the importing country or region and a is a simple summation vector. The operator $\circ$ refers to an *element-wise* multiplication of B and e_{GMRIO}. This gives e_{imp} as the import intensities by product group according to the specific import shares for the importing country and according to the environmental pressure intensities and economic structure of the MRIO used. According to the simplified SNAC method used, S_{imp} can then be calculated as:

$$S_{imp} = e_{imp} A_{imp} (I - A_{dom})^{-1} Y_{dom} + e_{imp} Y_{imp}$$

Equation 7

Where A_{imp} is the intermediate demand for imported goods per unit output and Y_{imp} is the direct final demand for imported goods. Other terms are as before.

2.2.2 Input data

Table 3 shows the input data required for the methods considered. The SRIO with DTA uses as input data statistics already produced in National Statistical Institutes. Firstly, the method uses the air emissions accounts, produced following the guidelines in the SEEA CF, and the EU also by Regulation No 691/2011. Domestic IO tables are produced in NSOs by national accounts. Table 3 also shows that the simplified SNAC used by Statistics Sweden also makes uses of air emissions accounts and domestic input-output tables. On top of these, the simplified SNAC requires a global MRIO. Note that the MRIO includes environmental extensions. Statistics Sweden currently uses EXIOBASE[17], being the MRIO that was shown in research to be the best according to evaluation covering a range of parameters[18]. Table 3 also shows that the simplified SNAC also makes use of statistics on product imports to the country or region in question. It is important to note that these statistics provide information not only on the value of products imported, but also the country or region from which the imports were exported. Domestic input-output tables do have data about product imports but they do not in general provide information about the exporting country.

[17] Journal article here: https://onlinelibrary.wiley.com/doi/full/10.1111/jiec.12715

[18] Journal article here: https://www.sciencedirect.com/science/article/abs/pii/S0959652618334231

Table 3: Required data for the methodologies considered (x indicates that the data source is used for the method in question)

Data sources	Simplified SNAC – Statistics Sweden	SRIO with DTA – Eurostat, Statistics New Zealand
Air emissions accounts[1]	x	x
Domestic input-output table	x	x
Environmentally-extended MRIO	x	
Import statistics by product group and geographical origin	x	

[1]physical energy flow accounts are used for Eurostat's data on domestic energy use

2.3 Output

The material shows the variety of applications for statistics produced with EEIO. This section firstly presents an overview of the types of variables included in the statistics produced, which are then demonstrated in detail with examples from the statistics themselves.

2.3.1 Overview of published data

Data with a consumption perspective are provided to users through database tools allowing users to produce their own tables (Statistics Sweden[19], Eurostat[20,21]) or in excel tables (Statistics New Zealand[22]). Data are broken down according to the following parameters:

Physical parameters: There is a focus amongst the examples gathered on emissions of different GHGs (reported for each gas separately and aggregated as carbon dioxide equivalents). Data is also provided for other air emissions – SOx, NOx, carbon monoxide, ammonia, particles, Volatile Organic Compounds. Eurostat also provide data with a consumption perspective beyond only air emissions, covering net domestic energy use.

Time series are available back to 2008 (Statistics Sweden, Eurostat GHGs), 2007 (Statistics New Zealand) and 2014 (Eurostat, domestic energy use). Currently data is available up to 2017 (Statistics Sweden, Statistics New Zealand and Eurostat – domestic energy use) and 2018 (Eurostat, GHGs).

Macroeconomic aggregates: Import, Domestic production (GDP), gross fixed capital formation, final consumption, exports. Emissions and domestic energy use data according to these breakdowns are often further broken down. In particular, final consumption is further broken down into household consumption, government consumption and consumption by non-profit institutions serving households (NPISH).

Product categories: 64 groups (Eurostat, by CPA – classification of products by activity), 50 product groups (Statistics Sweden, by Swedish CPA-related classification)

Purpose of consumption: Statistics Sweden and Statistics New Zealand produce data on air

[19] http://www.statistikdatabasen.scb.se/pxweb/en/ssd/START__MI__MI1301/?rxid=da0e0054-f070-48ce-8411-d08428b9a484

[20] https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_ac_io10&lang=en

[21] https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_ac_pefafp&lang=en

[22] https://www.stats.govt.nz/information-releases/greenhouse-gas-emissions-consumption-based-year-ended-2017

emissions from private consumption disaggregated according to the classification of individual consumption by purpose (COICOP), from 13 to 108 individual categories.

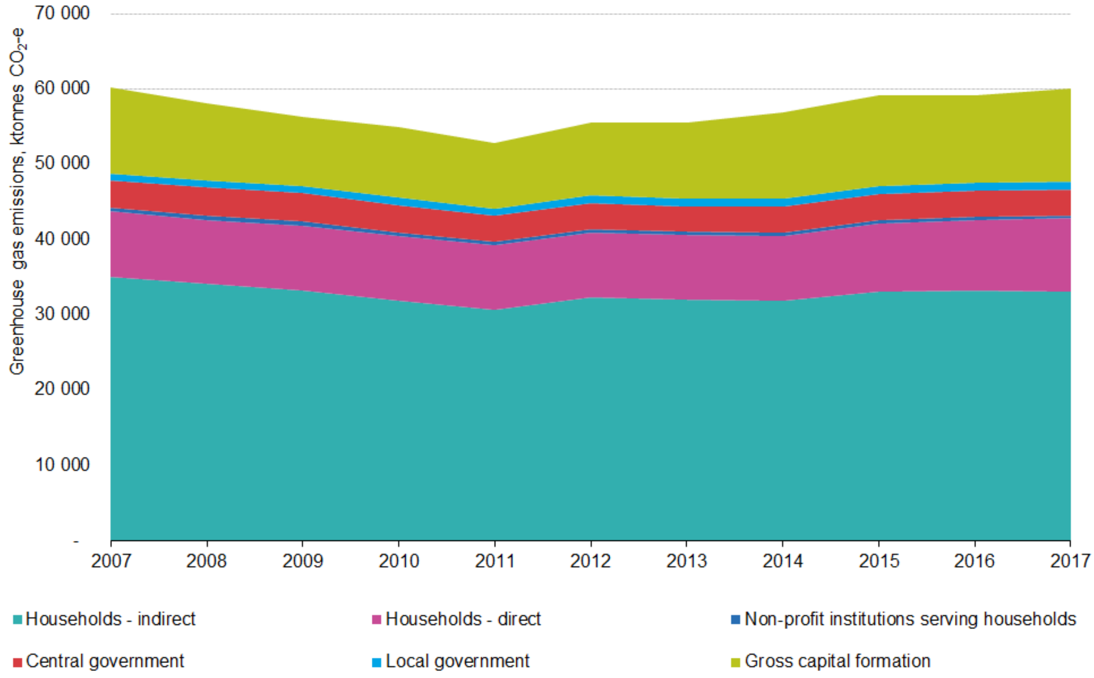
Statistics New Zealand provides a breakdown of air emissions arising due to gross fixed capital formation by type of asset. Statistics New Zealand also produce estimates of consumption-based GHG emissions from tourism, disaggregating for tourist origin (domestic and international) and emissions origin (direct and indirect) in a time series from 2007 to 2017.

2.3.2 Example – GHG emissions from domestic final use

For New Zealand and Sweden respectively, Figure 2 and Figure 3 both show the GHG emissions arising from the same macroeconomic aggregate, namely domestic final use. GHG emissions for this aggregate are often termed the “consumption footprint” or “carbon footprint” of a nation or region. In Figure 2 and Figure 3 alike, GHG emissions are further broken down into the same categories for final use. However, the figures differ in the further disaggregation that is applied. In Figure 2, the household category is broken down into direct emissions (arising in particular from fossil-fuelled household vehicles as well as fossil-fuelled home heating) and indirect emissions (arising elsewhere in the production chain for products consumed by households). The government category is further broken down into local and central. In Figure 3, each final use category is broken down further by the origin of emissions (domestic or imported).

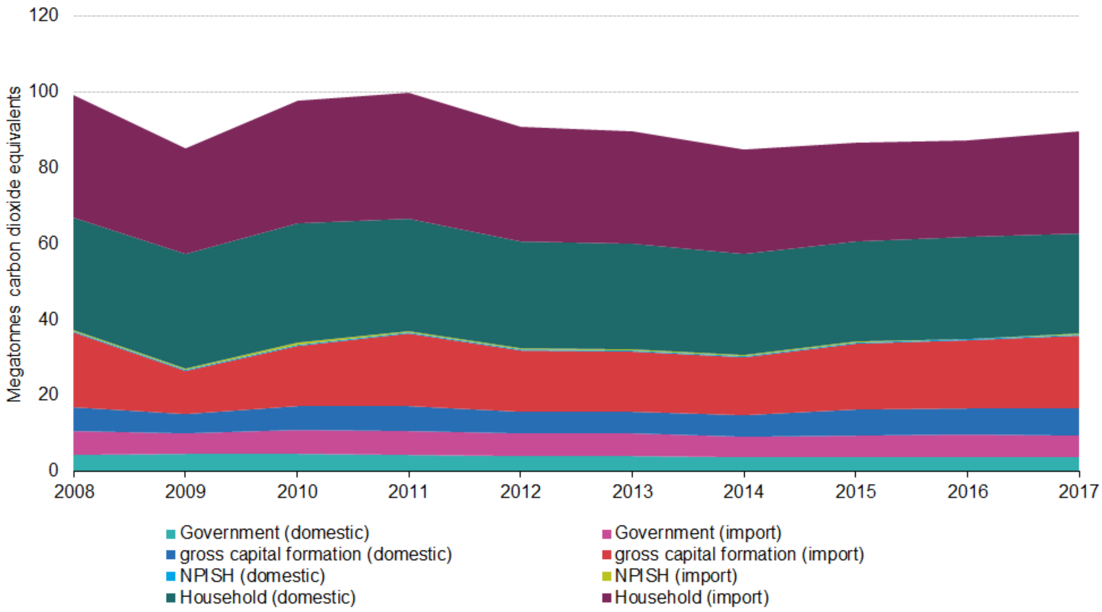
The figures show that the largest proportion of GHG emissions due to domestic final use are from household consumption, followed by gross capital formation and then government consumption. According to Figure 2, New Zealand’s consumption-based emissions have barely changed, with emissions initially decreasing following the global financial crises due to subdued demand and decreased emissions intensities, and then increasing from 2011 onwards as demand increased. Gross fixed capital formation in particular has shown a significant increase, in part due to the Christchurch rebuild following the Canterbury earthquakes. According to Figure 3, GHG emissions due to domestic final use have decreased by about ten percent in Sweden between 2008 and 2017. The figure also shows that about half of the GHG emissions due to household consumption arise due to imports and half due to domestic production. Meanwhile, for government consumption and gross capital formation, a larger proportion arise due to imports.

Figure 2: GHG emissions from domestic final use in New Zealand



source: Statistics New Zealand

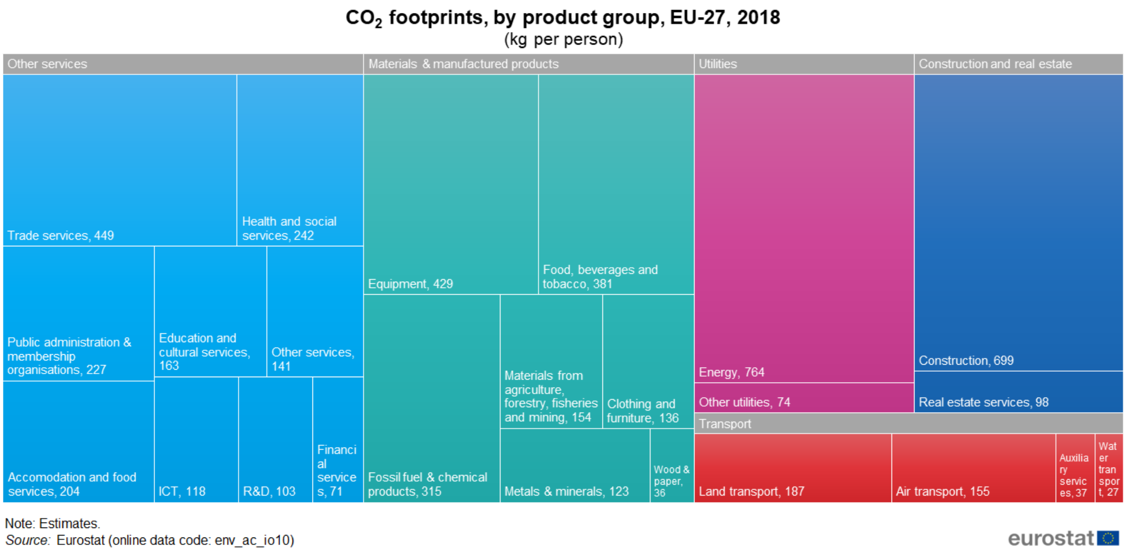
Figure 3: GHG emissions from domestic final use in Sweden



Source: Statistics Sweden

Figure 4 shows the GHG emissions from domestic final use for the EU-27 from Eurostat. The presentation differs from those in Figure 3 and Figure 4 amongst others because it shows only carbon dioxide emissions and not other GHGs. It also omits emissions arising directly from households (principally fossil fuel combustion for heating and transportation purposes). Figure 4 shows that the energy sector is the largest single contributor to carbon dioxide emissions followed by construction. Meanwhile the consumption of "other services" is responsible for about a third of carbon dioxide emissions. This is noteworthy because carbon dioxide emissions from "other services" from a *production* perspective tends to be much lower. This illustrates well the fact that the consumption perspective used here accounts not only for direct emissions from a producing industry but also the emissions arising from the intermediate supply chain necessary to provide a given sector's final products.

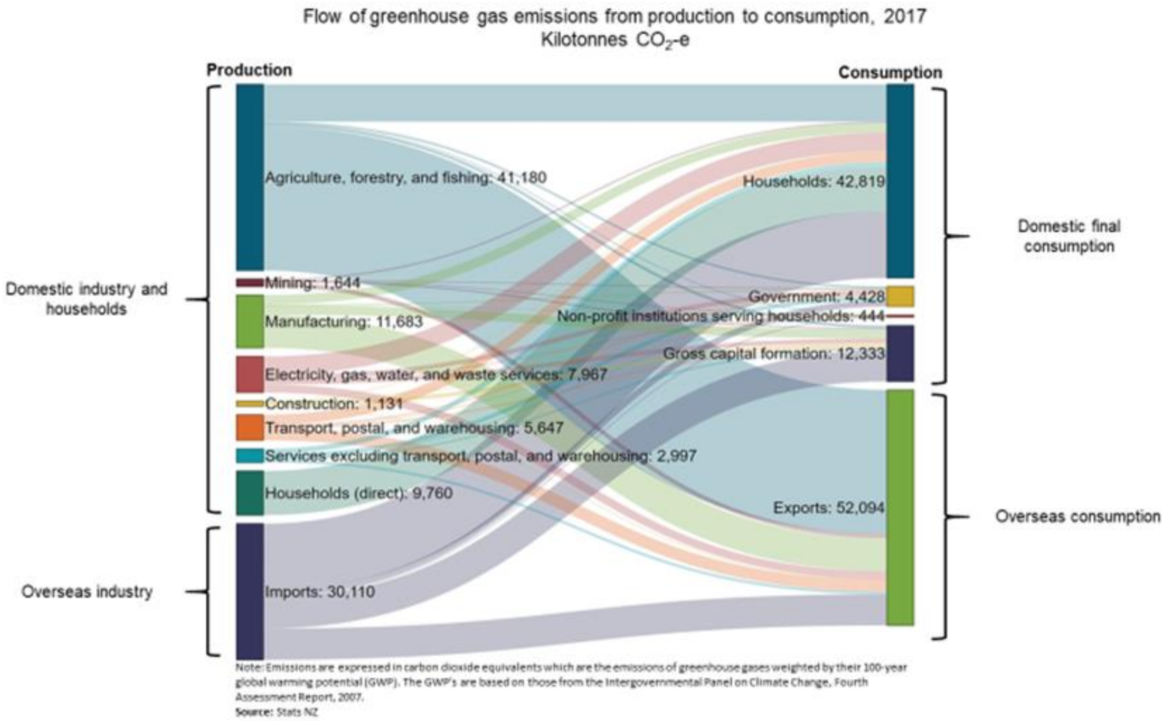
Figure 4: GHG emissions for domestic final use for the EU-27 for 2018. Note that direct emissions from households are not included.



Source: Eurosta

2.3.3 Example – GHG emissions from supply and demand in the economy

Figure 5: Sankey diagram showing emissions arising due to the supply side in the accounting identity and the demand side for New Zealand.

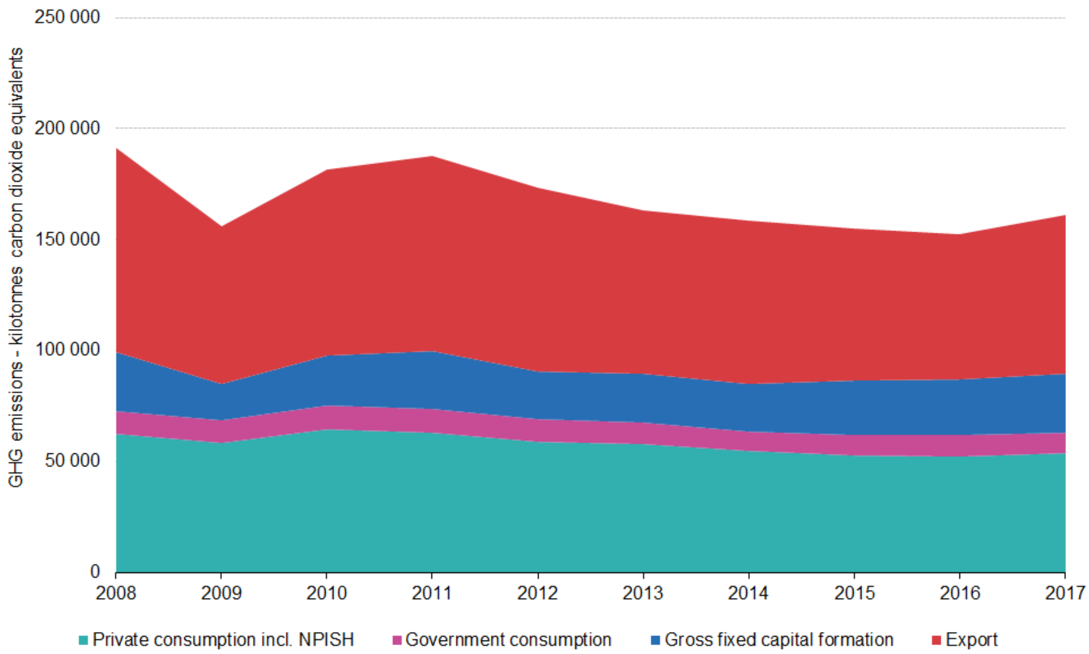


Source: Statistics New Zealand

Figure 5, Figure 6 and Figure 7 show different ways of visualising statistics on GHG emissions as they relate to the accounting identity between supply and demand in a national economy. Figure 5 shows that a large quantity of New Zealand's production emissions are "exported", in particular from the agricultural sector. A large proportion of emissions arising from New Zealand's manufacturing sector are also "exported". Meanwhile, about one third of GHG emissions from New Zealand's domestic final consumption arise from products imported to New Zealand.

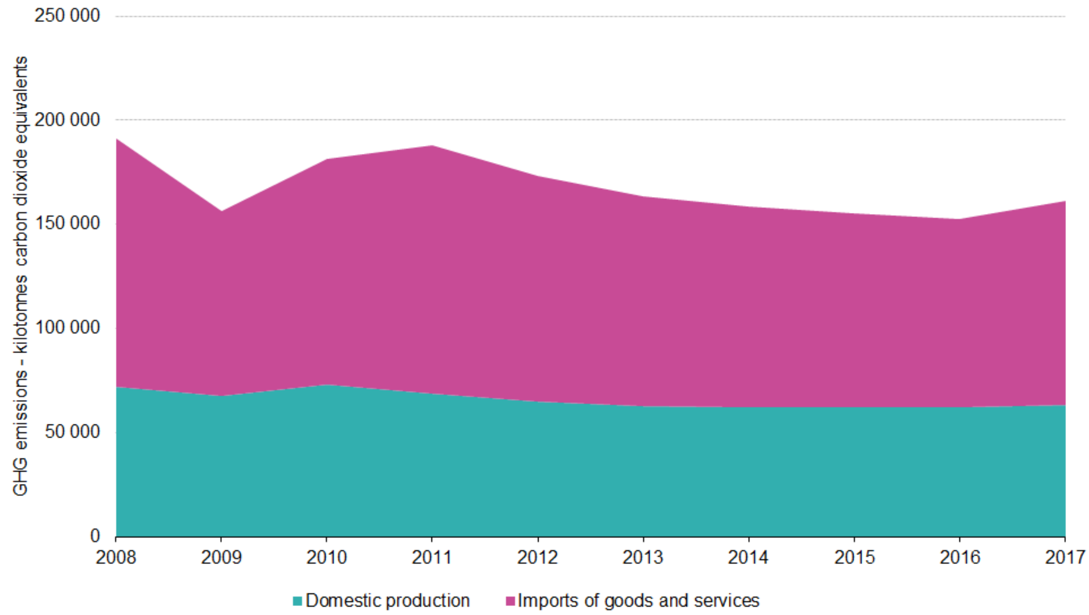
Figure 6 and Figure 7 show time series for Sweden's GHG emissions from the perspective of the demand and supply side in the economy respectively. Figure 7 for example shows emissions from a supply perspective. It shows that emissions arising from products imported into the Sweden account for about two thirds of the total emissions. Figure 6 meanwhile shows the demand perspective. Note that the sum of private consumption, government consumption and gross fixed capital formation in Figure 6 is equal to the total shown for domestic final demand as shown in Figure 3. It is interesting to note that emissions arising due to exports amount to about one third of the total emissions from the *total* final demand as shown.

Figure 6: **Time series of yearly GHG emissions due to total final demand in Sweden, including exports. NPISH – non-profit institutions serving households**



Source: Statistics Sweden

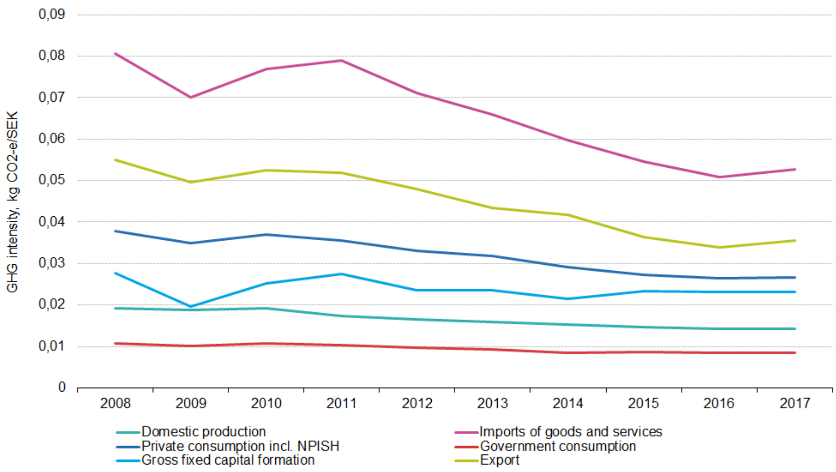
Figure 7: **Time series of yearly GHG emissions due to supply in the Swedish economy**



Source: Statistics Sweden

As an example of the interoperability of the statistics, Figure 8 shows the GHG emissions intensity for all the aggregates in Sweden's accounting identity. The figure shows that the intensity for imported products is considerably higher than that for domestic production. A significant contributor to this difference is that electricity and heat production (both district heating and on-site combustion) are to a great extent free of fossil fuels in Sweden. A further contributing factor is the type of products imported may simply have a higher emissions intensity. The figure further shows that emissions in all aggregates have a decreasing trend over the time series of the data.

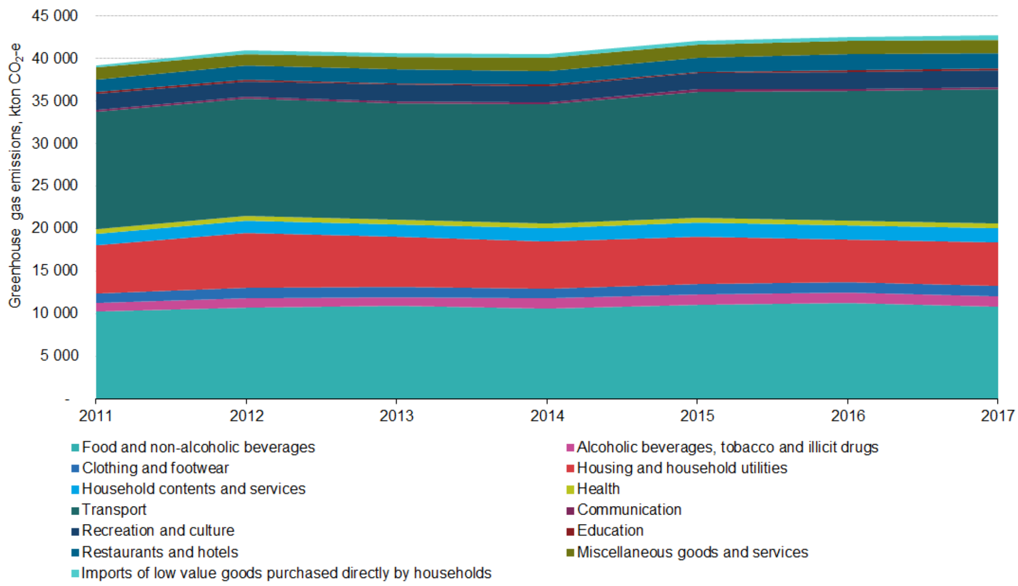
Figure 8: GHG emissions intensities for aggregates of Sweden's national income identity. Calculated for constant 2015 SEK



Source: Statistics Sweden

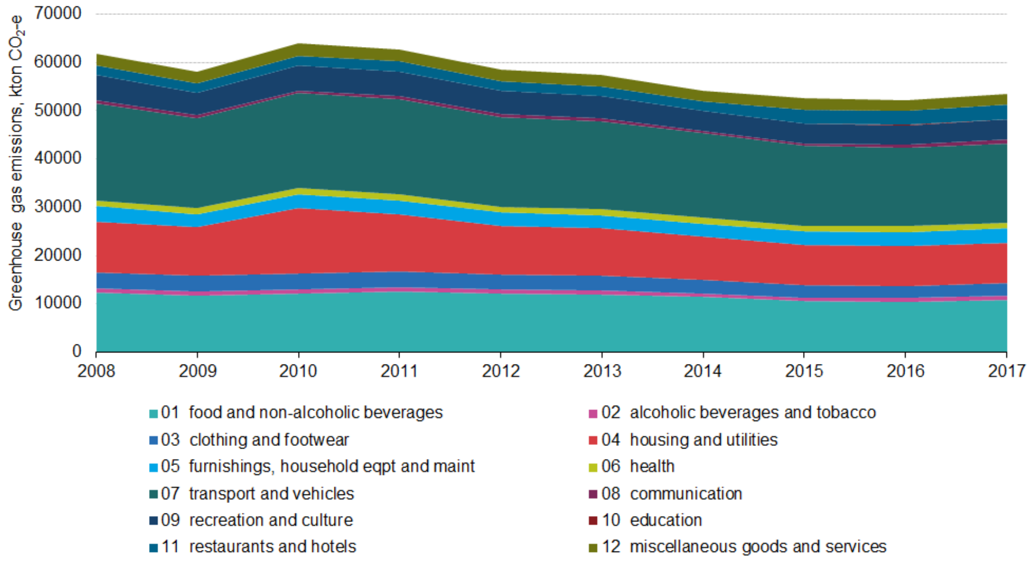
2.3.4 Example – Emissions by *purpose* of consumption

Figure 9: GHG emissions due to household consumption in New Zealand, categorised by the classification of individual consumption by purpose (COICOP) 2011 to 2017



Source: Statistics New Zealand.

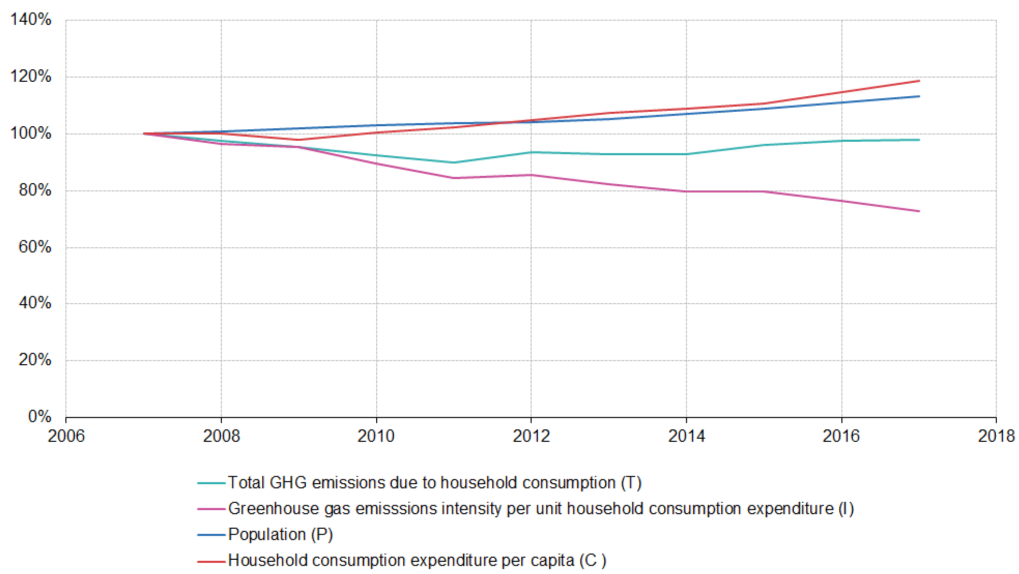
Figure 10: GHG emissions due to household consumption in Sweden, categorized by the classification of individual consumption by purpose (COICOP), 2008 to 2017



Source: Statistics Sweden.

Figure 9 and Figure 10 show GHG emissions due to household consumption in New Zealand and Sweden respectively categorized according to COICOP. Both figures show that consumption of food, housing and utilities and transport together account for a large majority of emissions.

Figure 11: Indexes of total GHG emissions, GHG emissions intensity for household consumption, household consumption expenditure per capita and population for New Zealand.



Source – Statistics New Zealand.

Figure 11 gives a further example of the possibilities for joint presentation of statistics produced with EEIO. The figure shows indexes for household consumption expenditure per capita (C - monetary expenditure per person), population (P), the embodied GHG emissions intensity for household consumption (I - in carbon dioxide equivalents per unit monetary expenditure) and total GHG emissions due to household consumption (T – in carbon dioxide equivalents). A particularly interesting feature of this presentation is the fact that the terms constitute a KAYA-identity for household consumption, where the following relation holds:

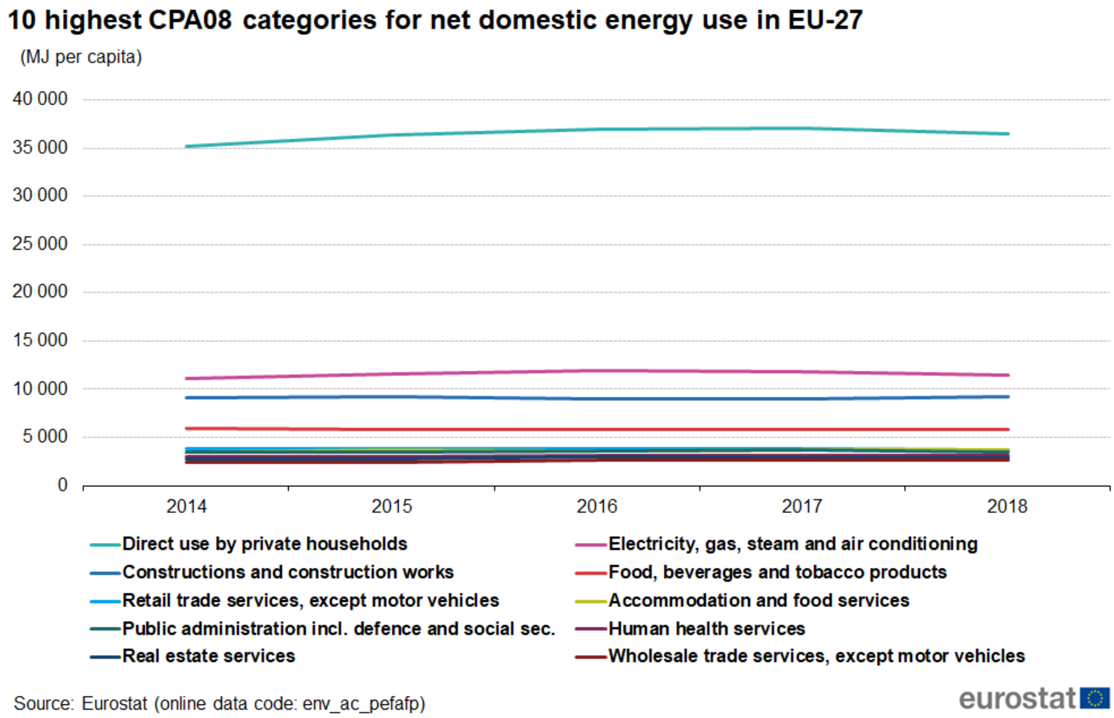
$$T = C \cdot P \cdot I$$

Equation 8

The data show that though the calculated GHG emissions intensity for household consumption expenditure in New Zealand (I) has decreased by almost 30 percent over the time series, there is little change in total GHG emissions (T) because of increased population (P) and increased expenditure per capita (C).

2.3.5 Example – domestic energy use – Eurostat

Figure 12: Domestic energy use for the top-10 product categories (including direct use by private households) in the EU-27 in MJ per capita



Source: Eurostat

Figure 12 shows the domestic energy use for the top 10 product categories (including direct use by private households) from Eurostat's database of domestic energy use estimates, produced with EEIO. Together these ten categories (out of 65 categories in total) account for over 70 percent of total domestic energy use of 117 MJ/capita in 2017. Approximately one third of the total direct energy use is consistently assigned to private households. Electricity, gas, steam and air conditioning, construction and the food industry are also comparatively high users of domestic energy. Land transport is one of the lower domestic energy users shown in the figure. The total energy use for land transport is clearly much higher than this since the EEIO method applied allocates the intermediate use of land transport for the purpose of producing other products to those products and not to final demand for transport.

2.3.6 Published documentation and communication

Technical documentation, aimed largely at experts and highly-interested users is available alongside published data on relevant websites[23,24,25]. Information aimed at a broader audience is also published and presented. Statistics New Zealand's media release in conjunction with publication of the statistics aims to introduce the main findings to a general public, without alienating them with technicalities[26]. Statistics New Zealand's release page for the statistics[27], though also aimed at a broad audience goes more in depth. The release page presents for example how the statistics relate to economic statistics, and how they relate to air emissions statistics with territorial and SEEA-production perspective. Statistics New Zealand also produced a paper specifically aimed at explaining the difference between different perspectives for air emissions statistics[28]. Eurostat have produced a "Statistics Explained" article, explaining amongst other things the difference between air emissions statistics with territorial, consumption and production perspectives. Statistics Sweden links to the Swedish Environmental Protection Agency's webpage explaining the difference in the three perspectives[29]. Statistics Sweden's news release also aimed to explain the context of the statistics for a broad audience[30]. Statistics Sweden also held a well-attended breakfast seminar in conjunction with the release of the statistics in 2019.

[23] Stats NZ sources and methods paper: https://www.stats.govt.nz/assets/Uploads/Environmental-economic-accounts/Environmental-economic-accounts-Sources-and-methods-third-edition/environmental-economic-accounts-sources-and-methods-third-edition.pdf

[24] Eurostat's explanatory texts and metadata: https://ec.europa.eu/eurostat/cache/metadata/en/env_ac_io10_esms.htm

[25] Statistics Sweden's quality declaration: https://www.scb.se/contentassets/f0d9c7eda5be4b8a96c5827e4bebf513/mi1301_kd_2017_miljopaverkan_fran_konsumtion_191119.pdf

[26] Statistics New Zealand's media release https://www.stats.govt.nz/news/transport-drives-households-carbon-footprint-up

[27] Statistics New Zealand's release page https://www.stats.govt.nz/information-releases/greenhouse-gas-emissions-consumption-based-year-ended-2017

[28] https://www.stats.govt.nz/methods/approaches-to-measuring-new-zealands-greenhouse-gas-emissions

[29] The Swedish Environmental Protection Agency's explanation of different system boundaries for national emissions https://www.naturvardsverket.se/Sa-mar-miljon/Klimat-och-luft/Klimat/Tre-satt-att-berakna-klimatpaverkande-utslapp/ . The Swedish Enviornmental Protection Agency is responsible for producing Sweden's GHG emissions inventory submitted to the UNFCCC.

[30] Statistics Sweden's news release 2019 - https://www.scb.se/en/finding-statistics/statistics-by-subject-area/environment/environmental-accounts-and-sustainable-development/system-of-environmental-and-economic-accounts/pong/statistical-news/environmental-accounts--environmental-pressure-from-consumption-2017/

3 Monetary-physical hybrid EEIO approaches for SEEA – Waste and Material flow analysis in raw material equivalents

3.1 Background

The examples in this chapter shed light on the use of EEIO to produce data about the flow of material in an economy. In the first example, Eurostat uses EEIO to produce material flow accounts in raw material equivalents (MFA-RME). These accounts offer a contrasting perspective to other material flow accounts that Eurostat produces, for example domestic material consumption (DMC). DMC however records imports and exports according to the traded weight of the goods, rather than the weight of the raw materials required to produce them. MFA-RME in contrast aims to calculate the total weight of raw materials and therefore includes raw materials for imports and exports that the DMC does not. MFA-RME therefore provides an important perspective on material flows that other data produced do not cover. MFA-RME therefore provides data that is relevant for in particular the Roadmap to a resource efficient Europe[31].

The second example presents the use of EEIO to analyse waste flows in society. This approach is well-established in the research community[32,33]. There are nevertheless examples of high quality, detailed physical data on waste production at a national level produced by government agencies. The presentation of waste input-output analysis here is based in research, in particular Nakamura (2020)[34] but uses data produced by the Japanese Ministry of the Environment, as described further in subsequent sections. In a recent research review[1] it is recognised that the production of high quality and detailed physical statistics on waste generation and treatment is a key element for improving waste analyses using input-output methods.

A common feature for the approaches presented in this chapter is that they both use a combination of physical and monetary data in input-output tables to model exchanges in the economy. Both of the approaches presented in this chapter also offer data that are relevant for tracking progress towards the sustainable development goal (SDG) 8 decent work and economic growth and SDG 12 responsible production and consumption.

[31] https://ec.europa.eu/environment/resource_efficiency/about/roadmap/index_en.htm

[32] Towa, E., Zeller, V., & Achten, W. M. (2020). Input-output models and waste management analysis: A critical review. *Journal of Cleaner Production*, *249*, 119359.

[33] Nakamura, S., & Kondo, Y. (2002). Input-Output Analysis of Waste Management. *Journal of Industrial Ecology*, *6*(1), 39–63.

[34] Nakamura, S. (2020). Tracking the Product Origins of Waste for Treatment Using the WIO Data Developed by the Japanese Ministry of the Environment. *Environmental Science & Technology*.

3.2 Methodologies

The methodologies used in each approach are summarized below.

3.2.1 Material flow accounts in raw material equivalents – Eurostat

3.2.1.1 CALCULATION PROCEDURE

Eurostat uses a so-called adapted domestic technology assumption input-output (ADTA-IO) model to estimate material flows in raw material equivalents. According to the principles for such a model, the raw material equivalent S required to satisfy final demand y is given by:

$$S = F(I - A)^{-1}y$$

Equation 9

Where A is the technology co-efficient matrix of intermediate demand in the economy, F is the raw material input per total sectoral output. A is largely based on the monetary exchanges as in a standard input-output table. However for agricultural crops and products of forestry and fishing, fossil energy carriers, and other mining and quarrying products the monetary exchanges are replaced by physical ones in A. F is a matrix with disaggregation by industrial sector and by type of material. According to the non-adapted DTA for imports, the raw material equivalent S_m for imports m is given by:

$$S_m = F(I - A)^{-1}m$$

Equation 10

The ADTA approach used by Eurostat adapts the A and F terms from the domestic data as shown in Equation 10 for 35 product groups, based on the following data:

- regionalised information about raw material equivalents and recycling rates of direct metal imports
- regionalised information about the energy mix of electricity generation
- evaluation of imports at domestic prices

Practically the calculation relies on input-output tables with a resolution of 182 x 182 product group resolution. This is a higher resolution than Eurostat's published input-output tables with 64 x 64 product group resolution. Input data used to establish the higher resolution is presented in the section below.

3.2.1.2 SOURCE DATA

The estimates are produced using a mixture of data produced in-house by Eurostat and external sources. The 182 x 182 product group monetary input output table uses Eurostat's standard 64 x 64 product group as a starting point. This is disaggregated to achieve the higher resolution using a number of sources. The intermediate exchange matrix is disaggregated further according to the structure of a 274 x 274 product group input output table for Germany, reference year 2010 produced as a special project of the German Environment Agency. Eurostat's European structural business statistics are used for the disaggregation of outputs and Eurostat's European external trade statistics (Comext) are used for the disaggregation of imports and exports for the high-resolution 182 x 182 product group input output table. The disaggregation process is performed by iterative adjustment.

The supplementation of physical data for monetary in the high-resolution input-output table uses Eurostat's energy statistics for energy carriers, Eurostat's economy-wide material flow accounts for domestic extraction and Eurostat's statistics on international trade (Comext) for imports.

To adapt the DTA for imports, the IFEU world metal model is used to provide regionalised information about RME for imported metals and recycling rates for metals. Eurostat's European external trade statistics (Comext) are used for the valuation of imports at domestic prices. Estimates of energy and electricity mixes outside of Europe are based on external energy balance data.

In addition to the estimates that Eurostat produces themselves according to the method described, Eurostat also produces a tool that supports national statistical institutes' compilation of national MFA-RME[35] and an accompanying handbook[36] and input data[37]. It is a simplified methodology that builds upon RME coefficients that are produced within the EU RME model. This tool supports countries' voluntary reporting of MFA-RME accounts to Eurostat.

3.2.2 Waste IO model

3.2.2.1 SUMMARY OF CALCULATION PROCEDURE

A more detailed account of the method used for the waste I-O model is can be found in the supplementary information to Nakamura (2020)[38]. The central matrix equation for waste input-output model is as follows:

$$\begin{pmatrix} x_I \\ x_{II} \end{pmatrix} = \left(I - \begin{pmatrix} A_I & A_{II} \\ SG_I & SG_{II} \end{pmatrix} \right)^{-1} \begin{pmatrix} y_I \\ Sw_y \end{pmatrix}$$

Equation 11

Where on the left hand side x_I is a unit vector representing the total output of products and x_{II} is a unit vector representing the output of waste treatment sectors. Inside the first set of brackets on the right hand side of Equation 11, A_I and A_{II} are technology coefficient matrices for products and waste treatment, S is an allocation matrix recording the share of each waste type submitted to particular types of waste treatment. G_I and G_{II} are the matrices of net-waste generation coefficients, which relate to net-waste generation as the technology co-efficient matrices A_I and A_{II} relate to producing industries. Inside the final set of brackets on the right hand side of Equation 11, y_I is the unit vector of final demand, w_y is the unit vector of the net supply of waste in final demand.

It should be noted that the form of the Equation 11 is analogous to the form of Leontief's solution for total output in a standard input-output analysis. Equation 11 extends the standard input-output analysis to also incorporate waste production and waste treatment sectors. The column of the Leontief inverse matrix in a standard input-output analysis gives the amount of inputs that are directly and indirectly required to produce a unit of product, or the inputs embodied in the product. Analogously, the column of the extended Leontief inverse matrix on the right hand side of Equation 11 gives the amount of waste that is directly and indirectly generated per unit of product, or the wastes embodied in the product.

The examples of the waste input-output analyses considered here (see Nakamura, 2020[39]) apply a simple DTA to model waste outside of the country in question.

---

[35] RME tool, country-level: https://ec.europa.eu/eurostat/documents/1798247/6874172/Country-RME-tool/

[36] RME tool handbook: https://ec.europa.eu/eurostat/documents/1798247/6874172/Handbook-country-RME-tool/

[37] RME tool input data: https://ec.europa.eu/eurostat/documents/1798247/6874172/Input-data-RME-tool/

[38] Nakamura, S. (2020). Tracking the Product Origins of Waste for Treatment Using the WIO Data Developed by the Japanese Ministry of the Environment. *Environmental Science & Technology*.

[39] Nakamura, S. (2020). Tracking the Product Origins of Waste for Treatment Using the WIO Data Developed by the Japanese Ministry of the Environment. *Environmental Science & Technology*.

3.2.2.2 SOURCE DATA

There are few national statistical offices that have produced waste IO tables. One key example are the tables produced by the Japanese Ministry of the Environment (MOE). The published data comprised in particular of an official waste IO table for the year 2011 with 80 production sectors, nine waste treatment sectors (incineration, dehydration, concentration, shredding, filtration, composting, feed conversion, gasification, and refuse-derived fuel), and 99 waste items. Of the 99 waste items in MOE-WIO, 24 refer to industrial waste (waste generated from industrial processes), 24 to municipal solid waste generated from households and business sectors, and 51 to secondary wastes derived from waste treatment sectors. One potential obstacle to the wider adoption of waste IO amongst National Statistical Offices is the paucity of high-resolution data on waste and waste management.

3.3 Output

3.3.1 Summary of Eurostat's data output – MFA-RME

Eurostat's output data is presented in two different database tables with two different levels of detail[40,41]. The variables for the presentations are summarized in Table 4 below. Both presentations have in common that they present data disaggregated for over 60 different types of material. One key difference between the presentations is that one presents data disaggregated for 63 product groups according to final demand, which is not considered in the other. In the database table without product group disaggregation, the environmental indicators reflect the national accounts' macroeconomic accounting identity such that:

Imports (RME) + Domestic extraction = Raw material consumption + Exports (RME)

Equation 12

and

Imports (RME) + Domestic extraction = Raw material inputs

Equation 13

The two database tables summarised in Table 4 are further connected by the following relation between the environmental variables they show:

Raw material consumption (RMC) = RMC due to household expenditure + RMC due to government expenditure + RMC due to NPISH + RMC due to gross capital formation

Equation 14

Where the term on the left hand side of Equation 14 comes from the database table "Material flow accounts in raw material equivalents – modelling estimates", the terms on the right hand side come from the other. Ultimately the terms shown in Equation 14 further reflect the breakdown used in the national account's domestic final demand.

---

[40] Material flow accounts in raw material equivalents by final uses of products - modelling estimates (env_ac_rmefd)

[41] Material flow accounts in raw material equivalents - modelling estimates (env_ac_rme)

Table 4: Summary of data presentation for Eurostat's MFA-RME modelling estimates

Variable	Name of database table: Material flow accounts in raw material equivalents – modelling estimates	Name of database table: Material flow accounts in raw material equivalents by final uses of products – modelling estimates
Materials	66 materials	
Time Series	2000 -2018 (though not for all geog. classifications, see below)	2008 - 2018
Product groups	N/a	63 product groups, according to CPA
Environmental Indicators	- Imports (RME)	RMC for final demand (total)
	- Exports (RME)	RMC for consumption: household expenditure, government expenditure, expenditure of non-profit institutions serving households (NPISH)
	- Raw material consumption (RMC)	RMC for gross capital formation: gross fixed capital formation, changes in inventories and valuables
	- Raw material input (RMI)	
	- Domestic extraction	
Geographical classifications	EU27/28 plus nine separate European nations	EU27/28
Units	Thousand tonnes and tonnes per capita	

3.3.2 Summary of the Waste Input-output model data output

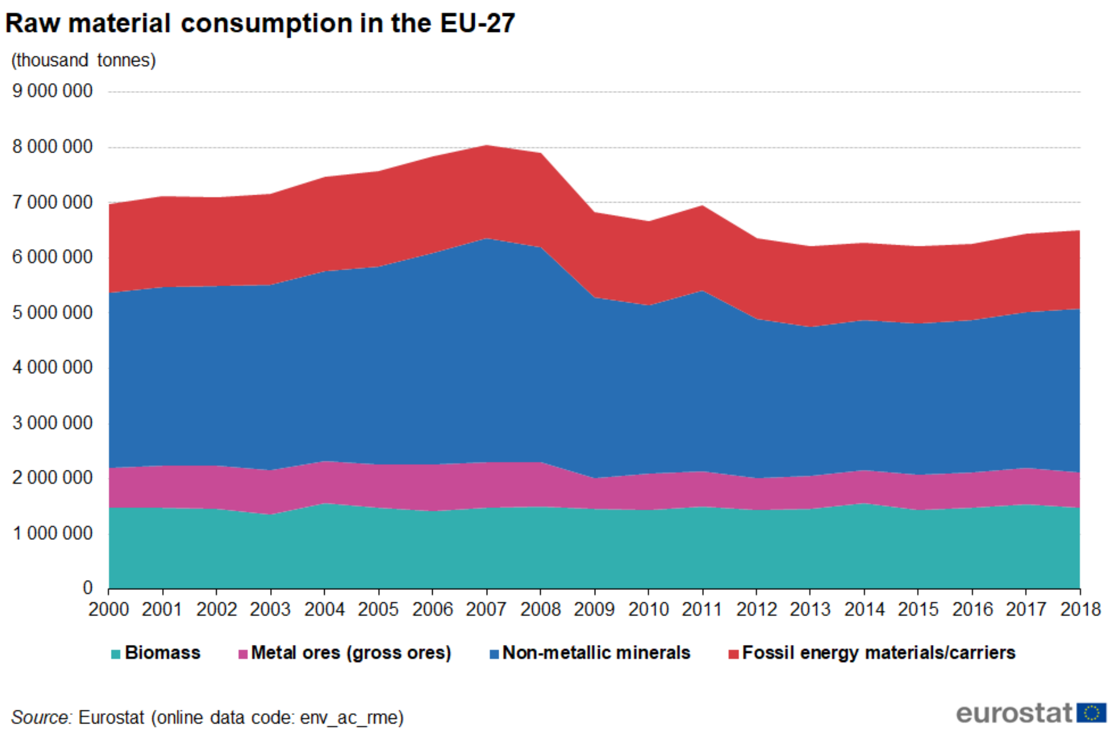
Waste IO analysis is currently used to present research results, however, the potential to produce high-quality datasets can be understood from the level of resolution in the waste IO tables themselves. Table 5 summarises the level of detail in waste input-output tables that have been produced and are in use. Both of them are for Japan, and for one reference year only. As shown in the table, the Japanese Ministry of Environment (MOE) waste input-output table was produced for the year 2011 and forms the basis for the analyses shown in subsequent sections. The WIO-WWW is a product of research, also for Japan and for the reference year 2000.

Table 5: Summary of the current data sets for Waste input-output modelling

	WIO-WWW[42]	Japanese MOE-WIO[43]
Waste items	79	99
Production sectors	103	80
Waste treatment sectors	13	9
Reference periods	2000	2011

3.3.3 Example: Eurostat – Domestic raw material consumption by material type

Figure 13: Raw material consumption for EU27 according to Eurostat's material flow accounts in raw material equivalents[44]



[42] WIO-WWW. *Waste Input-Output Table*. http://www.f.waseda.jp/nakashin/WIO.html

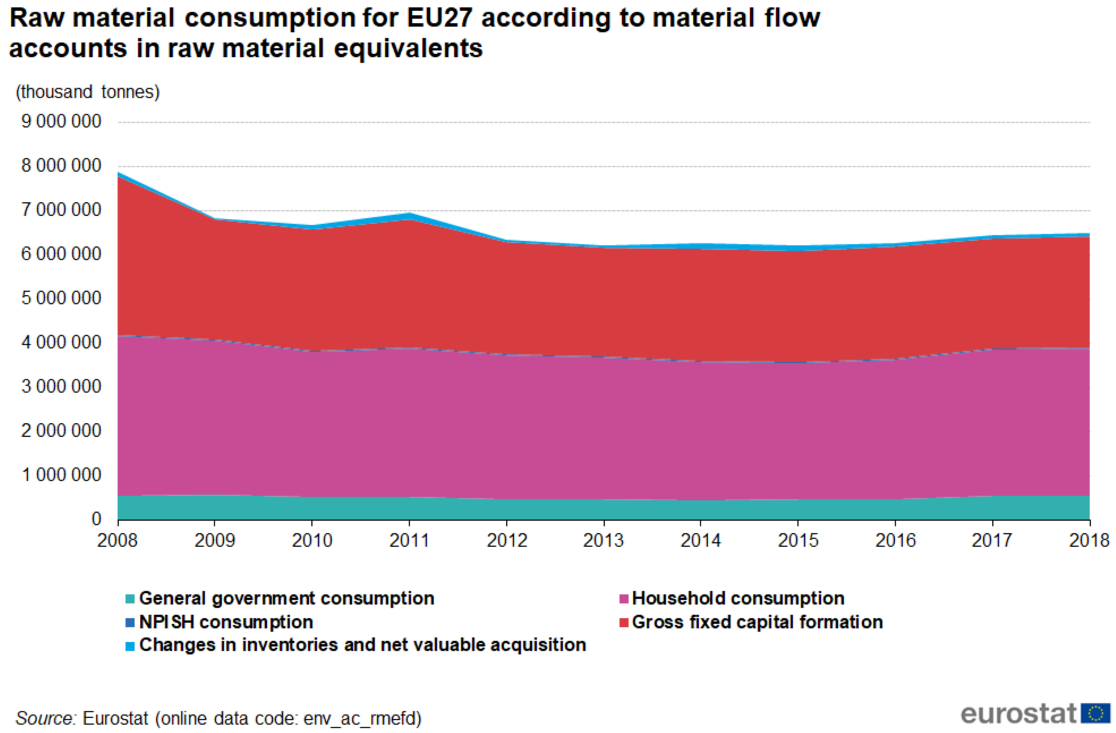
[43] Nakamura, S. (2020). Tracking the Product Origins of Waste for Treatment Using the WIO Data Developed by the Japanese Ministry of the Environment. *Environmental Science & Technology* and Ministry of the Environment the Government of Japan, Input-Output-Table for Environmental Analysis. https://www.env.go.jp/doc/toukei/renkanhyo.html

[44] http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_ac_rme&lang=en

Figure 13 shows one example of a time series from Eurostat's MFA-RME, showing raw material consumption for the EU28 from 2000 through the latest reference year, 2018. The series shows that demand for non-metallic minerals constitutes between 40 and 50 percent of the total RMC, depending on the reference year. Non-metallic minerals are comprised mostly of sand and gravel and are used in the construction industry. The decrease in their use between 2008 and 2009 is the major factor leading to a change in total RME over the time series. This decrease also occurred during the same time period as a decrease in gross value-added in the construction industry in connection with the economic crisis of 2008-2009. Biomass and fossil energy materials/carriers contribute approximately 20 to 25 percent each to the total, and metal ores contribute about 10 percent of the total. The data are further important since raw material consumption as shown is 26 percent higher the domestic material consumption according to Eurostat's standard economy-wide MFA statistics.

3.3.4 Example: Eurostat – Raw material input, raw material consumption and exports

Figure 14: Raw material consumption for EU27 according to Eurostat's material flow accounts in raw material equivalents[45]



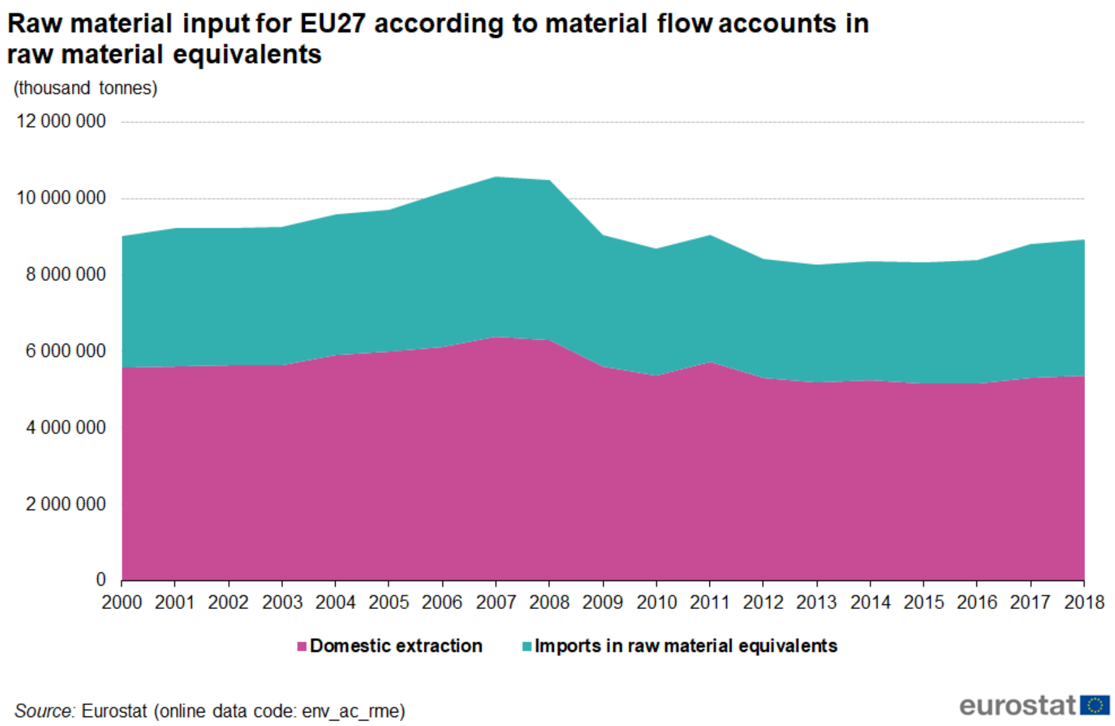
The data from Eurostat's MFA-RME database presented here reflect the aggregates used in the national accounts' macroeconomic balance, as well as the balance summarised in Equation 12 through Equation 14 in this chapter. The total raw material consumption in Figure 14 is identical to that shown in Figure 13 (though a shorter time series is available for the data shown in Figure 14). Figure 14 also shows that RMC due to household consumption consistently constitutes the largest portion of the total RMC, followed by gross fixed capital formation. Monetary expenditures due to household consumption are consistently larger than those due to gross fixed capital formation. Therefore, in light of the data shown in Figure 14 it can be understood that the raw material intensity

[45] http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_ac_rme&lang=en

for gross fixed capital formation is higher than for household consumption. This is so since expenditure in the gross fixed capital formation category is to a large extent on buildings and infrastructure (products of construction), which as discussed in previous paragraphs have a high material intensity for e.g. sand and gravel.

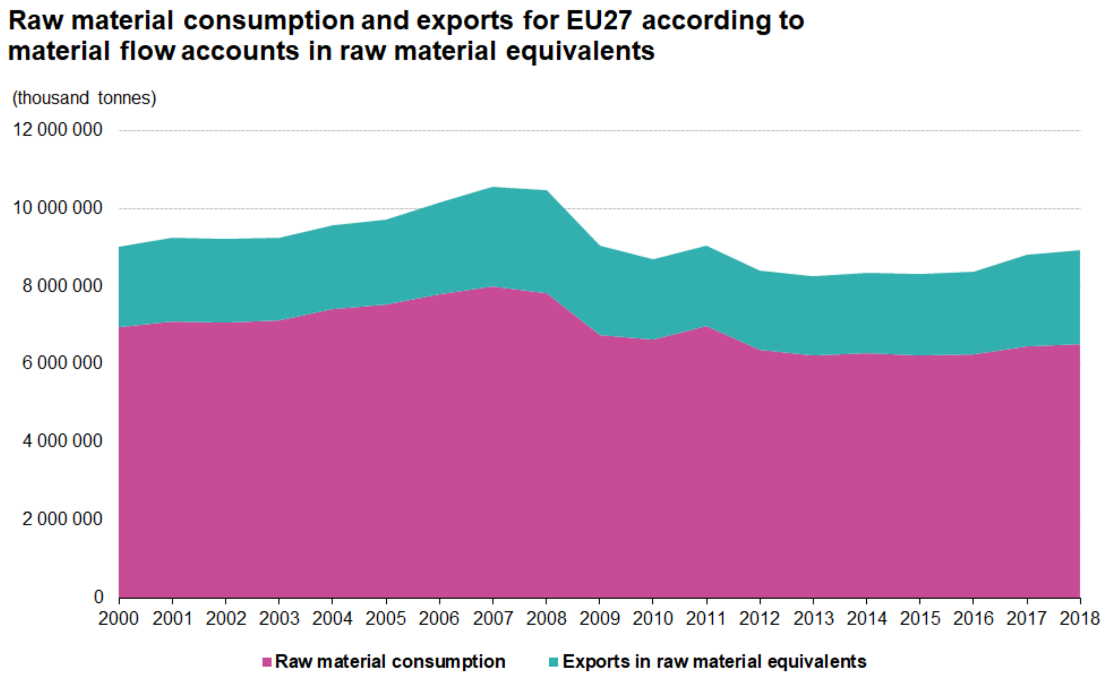
Figure 15 and Figure 16 show the aggregates on the right hand side and left hand side of Equation 12 respectively. It can be seen that the totals in both figures are identical. The figures show that the EU27 is consistently a net RME importer, since the imports shown in Figure 15 are consistently greater than the exports shown in Figure 16. It is further interesting to note that the raw material consumption shown in Figure 16 is identical to the totals shown in Figure 13 and Figure 14.

Figure 15: Raw material input for EU27 for 2000 - 2018 according to Eurostat's material flow accounts in raw material equivalents[46]



[46] http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_ac_rme&lang=en

Figure 16: **Raw material consumption and exports for EU27 for 2000 - 2018 according to Eurostat's material flow accounts in raw material equivalents**



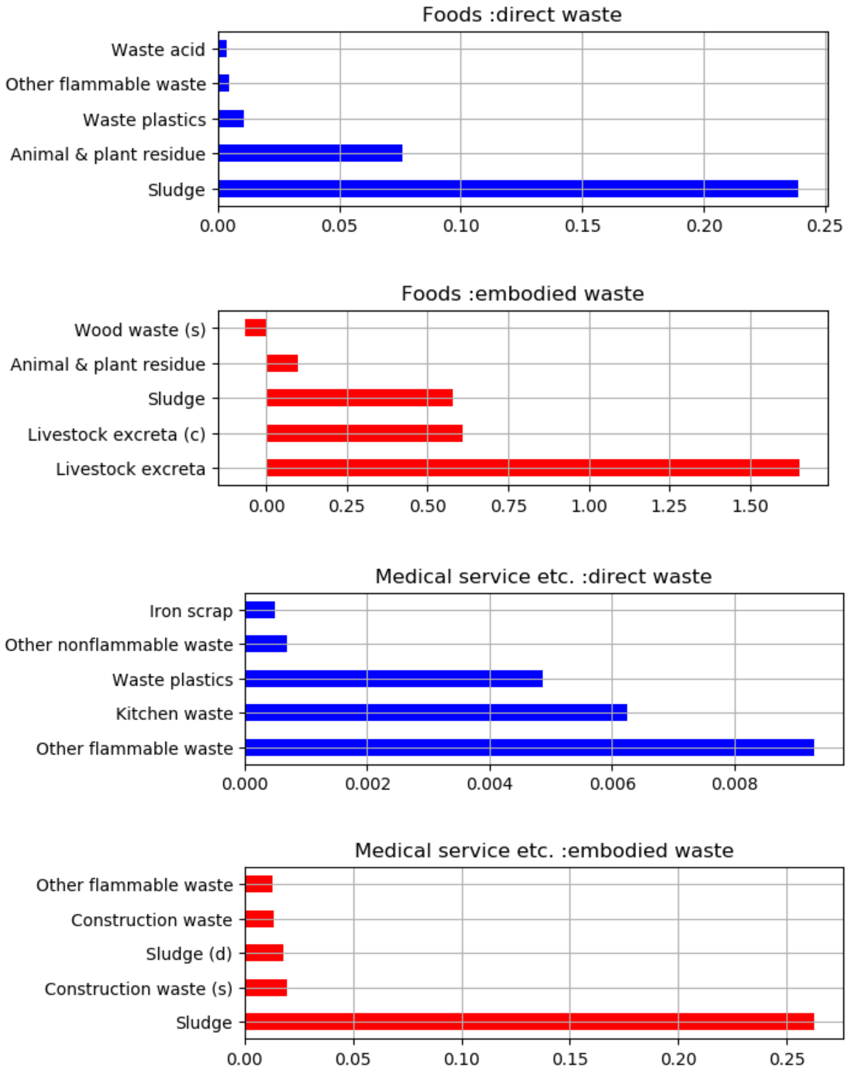
Source: Eurostat (online data code: env_ac_rme)

3.3.5 Example: Waste IO: Direct waste and embodied waste

One very useful application of the waste IO method is to compare the embodied waste arising due to products with the direct waste. Direct waste is that arising per unit production according to the column of the extended matrix of input coefficients on the right-hand side of Equation 11. As noted previously, embodied waste (direct and indirect) per unit production is given by the column of the extended Leontief inverse matrix on the right-hand side of Equation 11.

Figure 17 compares the direct and embodied waste generation per output for “Foods” and “Medical services” for the largest five waste items. We notice remarkable differences between direct and embodied waste generation in terms of both volume and composition. For “Foods,” the amount of embodied waste is thirty-one times larger than direct waste, while it is six times larger for “Medical service”. The composition of waste also changes when one moves from the direct to embodied waste. While “Sludge” is the largest direct waste in “Foods,” it is exceeded six times by “Livestock excreta” in terms of embodied waste. The thirty-one-time increase in “Medical services” in terms of embodied waste is mostly attributed to “Sludge”. The occurrence of a negative embodied amount of “Wood waste (s)” in “Foods” refers to the amount of “Wood waste (s) ” recycled over the supply chains of “Foods,” mostly in crop cultivation. These results indicate the importance of considering embodied waste. Waste management strategies dependent on direct generation alone could be misleading.

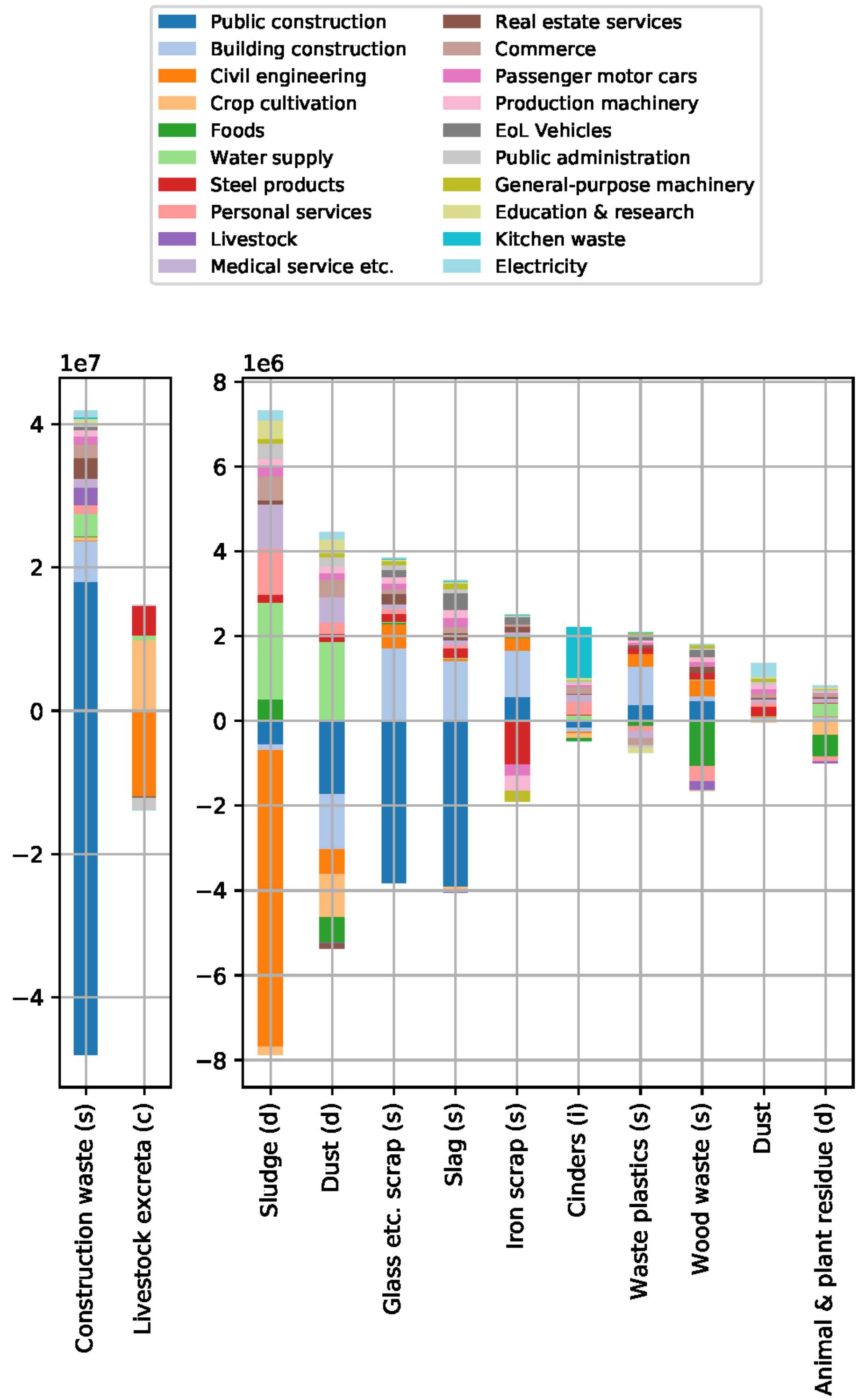
Figure 17: **Direct and embodied emissions of waste t (1000kg) per 1M Japanese yen**



As another demonstration of WIO is the *waste footprint* based on MOE-WIO. The waste footprint is a waste counterpart of carbon footprint. It identifies the product origins of waste by tracing the supply chain from waste for final disposal to final products purchased by consumers. Its measurement based on WIO was pioneered by Nakamura and Kondo (2009)[47], and has been applied by many other researchers since. The mathematical theory of waste footprint calculation can be found in Nakamura (2020)[48]. Figure 18 gives the waste for the landfill footprints of products. Negative values in the figure refer to waste recycling. One of the remarkable findings is that "Public construction" occurs as the largest recycler of “Construction waste,” "Slag" and "Glass etc. scrap.," which is attributed to the use of construction and demolition waste as aggregates in road construction, the primary component of "Public construction" (see Nakamura, 2000 for further results). Of the twenty sectors in Figure 18, six sectors are in the service industry, implying that service sectors are a major generator of waste for landfill. Footprint calculation can identify factors behind the waste flows that otherwise would not be recognizable.

[47] Nakamura, S., & Kondo, Y. (2009). *Waste Input-Output Analysis: Concepts and Application to Industrial Ecology*. Springer Science & Business Media.
[48] Nakamura, S. (2020). Tracking the Product Origins of Waste for Treatment Using the WIO Data Developed by the Japanese Ministry of the Environment. *Environmental Science & Technology*

Figure 18: **Waste for landfill footprint of products. Unit in t (1000kg). The occurrence of "Kitchen waste" as product item refers to the direct discharge from private final consumption**



3.3.6 Published documentation and communication

Eurostat produces technical documentation alongside published MFA-RME data[49]. Eurostat have also produced a "Statistics Explained" article on MFA-RME which presents data similar to those presented above, and also focusses on comparing material flow accounts with and without the raw material equivalent perspective[50].

As noted previously, the waste IO-based analyses for Japan presented in this report come from research results as previously referenced.

[49] Eurostat's explanatory texts and metadata: https://ec.europa.eu/eurostat/cache/metadata/en/env_ac_rme_esms.htm

[50] Statistics Explained – Material flow accounts statistics – material footprints - https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Material_flow_accounts_statistics_-_material_footprints

4 Concluding discussion and moving forward with EEIO for SEEA

EEIO-based data is now produced and published regularly by many national and supra national statistical offices. The preceding Chapters have presented some significant and representative cases of data production and publication with EEIO in the areas of GHG emissions, MFA-RME and waste IO. Each of the cases in their own way provides valuable knowledge for other statistical offices interested in developing their own work with EEIO. The sources referenced for each case further provide a valuable resource for further reading and knowledge sharing.

The final discussion below aims to draw some important themes from the cases presented as well as summarize and synthesise the views of a range of participants in the EEIO subgroup.

4.1 Methodology and data

A key decision in EEIO modelling is how to address the economic structure and environmental intensities of foreign nations. This is required in EEIO to model environmental pressures arising from imports. The examples presented in previous chapters address this issue in a number of different ways.

Statistics Sweden's statistics on GHG emissions from a consumption perspective are produced using the MRIO EXIOBASE to model GHG emissions from Sweden's imports. MRIO is also used by other statistical offices for producing and publishing data. The validity of this approach for statistics production has been supported by results of a research study that compared GHG emissions (and other environmental pressures) from Swedish consumption using a number of different MRIOs (including EXIOBASE, GTAP, WIOD and EORA)[51]. The study found a largely consistent picture of the overall patterns and hotspots for GHG emissions due to Sweden's imports.

A related methodological feature for Statistics Sweden is that the MRIO is combined with an SRIO for Sweden to model environmental pressures due to consumption arising inside the country. The approach is called a simplified SNAC (see Chapter 2). The approach approximates environmental pressures arising due to products that Sweden exports and re-imports. The method was validated before implementation in this respect by a research study showing that the approximation has a very small quantitative effect on the calculated pressures[52].

Studies applying MRIOs to produce data on environmental pressures for other countries have also shown notable differences, particularly when updating MRIO time series. The SRIO approach (as applied by Statistics New Zealand and Eurostat) resolves the issue of evaluating environmental pressures from imported goods by assuming that the economic structure and environmental pressures from imported goods are the same as those for the territory to which they are imported.

51 The Swedish footprint: A multi-model comparison - ScienceDirect

52 A Note on the Magnitude of the Feedback Effect in Environmentally Extended Multi-Region Input-Output Tables - Moran - 2018 - Journal of Industrial Ecology - Wiley Online Library

Producers are transparent with these assumptions and point out that the data presented represents the environmental pressures avoided in the territory itself through importing the goods. A further contrast between the SRIO approach and the MRIO approach is that the SRIO approach makes use of data that is regularly produced and updated internally by national statistical offices whilst the MRIO are also updated with data from statistical offices but need to harmonize data from the countries covered.

The experiences gathered for this report highlight that when establishing an EEIO methodology to produce and publish data, due consideration should be given to the choices presented here for modelling the environmental pressures from imported products. The examples further show that data derived from an MRIO or an SRIO approach (or a mixture of the two) gives important information to policy makers and other users, though the information differs. Due consideration should therefore also be given to communicating the assumptions that underpin the applied model. More generally it is important to recall that modelling is a common feature for statistics production in many areas, not just EEIO.

One methodologically important development for EEIO with respect to this is Eurostat's FIGARO[53] (Full International and Global Accounts for Research in input-Output) project in collaboration with the JRC. The project aims to develop a methodology and production process for EU inter-country input-output tables (EU-ICIOs). It is further intended that the tables should be able to be integrated in global tables in collaboration with the OECD and the UN. The EU-ICIO tables will represent all domestic and international flows among EU countries in NACE Rev. 2 (64*64 activities/products). This dataset should become the institutionalised reference dataset for consumption-based accounting, including environmental applications. Once time series are available, Eurostat plans to changeover from the consolidated EU SRIO to the FIGARO EU-ICIO tables. This will be directly feasible for air emission estimates. However it is considered that more work is needed for MFA-RME and land use as more granularity is needed in the FIGARO tables to make them suitable for these environmental extensions, e.g. in the agriculture and mining sectors. These observations are based on studies with existing MRIOs (e.g. EORA, GTAP and EXIOBASE) showing that the results differ notably depending on the level of granularity used in the modelling. Eurostat is investigating and developing a method to integrate more detail in the tables using other official statistics such as Comext trade data and PRODCOM production data. NSOs have also expressed an interest in using FIGARO when suitable time series are available, and also the same desire to increase the granularity for specific sectors.

In discussions amongst other EEIO-subgroup members other methodological issues also arose. For example, for the land use environmental extension members have observed that advances need to be made in the classification of different types of land use, and how they are assigned to different sectors before they can be used as an environmental extension in EEIO. There is also an interest to explore new environmental extensions for EEIO-based analyses such as for natural capital and ecosystem degredation.

4.2 Driving forces and barriers for EEIO-based data in the SEEA

National and supra-national statistical offices currently producing and publishing data with EEIO and participating in the EEIO subgroup agree that the methods and data produced communicate a strength of the SEEA in general. On a broad level the type of data produced is in demand from the general public and policy makers. The report has highlighted examples on local, national and supranational level where the produced data are highly-relevant for current policies, for example the European Green Deal. There may nevertheless be variations in the extent to which EEIO-based data

[53] Figaro-project_short-description.pdf (europa.eu)

can be integrated into policy contexts. On the one hand, EEIO-data can be used to establish and measure progress towards consumption-based targets. On the other hand, the modelled-nature of the data may be such that though it may be used to guide policy development broadly, it should not be used for something so specific as target-setting.

Another feature of EEIO methods is that achieves a high degree of integration between the environmental accounts and the national accounts, and by applying different environmental extensions can integrate otherwise disparate parts of the SEEA. On the other hand, as mentioned earlier in the report, EEIO-based analyses are not included as part of the Central Framework, rather as an analytical extension. Whilst this does not directly affect producing EEIO-data, it may lead to the production and publication of EEIO-based data having a lower priority at NSOs than areas that are included in the Central Framework. It is worth noting here that the System of National Accounts includes input-output tables and the Leontief model[54].

4.3 Communication

Unique communication issues arise when national and supranational statistical offices produce EEIO-based data. One underlying reason for this may be that EEIO-based data is integrated to such a great extent with national accounts data, considering in particular the possibility (highlighted in previous chapters) to produce data about environmental pressures due to each component in the national accounts income identity.

There is as yet no commonly agreed terminology for reporting EEIO-based data in the environmental accounts. For example, the notion "consumption-based accounting" may be used to communicate that accounts are established with a *consumption perspective* rather than a *production perspective*. In this sense, *production* is contrasted with *consumption* as the term *supply* contrasts with *use*. However, according to the national accounts, consumption is only one category in the domestic final use of products, which also includes investment. Furthermore, national accounts also applies the concept of *total final demand*, which as demonstrated in the above examples includes both *domestic final demand* and *exports*. The term *footprint* is also used, e.g. the *material footprint* or the *carbon footprint* of a nation.

Different stakeholders have differing levels of knowledge and interest in the statistics. These differing levels may be connected to the use of different terminology. For experts for example, it may be important to use a highly detailed terminology referring to aggregates and classifications used in the national accounts, for example to understand the methodology used to produce the statistics.

The general public may not understand and may ultimately be deterred by highly specific terminology. Policy makers may also have differing needs and understanding of terminology. Policy makers and the general public may for example be better acquainted with a more general term like a *carbon footprint*. Nevertheless, it is important to establish an understanding amongst a broad range of stakeholders in society an understanding of the difference between the three major system boundaries that are used when producing statistics about environmental pressures – production perspective, consumption perspective and territorial perspective. A key part of this is to establish an understanding of the different functions of the statistics produced with the different system boundaries.

It is also important to communicate to all users about data availability issues and assumptions required when producing the statistics that have implications for the results. One important way of addressing this is to provide as much transparency as possible about the methods used. Statistics New Zealand points out the value of the data they have produced but at the same time are careful to denote the statistics as "provisional" in light of the fact that Statistics New Zealand's current method relies on DTA. Eurostat also refer to EEIO-based data as "estimates", though the data are considered official statistics in Sweden.

[54] SNA complete.book (un.org)

The cases in this report have demonstrated different examples of how to present EEIO-based data, including joint presentations with economic data. In light of the wealth of interrelated data that can be produced using EEIO (some of which has been shown in the report), it may also be beneficial to present them in dashboards. Such dashboards and related graphics could for example facilitate visualisations for policy makers and increase the use of EEIO-based data in the policy sphere.

4.4 Moving forward

Members of the EEIO-subgroup of the London Group value the community of practice around EEIO-related questions that the group represents. One participant has observed that the initial learning curve to develop EEIO-production can be steep. Learning from peers through such a community of practice could therefore be a way to support this initial development. A set of guidelines for the producing and publishing EEIO-based data may be useful, however there are no formal plans or resources currently to develop something so comprehensive. Participants are also realistic that harmonisation in production of EEIO-based data is only something that, if desirable in general may only be achievable in a long-term time perspective. One avenue for collaboration with respect to improving harmonisation in a short to medium term is the results of the FIGARO project that represents a practical common starting point for any future discussions about harmonisation. Members have also expressed interest in for example developing a library of concordances between datasets produced by different statistical agencies.

5 References

Ayres, R. and Kneese, A. (1969). Production, consumption and externalities. *The American Economic Review*, vol. 59, No. 3 (June), pp. 282-297.

Leontief, W. (1936). Quantitative input and output relations in the economic system of the United States. *Review of Economic Statistics*, vol. 18 (January), pp. 105-125.

Leontief, W. (1970). Environmental repercussions and the economic structure: an input-output approach, *Review of Economics and Statistics*, vol. 52, No. 3, pp. 262-271.

Leontief, W. (1977). *The Structure of the American Economy, 1919-1939: An Empirical Application of Equilibrium Analysis*. Armonk, New York: M.E. Sharpe Reissue.

Hoekstra, R (2010). (Towards) a complete database of peer-reviewed articles on environmentally extended input-output analysis. *Paper prepared for the 18th International Input-Output Conference,* 20-25 June 2010, Sydney, Australia.

Hoekstra, A.Y., Mekonnen, M.M., (2012). The water footprint of humanity. *Proc. Natl. Acad. Sci*. 109, 3232–3237.

Weinzettel, J., Hertwich, E.G., Peters, G.P., Steen-Olsen, K., Galli, A., (2013). Affluence drives the global displacement of land use. *Glob. Environ. Change* 23, 433–438.

Wiedmann, T., (2009). A review of recent multi-region input-output models used for consumption-based emission and resource accounting. *Ecol. Econ.* 69, 211–222.

Wiedmann, T.O., Schandl, H., Lenzen, M., Moran, D., Suh, S., West, J., Kanemoto, K., (2015). The material footprint of nations. *Proc. Natl. Acad. Sci.* 112, 6271–6276.

Wood, R., Stadler, K., Simas, M., Bulavskaya, T., Giljum, S., Lutter, S., Tukker, A., (2018). Growth in Environmental Footprints and Environmental Impacts Embodied in Trade: Resource Efficiency Indicators from EXIOBASE3. *J. Ind. Ecol*. 22, 553–564.

GETTING IN TOUCH WITH THE EU

In person

All over the European Union there are hundreds of Europe Direct information centres. You can find the address of the centre nearest you at: https://europa.eu/european-union/contact_en

On the phone or by email

Europe Direct is a service that answers your questions about the European Union. You can contact this service:

– by freephone: 00 800 6 7 8 9 10 11 (certain operators may charge for these calls),
– at the following standard number: +32 22999696 or
– by email via: https://europa.eu/european-union/contact_en

FINDING INFORMATION ABOUT THE EU

Online

Information about the European Union in all the official languages of the EU is available on the Europa website at: https://europa.eu/european-union/index_en

EU publications

You can download or order free and priced EU publications at: https://op.europa.eu/en/publications. Multiple copies of free publications may be obtained by contacting Europe Direct or your local information centre (see https://europa.eu/european-union/contact_en).

EU law and related documents

For access to legal information from the EU, including all EU law since 1952 in all the official language versions, go to EUR-Lex at: http://eur-lex.europa.eu

Open data from the EU

The EU Open Data Portal (http://data.europa.eu/euodp/en) provides access to datasets from the EU. Data can be downloaded and reused for free, for both commercial and non-commercial purposes.

KS-TC-21-001-EN-N

Producing environmental accounts with environmentally extended input output analysis

This report demonstrates the potential of environmentally extended input output analysis (EEIO) as recommended by the System of Environmental-Economic Accounting (SEEA). It presents practical examples produced and disseminated by statistical offices.

For more information

https://ec.europa.eu/eurostat/

Publications Office
of the European Union

ISBN 978-92-76-30150-9