MICA
Minerals Intelligence Capacity Analysis

FACT SHEET

Environmental Extended Input Output Analysis (EEIOA)

Description of the method of Environmental Extended Input Output Analysis (EEIOA).

Scope (conceptual model & main characteristics)

Input-Output Analysis (IOA) is used for various types of economic analyses within and outside government. The use of IO-tables is important for analysing structural changes in the production system of national economies. IOA uses monetary units to describe exchanges between production sectors. Either the sectors or the products they exchange can be the elements in the IOA system. Environmental Extended IOA (EEIOA) applies environmental extensions (extractions and emissions) to the different elements in the system.

The object of analysis is the structure of a national economy, described in terms of the monetary exchanges between the elements of the system investigated. These are listed in a so-called IO-table. In EEIOA extractions and emissions are additional objects of analysis.

Supply and use tables (SUTs) form the basis of the IO-tables. SUTs are matrices, industry by product, describing the transactions between sectors in products of a national economy in physical as well as monetary terms. Supply and use tables are used to derive the Gross Domestic Product (GDP) of a country. Supply and use are rearranged in a single symmetric table with identical classification of either industries or products employed for both rows and columns. The Input Output Table thus derived from SUTs (SUIOT) can be extended with national environmental accounts

per industry/product in physical terms (kg emissions or extraction) (Timmer et al., 2012; EUROSTAT, 2016b; Eurostat, 2011; Eurostat, 2008).

A comprehensive explanation on compilation methodologies and possible applications of the tables are provided in the Eurostat Manual of Supply, Use and Input-Output Tables (Eurostat, 2008).

Note that the main focus of SUIOTs is on the production phase. The use phase, like private households' activities, might also be part of the SUIOT. If it is taken into account it generally is very aggregated. All activities are aggregated into a few sectors: households and governments. Additional transformations are necessary to split these sectors up into different household activities. Waste treatment sector is poorly monitored in SUT.s This is mainly because the interactions are based on monetary transactions.

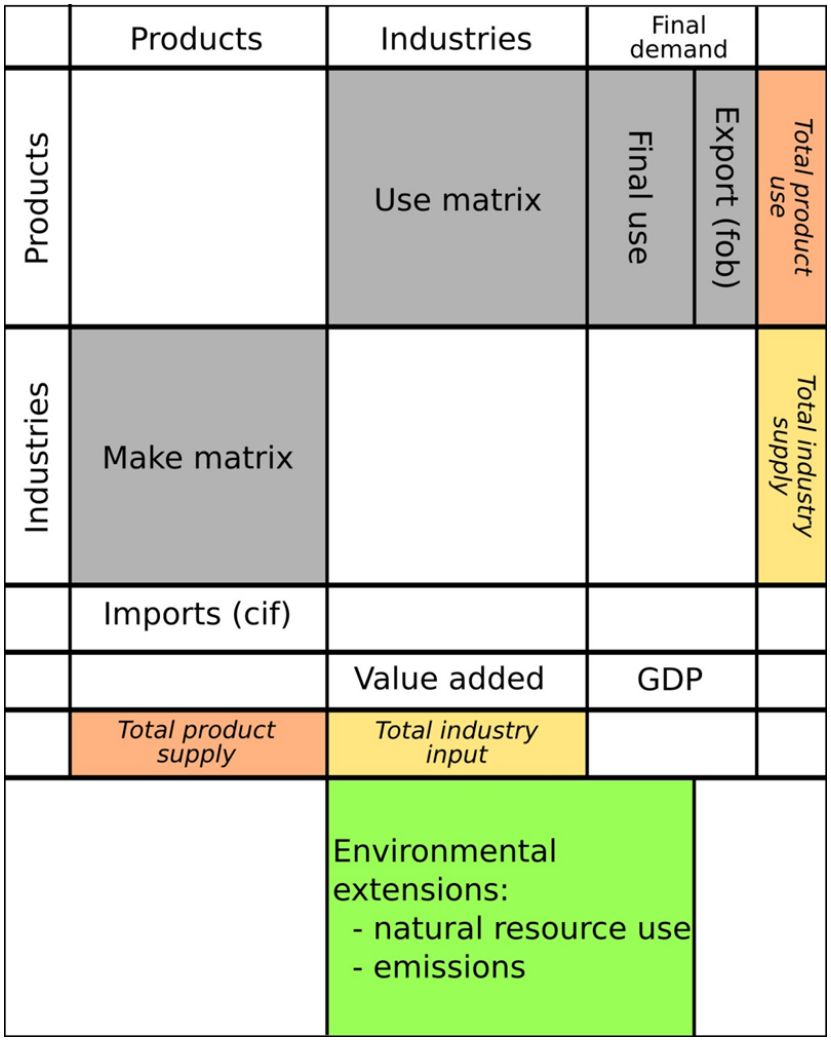

Figure 1 Environmentally Extended Supply Use and Input Output framework

The construction of SUTs, IOTs and SUIOTs including the environmental information is a statistical activity. Using IOTs as a model is the main acitivity of Input Output Analysis: the translation of the transactions into transfer coefficients, and of registered

emissions and extractions into environmental multiplyers in terms of mass per monetary unit. Such a static model can be used to assess the impacts of certain management or regime changes.

Contexts of use, application fields	-> contexts (e.g., environmental, economic, social assessment) -> which types of stakeholder questions are concerned?

The main use of IOA, and also of EEIOA, is to display all transactions within an economy; simultaneously illustrating the connection between producers and consumers and the interdependence of industries. The input-output method is thus used to capture the state of the industrial structure. This model permits an analysis of static changes, which helps identify targets which have the most effect on the waste streams and the product/process environment. Pollution and other undesirable external effects of productive or consumptive activities can, for all practical purposes, be considered as a part of the economic system. Due to its goal and scope IOA (and EE-IOA) is mainly used by government and academia.

The EEIOT in first instance is an accounting method. The advantage of the EEIOT is the integrated monitoring of environmental and economic data. For this reason the EEIOA framework is a appropriate method to derive indicators for eco-efficiency and resource efficiency.

If these data are transformed into factors the EEIO accounting framework is transformed into an EEIO model. The EEIO model may be employed in various ways in order to analyze on a macro level both ex-post and ex-ante environmental effects of changes in demand of goods, technology of processes or structure of the economy:

Structural Decomposition Analysis (SDA)

Structural decomposition analysis (SDA) aims at identifying the driving forces of changes in time of an aggregate measure. When dealing with EEIOA, the measure to be decomposed could be the change in environmental pressures exerted by economic activities. The investigation of changes through time requires the availability of data for multiple time periods. Starting from an accounting identity (such as total sectoral environmental pressures defined as $e=wLf$), decomposition aims at identifying the role of each component of the identity keeping the other elements fixed. In the example of environmental pressures, the main drivers could be: (i) changes in environmental intensity (Δe); (ii) changes in the mix of intermediate inputs (ΔL); and (iii) changes in final demand (Δf). The initial identity could be further decomposed in order to identify additional and more specific driving forces (e.g. final demand changes could be split into changes in the composition of final demand and changes in the scale of final demand). For further details on basic concepts of SDA refer to chapter 13 of Miller and Blair (2009).

Consumption vs production perspective

EEIOA allows to provide estimates of overall (worldwide) environmental pressures (both direct and indirect along the supply chain) exerted to satisfy the domestic demand of a country (consumption perspective). So a MR-EE-SUIO model is an appropriate method to do a supply chain analysis of a sector in a country or a footprint analysis (see separate factsheet) of the final demand of a country. In order to estimate environmental pressures from the consumption perspective, the EEIO model should be modified by using a worldwide production technology (including both domestic and imported intermediate inputs). Environmental coefficients should be adjusted (if possible) to reflect differences in environmental intensities across trade partners. . For a review of the methodology refer to Serrano and Dietzenbacher (2010).

Integrated analysis in economic structure and environmental pressure over time

In an EE-SUIOT the transactions between industries give a description of the structure of the regional economy. Comparison of different EE-SUIOT over time might be used to identify changes in this structure, together with changes in the environmental pressure. These changes might be caused by innovations.

Contribution analysis

With an EE-SUIOT it is possible to do a contribution analysis of the most important sectors contributing to the emissions and extractions of a region, both for a regional based intervention profile or a functional based intervention profile. For example, an EEIO model might be used to attribute extractions to specific sectors in which the extractions are supplied.

Scenario analysis and counterfactual analysis

IOA and EEIOA may be used also for ex-ante modelling. Starting from observational data, it is possible to build scenarios or counterfactuals by modifying any of the elements of the three main components of EEIO models: environmental coefficients, Leontief matrix, vector of final demand. This could be useful to compare how different technologies (both in terms of mix of intermediate inputs and in terms of intensity of environmental pressures) and different vectors of final demand (corresponding to different assumptions on behaviours of consumers) affect aggregate environmental pressures.

Price (Ghoshian) models

IOA could be used to describe relative prices of industry output by assuming that quantities are held fixed and price changes are completely transmitted to downstream sectors and to final demand (Oosterhaven, 1996). This category of models could be used to provide some estimate on the effect of changes in the relative prices of a product (possibly due to the introduction and the diffusion of

innovations) on the prices of other products or changes in (carbon) taxation of energy products.

Type(s) of data or knowledge needed and their possible source(s)	-> which types of data are needed to run the method, from which sources could they come… -> could be qualitative data or quantitative data, and also tacit knowledge, hybrid, etc.

Data requirements and availability:

Many countries have databases for IOA, be it of different quality and detail.

The option of employing EEIOA depends on the availability of input-output tables and corresponding environmental extensions (NAMEA -like data, Eurostat, 2016a). Moreover, when dealing with analysis of time series and structural decomposition analysis, such information needs to be available for more than one period. Recent efforts by Eurostat and EU-funded research projects improved data coverage for both input-output tables and environmental extensions.

Environmental Extended Supply Use and Input Output Tables (EE-SUIOT from Eurostat)

Eurostat now provides input-output tables for most EU member states for years 1995, 2000 and 2005 at the 2-digit Nace Rev. 1.1 level and at the 2-digit Nace Rev. 2 level (years 2008, 2009 and 2010, for few countries so far).

Moreover, Air Emissions Accounts by activity (formerly called NAMEA) are available for the period 1995-2009 although the coverage is less complete (Eurostat, 2016a).

Eurostat's EU27 consolidated Environmentally Extended Supply Use and Input Output Tables are a combination of Air Emissions Accounts by activity (NACE industries and households) (Eurostat, 2016a) and Consolidated supply, use, and input-output tables (product-by-product) at basic prices (Eurostat 2016b,c,d). Illustrative results based on these integrated data of Environmental Input Ouput analysis are given in Domestic and global emissions of greenhouse gases and air pollutants induced by final use of product.

For a detailed description we refer to the Technical Documentation of EE-SUIOT. (Eurostat, 2011, 2014). Due to confidentiality reasons the EE-SUOITs are published only for the aggregated EU27 and euro area. National time series start in general in 1995. However, the consolidated tables cover the years 2000 to 2006.

World Input Output Database (WIOD)

The WIOD project built single-country and worldwide input-output tables for the period 1995-2009, also providing some environmental extensions (air emissions and energy inputs). Sectoral disaggregation is not so detailed (35 sectors) but huge effort has been put to provide input-output tables evaluated at the previous year prices thus allowing sound SDA.

The World Input Output Database (WIOD) project is funded by the European Commission, Research Directorate General as part of the 7th Framework Programme, Theme 8: Socio-Economic Sciences and Humanities. The database is a set of harmonized supply and use tables, alongside with data on international trade in goods and services. These two sets of data have been integrated into sets of intercountry (world) input-output tables. The economic Input Output data are combined with extensive satellite accounts with environmental and socio-economic indicators at an industry-level (Timmer, 2012).

The World Input-Output Database consists of time series of:

- World Input-Output tables and International Supply and Use tables
- National Input-Output tables and National Supply and Use tables
- Socio-Economic Accounts
- Environmental Accounts

The WIOD classification for the national SUTs has 59 products and 35 industries based on the CPA and NACE rev 1 (ISIC rev 2) classifications.

The environmental accounts include industry energy use and emissions to air. Furthermore the database contains 4 types of land use data for agriculture, and material extractions on an aggregated level based on EW-MFA (see factsheet Economy Wide Material Flow Account).

The database covers 27 EU countries and 13 other major countries in the world for the period from 1995 to 2009.

EXIOBASE

EXIOBASE is a MR-EEIOA database and model, with a global coverage (27 EU countries, 17 other countries and RoW). It boasts many environmental extensions including emissions to air, land and water use, and the extraction of a number of specific resources. It has a very detailed sector disaggregation (129 sectors). Time series have been constructed covering 1995 – 2011.

Model used (if any, geological mathematical, heuristic…)	-> e.g., geological model for mapping -> e.g., mathematical model such as mass balancing, matrix inversion, can be stepwise such as agent -based models, dynamic including time or quasidynamic specifying time series… -> can also be a scenario

The IO framework in first instance is an accounting method. Information is collected about interactions between sectors in the economic system. If these data are transformed into multiplyers, the IO accounting framework can be transformed into a static linear IO model that can be used to assess the effects of changes.

IOA is expressed in a set of linear equations, followed by an indication of the connection between the purely algebraic solution to the input-output, using the Leontief inverse matrix, and the logical economic content of the round-by-round view of production interrelationships in an economy. For environmental purposes there are three (different) basic categories of models: the Generalised IO Model, the Economic/Ecologic Model and the Commodify-by Industry Model.

Input-output tables represent the distribution of sectoral gross output in matrix form, in which each row represents the breakdown of sectoral gross output into intermediate consumption (further broken down by the sector) and in final consumption. If the sectoral breakdown of intermediate inputs corresponds to the same sectors in the economy, the matrix representing intersectoral flows is a square matrix (Z). The vector of sectoral gross output (x) is given by the sum of intermediate inputs (Zi, where i is a vector of ones) and final consumption (vector f). An alternative way of representing gross sectoral output is to use a matrix of technical coefficients (A=Z<x>-1)(note: <x> is a square diagonal matrix having the element of the vector x on its diagonal) , with the vector of gross output now defined as x=Ax+f. The final step is to express the vector of gross sectoral output as a function of final demand and technology (in terms of mix of intermediate inputs) only: x=(I-A)-1f where I is the identity matrix. The matrix (I-A)-1 is defined as the Leontief matrix (L). The equation x=Lf fully describes how changes in the vector of final demand (f) reflect in changes in the vector of sectoral gross output (x).

This simple representation of the economy can be easily extended to account for environmental pressures driven by the production of gross output. This extended model is built by pre-multiplying a vector of sectoral coefficients of environmental pressures (w=e<x>-1 where w is the vector of coefficients of environmental pressures and e is a vector of total direct sectoral environmental pressures) to the basic input-output model (x=Lf). The final identity which describes total sectoral environmental pressures is e=wLf. In this equation, changes in the vector of final demand (f) are linked to changes in the vector of sectoral environmental pressures. For a more detailed overview of basic concepts of input-output analysis refer to chapter 2 of Miller and Blair (2009).

System and/or parameters considered	-> **the system can be described by its boundaries**. These can refer to a geographic location, like a country, or a city, the time period involved, products, materials, processes etc. involved, like flows and stocks of copper, or the cradle-to-grave chain of a cell phone, or the car fleet, or the construction sector, or the whole economy… -> **parameters** could possibly refer to geographic co-ordinates, scale, commodities considered, genesis of ore deposits and others…

The primary object of analysis in IOA are the monetary exchanges between the elements of the system investigated. These are listed in an IO-table. In EEIOA extractions and emissions are additional objects of analysis.

SUTs and IOTs are composed for national economies. They can be aggregated into larger units, for example the EU, or even the world. Linking national IOTs via trade-flows into Multi-Regional IOTs enables the analysis of international trade flows.

With a MR-EE-IOT framework it is possible to derive two types of environmental intervention profiles for a specific country representing different system boundaries:

- Territorial or production based extractions and emissions, expresses the environmental pressure within the national territory due to the activities in the total national economy
- footprint or consumption based extractions and emissions; The EEIOT together with the 'final demand' of products and services can be used to derive this 'consumption based environmental intervention profile ' of a total national economy.

IOA follows a region-oriented system definition. It is effect oriented, analysing the changes which occur in the different elements due to a specific change in demand. This tool uses linear algebra which allows all economic activity to be directly related to final demand.

With an EE-SUIOT framework it is possible to derive two types of intervention (emission and extraction) profiles for a specific country representing different system boundaries:

- territorial based interventions, expresses the environmental pressure in a region due to the activities in the total regional economy (mainly focused on activities of production, but sometimes also but to a less extend use and waste treatment in the region)
- function based interventions or consumption based interventions; The EEIOT together with the 'final demand' of products and services (expressed in monetary terms) can be used to derive this 'consumption based intervention profile' of a total regional economy.

Time / Space / Resolution /Accuracy / Plausibility…	-> to which spatio-temporal domain it applies, with which resolution and/or accuracy (e.g., near future, EU 28, 1 year, country/regional/local level…) -> for foresight methods can also be plausibility, legitimacy and credibility…

An input-output model is constructed for a particular economic area, using administrative boundaries. Usually the economic area is a nation state. The economy

is divided into a number of sectors. The resolution differs from 10 to 500 sectors. Global MR-EEIOA models distinguish 50 – 120 sectors. The time resolution is one year. See also section data needs/databases.

Problems with consistency occur especially when linking national IOTs. Discrepancies between country data have to be resolved via a reconciliation procedure that sometimes leads to significant errors. Uncertainties occur especially in the translation from the monetary to the physical. This includes the environmental extensions which often are rather crude. In IOA there are standardized ways to account for uncertainties (see separate fact sheet on Input Output Analysis).

Indicators / Outputs / Units	-> this refers to what the method is actually meant for. Units are an important part but that is most of the time not sufficient to express the meaning. For example, **the indicators used in LCA express the cradle-to-grave environmental impacts of a product or service**. This can be expressed in kg CO_2-equivalent. But also in €. Or in millipoints. Or in m^2year land use. -> for foresight methods the outputs are products or processes

The type of interventions represented in EEIOA may be resource flows into, or emissions from different economic sectors. Indicators usually have the dimension of resource or eco-intensity, or resource productivity. Using an EEIOA framework it is possible to derive two types of intervention profiles (emissions and extractions) for a specific country:

- production based interventions or territorial based interventions
- consumption based interventions or function based interventions

The environmental satellite account of the EEIOT expresses the environmental pressure in a region due to the activities in the regional economy (activities of production, use and waste treatment in the region) and thus specify the first intervention profile.

In a consumption based emission approach, the emissions are related to the consumption in that region. The EEIOT together with the final demand of products and services (expressed in monetary terms) can be used to derive this consumption based intervention profile, which not only includes the production, domestic as well as foreign, to the extent required for domestic consumption. This can be characterized as a function based or a "footprint" approach (see separate factsheet on footprints). A carbon footprint account of the countries of the world is available, derived from trade-linked EEIOA, as well as EEIOA derived water footprint accounts are also available (GFN, 2012; Hertwich & Peters, 2009; Hoekstra & Mekonnen, 2012].

Treatment of uncertainty, verification, validation	-> evaluation of the uncertainty related to this method, how it can be calculated/estimated

While the physical measure is perhaps a better reflection of one sector's use of another sector's product, there are enormous measurement problems when sectors actually sell more than one good. For these and other reasons, accounts are generally kept in monetary terms, even though this introduces problems due to changes in prices, which do not reflect changes in the use of physical inputs. Furthermore IOA suffers from limitations of high levels of aggregation in international input-output tables.

As an analytical tool IOA is dependent on the choice of the "right" conditions, i.e., of what is going to be taken into account. The environmental problems that are considered to be relevant can vary from one study to another. Analysis using IOA assumes that the technical and pollution coefficients do not change over time. Clearly this is unrealistic for changes over a long time period.

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Main publications / references	-> e.g. , ILCD handbook on LCA, standards (e.g. , ISO) -> can include reference to websites/pages

CREEA-website: http://www.creea.eu/

Eurostat, 2008. Eurostat Manual of Supply, Use and Input-Output Tables. European Commission, Eurostat, Joint Research Centre, Luxembourg. http://ec.europa.eu/eurostat/documents/3859598/5902113/KS-RA-07-013-EN.PDF/b0b3d71e-3930-4442-94be-70b36cea9b39?version=1.0

Eurostat, 2011. Technical Documentation eeSUIOT project: Creating consolidated and aggregated EU27 Supply, Use and Input- Output Tables, adding environmental extensions (air emissions), and conducting Leontief-type modelling to approximate carbon and other 'footprints' of EU27 consumption for 2000 to 2006. European Commission, Eurostat, Joint Research Centre, Luxembourg. http://ec.europa.eu/eurostat/cache/metadata/Annexes/naio_10_esms_an1.pdf

Eurostat, 2014. Technical Documentation on the European consolidated tables for years 2010 and 2011.
http://ec.europa.eu/eurostat/cache/metadata/Annexes/naio_10_esms_an2.doc

Eurostat, 2016a (accessed May 2016; last modified March 2015). Air Emissions Accounts by activity (NACE industries and households)
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Eurostat 2016c (accessed May 2016). ESA95 supply, use, and input-output tables
http://ec.europa.eu/eurostat/web/esa-supply-use-input-tables

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http://ec.europa.eu/eurostat/cache/metadata/en/naio_10_esms.htm

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http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_ac_io&lang=en

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Eurostat 2016b (accessed May 2016; last modified January 2016). Consolidated supply, use, and input-output tables (product-by-product) at basic prices

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EXIOPOL-website: http://www.feem-project.net/exiopol/

EXIOBASE- website: http://www.exiobase.eu/

Heijungs, R., A. de Koning, S. Suh and G. Huppes. (2006). *Toward an information tool for integrated product policy: Requirements for data and computation.* Journal of Industrial Ecology10(3): 147-158. DOI: https://doi.org/10.1162/jiec.2006.10.3.147

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Related methods	-> List of comparable methods, their particularities… (or a link to one or several other fact sheet(s))

Compatibility with other types of information:

Current EEIOA is focused on expanding the scope to cover consumption, disposal, health effects, environmental impacts, etc. Given the region-oriented type of system definition it can be linked to MFA studies.

Hybrid LCA is a combination of LCA and EEIOA. The structure of the two methods is similar, and the combination may overcome some of the drawbacks of either method. LCA has a high resolution but has a limited scope, while EEIOA has a low resolution but represents the total economy (Suh & Nakamura, 2007; Heijungs et al., 2006). To relate micro level changes to effects on the macro level it is necessary to embed the micro system into a macro system. In this sense both methods, LCA and EEIOA, seem to be complementary. In Van Oers et al. (2013) the possibilities of the use of hybrid LCA EEIO models in the EmInInn project is further elaborated.

Some examples of operational tools (CAUTION, this list is not exhaustive)	-> e.g., software… Only give a listing and a reference (publication, website/page…) -> **should be provided only if ALL main actors are properly cited**

Many countries have databases and derived models for EEIOA, be it of different quality and detail, either compiled by national statistical bureaus and/or universities.

Some examples of Multi Regional databases and models are given in the section 'Type(s) of data or knowledge needed and their possible source(s)', like EXIOBASE, WIOD and the EE-SUIOTs from Eurostat.

Key relevant contacts	-> list of relevant **types** of organisations that could provide further expertise and help with the methods described above.

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Wiedmann, T.O. and M. Ienzen. Integrated Sustainability Analysis (ISA), School of Physics A28, The University of Sydney, Sydney, NSW 2006, Australia http://www.isa.org.usyd.edu.au/

Glossary of acronyms /abbreviations used	-> Definition