MICA
Minerals Intelligence Capacity Analysis

FACT SHEET

Footprint methods

Description of the Footprint methods.

Scope (conceptual model & main characteristics)

Footprint

The term "footprint" was initially introduced by Mathis Wackernagel and William Rees in the early 1990s (Rees and Wackernagel, 1992), when the indicator "Ecological Footprint" was first presented. The Ecological Footprint is an aggregated indicator that calculates the total environmental pressure related to consumption in terms of square meters of land required. "Consumption" can refer to a product, to the annual consumption of a person, or to the annual consumption of a nation.

Later additions to the Ecological Footprint are the comparison with the area of bioproductive land for the country-level assessments, and to the addition of land needed to absorb the waste (CO2) produced (WWF et al., 2012). Ecological Footprints use a consumption-based system, and a global perspective, i.e. they include all biologically productive areas world-wide to satisfy consumption, including those embodied in internationally-traded products. (Giljum *et al.,* 2013)

More recently, the term "footprint" is also introduced for other indicators than the land use. These indicators use the same type of consumption based system, but express the pressure of that system in different terms. We now have the following footprints, in addition to the Ecological Footprint:

- Water footprint
- Land footprint
- Materials footprint
- Carbon footprint
- Product Environmental Footprint (PEF, also described in the LCA factsheet).

Even more recent is the notion that "footprints" can also be calculated for intermediate consumption, turning the system into a cradle-to-gate rather than a cradle-to-grave chain.

The **water footprint** is the total amount of fresh water that is used directly and indirectly to produce the goods and services which satisfy domestic final consumption. For effective water management the water footprint ideally distinguishes between different types of water flows: (1) water withdrawal and water consumption; the first term being the whole amount of water abstracted from the environment, the second being only the amount which is not returned at all (incorporated in the product) or at much later point in time or to another catchment. (2) Blue and green water; the first being water stemming from surface and groundwater, the second stemming from rainwater. Comprehensive water accounts – and the resulting footprint analyses – encompass all these aspects appropriation of water by human society (WFN, 2016; Mekonnen & Hoekstra, 2011; Chapagain & Hoekstra, 2004).

The **land footprint** assesses the domestic and foreign land areas, which are directly and indirectly required to satisfy domestic final consumption. It is important to note that land footprint approaches differ from calculations of the ecological footprint, as no weighting of land areas by different bio-productivities is applied. In contrast to the category of materials, no harmonised definition of the land footprint exists so far. Due to data restrictions, land footprint studies have so far often focused on the agricultural and forestry areas. However, important questions still need to be resolved, before land footprint indicators can fully be integrated into a footprint-type indicator set.

The **material footprint** illustrates the global, life-cycle wide material extraction and use related to the final consumption of a country, whether occurring within the country or beyond the countries‘ borders. Material footprint is therefore a newer term for "ecological rucksacks" (Schmidt-Bleek, 1992; Schmidt-Bleek, 2009), which also refer to the life-cycle wide material inputs of products. Material footprints can be focused on used material extraction (resulting in the indicator Raw Material Consumption) or also include unused material extraction (delivering Total Material Consumption). Through underlying guidelines such as those elaborated by EUROSTAT (2013) or the OECD (2007) the methodological developments of the material footprint indicator are already quite advanced.

The **carbon footprint** captures the full amount of greenhouse gas emissions that are directly and indirectly caused by an activity or are accumulated over the life stages of products, which are consumed in a country (Wiedmann, 2011). Three standards for carbon footprinting have been already published, including the PAS 2050 standard (BSI, 2008), the Product Life Cycle Accounting and Reporting Standard by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD) (WRI & WBCSD, 2011), and the International Organisation for Standardisation developed the ISO 14067 on the Carbon Footprint of Products (ISO, 2012).

Each of the above footprints have their own methodology, data needs and indicators. However, the general principle of all the footprint methods is that they take the consumption- or function based perspective to calculate environmental impacts. Given this consumption perspective, methodologies like Life Cycle Assessment (LCA) and Environmental Extended Input Output Analysis (EEIOA) can be used to calculate footprint indicators. For details see factsheets on LCA and EEIOA. Giljum et al (2013) describe three types of methodologies to calculate footprint-type indicators based on IOA, LCA or a hybrid of these two methods. The report also gives an overview of databases that are useful to derive footprint indicators for materials, water, land and carbon (Giljum et al., (2013). For example research is undertaken to use input-output tables as input to calculate Carbon, water, land and materials Footprint accounts (Tukker et al., 2014). This factsheet will now focus on the footprint methodologies that are not based on LCA or IOA.

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

The Ecological Footprint show whether the current consumption is within the limits of what the earth can sustain (Schaefer et al. 2006). They have a strong communicational and educational strength. These Footprints indicators that take into account carrying capacity are very effective for raising awareness on environmental sustainability and can be used to evaluate personal lifestyles (Giljum et al. 2007). However, the Ecological Footprint has also attracted criticism because of the comparison with this biocapacity indicator (ref debate in the Journal of Industrial Ecology). A country such as the USA or Australia, with very high per capita footprint, comes out as sustainable because their consumption doesn't overshoot their bioproductive land. A country such a the Netherlands, densely population but with a much lower per capita footprint, overshoots its biocapacity by a factor 3-6. The information this provides for environmental policies is at best confusing.

Footprint applications without the carrying capacity dimension are found to be useful at many scale levels. They are used by countries, by persons and by sectors to assess the worldwide impact of their actions, and thus form a valuable addition to the usually territorially bounded environmental information. Such applications have shown that some countries have exported the more polluting stages of the life cycle, and that there are countries that provide the rest of the world with resources. The EU Resource Efficiency Roadmap has defined an indicator set where territorial indicators of material, water and land use and GHG emissions are complemented by a number of footprint indicators for material, water and land use and GHG emissions.

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.

1. National Ecological Footprint, based on carrying capacity

The data necessary to calculate the National Ecological Footprint Accounts are mainly from international statistical and scientific agencies. The primary resources are tracked based on FAOSTAT data. The FAO documents data on production, import and export data of many resources. The primary resources embodied in manufactured products are tracked using data from the UN Statistical Department COMTRADE global trade database. For an overview of more details on required data is refered to van der Voet et al., (2009) and the original guides for calculation of ecological footprints (GFN, 2010; Wackernagel et al., 2005)

2. Water footprint from waterfootprint network

All water footprints are based on a basic water balance of a process using the following data

1. Water Evaporation;
2. Water Incorporation into the product;
3. Lost Return flow to the same catchment area, for example, it is returned to another catchment area or the sea;
4. Lost Return flow in the same period, for example, it is withdrawn in scarce period and returned in a wet period.

In addition to calculate grey water footprints information is needed on pollutant loads by a process and standards for maximum acceptable concentration and natural concentration levels of pollutants in the water.

The water footprint network has published the Global Water Footprint Assessment Standard lays out the internationally accepted methodology for conducting a Water Footprint Assessment. http://waterfootprint.org/en/standard/global-water-footprint-standard/

Water footprints which are calculated using the the Global Water Footprint Assessment Standard are provided in WaterStat.

WaterStat currently includes five datasets:

1. Product water footprint statistics
2. National water footprint statistics
3. International virtual water flow statistics
4. Water scarcity statistics
5. Water pollution level statistics

http://waterfootprint.org/en/resources/water-footprint-statistics/

3. Land footprint

The data needs for the land footprint are similar to those of the ecological footprint (see first item). However, in the land footprint the land use is NOT compared to carrying capacity references and also the land necessary for the absorbtion of CO_2 is not taken into account.

4. Materials footprint

Material footprints are based on EW-MFA, see the factsheet EW-MFA. Eurostat produces measures of domestic material consumption (DMC) as part of the economy-wide material flow accounts (EW-MFA). Those statistics however do not provide an entirely accurate picture of global material footprints because they record the international flows of materials differently than the materials extracted from the environment (called domestic extraction in EW-MFA). Imports and exports are recorded in material flow accounts as the actual weight of the traded goods when they cross country borders instead of the weight of materials extracted to produce them. As the former are lower than the latter economy-wide, material flow accounts and the derived DMC underestimate the material footprint. To adjust for this, the weight of processed goods traded internationally is converted into the corresponding raw material extractions they induce. So import and export flows must be expressed in their raw material equivalents (RME). These are estimated with models that are still under development and therefore do not produce official statistics yet.

http://ec.europa.eu/eurostat/statistics-explained/index.php/Material_flow_accounts_-_flows_in_raw_material_equivalents

5. Carbon footprint

The carbon footprints are mostly based on EE-IOA and LCA methodologies, for details is referred to the respective factsheets.

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

1. National Ecological Footprint

The Ecological Footprint accounts consist of a supply side (Biocapacity) and a demand side (Ecological Footprint).

2. Water footprint from waterfootprint network

The water footprint of one single 'process step' is the basic building block of all water footprint accounts. See the section 'systems' for how water footprints are calculated for other systems.

Water footprints may be broken down into three different sub indicators, green, blue and grey water footprint.

The blue water footprint is an indicator of consumptive use of so-called blue water, in other words, fresh surface or groundwater. The term 'consumptive water use' refers to one of the following four cases:

1. Water evaporates (BlueWaterEvaporation);
2. Water is incorporated into the product (BlueWaterIncorporation);
3. Water does not return (LostReturnflow) to the same catchment area, for example, it is returned to another catchment area or the sea;
4. Water does not return (LostReturnflow) in the same period, for example, it is withdrawn in scarce period and returned in a wet period.

The blue water footprint in a process step is calculated as:

WFproc,blue = BlueWaterEvaporation + BlueWaterIncorporation + LostReturnflow [volume/time]

The green water footprint in a process step is equal to:

WFproc,green = GreenWaterEvaporation + GreenWaterIncorporation [volume/time]

The distinction between the blue and green water footprint is important because the hydrological, environmental and social impacts, as well as the economic opportunity costs of surface and groundwater use for production, differ distinctively from the impacts and costs of rainwater use.

The grey water footprint of a process step is an indicator of the degree of freshwater pollution that can be associated with the process step. It is defined as the volume of freshwater that is required to assimilate the load of pollutants based on natural background concentrations and existing ambient water quality standards.

The grey water footprint is calculated by dividing the pollutant load (L, in mass/time) by the difference between the ambient water quality standard for that pollutant (the maximum acceptable concentration cmax, in mass/volume) and its natural concentration in the receiving water body (cnat, in mass/volume).

3. Land footprint

Land footprint are based on domestic final consumption of products by nations or individuals and multiplies this consumption with land areas necessary to produce these products. Up until now mainy land foodprints are limited to products from agriculture and forestry.

4. Materials footprint

The material footprint is based on EW-MFA, for details see factsheet EW-MFA. However, the traded flows are converted from kg product into kg Raw Material Equivalents (RME). In order to do this all the raw materials that are extracted along the cradle to gate or cradle to grave chain of the consumed product are aggregated into a mass indicator. Trade flows in RME are estimated by Eurostat based on an environmentally extended hybrid input-output model for the aggregated EU economy. These embedded raw materials in trade products are combined with the domestic extracted raw materials to define the Raw Material Consumption expressed in Raw Material Equivalents (RME).

5. Carbon footprint

The carbon footprints are mostly based on EE-IOA and LCA methodologies, for details is referred to the respective factsheets. The footprint score is based on an inventory of the emissions of all the green house gasses emitted by the system. The emissions are multiplied with weighting factors that express the relative contribution of the substance emission to global warming. In LCA terminology this is called characterization. The final footprint score is expressed in kg CO2 equivalents.

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 system of all footprints is consumption based: the total amount of land, water, materials or carbon that is required for the consumption of a person, a country, or a sector. The details differ per application.

1. National Ecological Footprint

The system of the national footprint is consumption based: the total amount of land required to fulfill the demand of the nation's population. This land can be located anywhere in the world. The reference, the nation's biocapacity, is the sum of all bioproductive land within the nation's territory.

The National Footprint Accounts include more than 700 renewable resources, among which crops, fuelwood, forage and fish and one waste product, carbon dioxide. The Ecological Footprint does not account for the depletion of non-renewable resources like metals.Six land categories are tracked: cropland, grazing land, fishing grounds, forest area, builtup and and carbon demand on land. These land categories are expressed in standardized units of biologically productive area: global hectares. One global hectare is equal to one hectare with a productivity equal to the average productivity of all the bioproductive areas on Earth. Two conversion factors are used to translate real hectares into global hectares:

1. yield factors, that compare national average yield per hectare to world average yield in the same land category;
2. equivalence factors, that capture the relative productivity among the various land and sea area types.

For the demand side of the accounts, the Footprints of renewable resources, built-up area and fossil fuels are calculated.

The Footprint of built-up area is equal to the foregone agricultural productivity of these areas. It is assumed that built-up areas occupy formerly cropland.

The Footprint of fossil fuels is equal to the bioproductive area needed to assimilate the waste (CO2). It is estimated by the bioproductive area needed to sequester the CO2 emission through afforestation.

For the supply side of the accounts, the biocapacity of a country is calculated. The number of hectares are multiplied by their equivalence factors and the national yield factors. The global hectares of the six land categories are then summed to get the total national biocapacity. (GFN, 2010)

2. Water footprint from waterfootprint network

Water footprints can be based on different system definitions:

- The water footprint of a product = the sum of the water footprints of the process steps taken to produce the product (considering the whole production and supply chain).
- The water footprint of a consumer = the sum of the water footprints of all products consumed by the consumer.
- The water footprint of a community = the sum of the water footprints of its members.
- The water footprint of national consumption = the sum of the water footprints of its inhabitants.
- The water footprint of a business = the sum of the water footprints of the final products that the business produces.
- The water footprint within a geographically delineated area (for example, a municipality, province, state, nation, catchment or river basin) = the sum of the process water footprints of all processes taking place in the area.

The methodology for calaculation of the water footprints and the data needs are described in detail in the water footprint standard http://waterfootprint.org/en/standard/global-water-footprint-standard/

3. Land footprint

The land footprint refers the domestic and foreign land areas, which are required to satisfy consumption, mostly limited to agricultural and forestry products. "Consumption" can refer to a product, to the annual consumption of a person, or to the annual consumption of a nation.

4. Materials footprint

The materials footprint refers the domestic and foreign extracted raw materials, accumulated over the life stages of products, which are consumed. "Consumption" can refer to a product, to the annual consumption of a person, or to the annual consumption of a nation.

5. Carbon

The carbon footprint refers the domestic and foreign emitted Green House Gasses (expressed in CO2-equivalents) accumulated over the life stages of products, which are consumed. "Consumption" can refer to a product, to the annual consumption of a person, or to the annual consumption of a nation.

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…

1. National Ecological Footprint

National Footprint Account (NFA) results are available for 200 countries. Time series data is not available for all nations. http://data.footprintnetwork.org/

2. Water footprint from waterfootprint network

Water footprints are available in Waterstat for the period 1996-2005 for crops, animal products, biofuels, industrial products, national production and national consumption by countries worldwide. http://waterfootprint.org/en/resources/water-footprint-statistics/

3. Land footprint

Land footprints can be derived for products or the consumption by individuals or the yearly consumption of goods by nations.

There are no formalized time series of land footprints for countries available yet.

4. Materials footprint

Eurostat's material flow accounts in RME include a breakdown by four main material categories; biomass, metal ores, non-metallic minerals, and fossil energy materials/carriers, each with several more detailed breakdowns, with a total of 67 categories (including grouped categories). The Eurostat material footprints are reported yearly for 28 European member states.
http://ec.europa.eu/eurostat/statistics-explained/index.php/Material_flow_accounts_-_flows_in_raw_material_equivalents

5. Carbon footprint

Carbon footprints can be derived for products or the consumption by individuals or the yearly consumption of goods by nations.

Yearly carbon footprints are available for nations worldwide.

There are several carbon footprint tools on the internet that calculate carbon footprints of products or of individual consumption.

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

1. National Ecological Footprint

The EF is expressed in units of surface (m2, ha or km2). In fact it is surface being used for one years consumption of a nation, but the "year" dimension has disappeared from the indicator. When compared to the reference, the indicator becomes dimensionless: m2/m2. It then expresses the fraction of the biocapacity that is "used up".

(Wackernagel et al. 2005; GFN, 2009 & 2010)
http://www.footprintnetwork.org/en/index.php/GFN/

2. Water footprint from waterfootprint network

Different water footprints indicators can be calculated using the methodology of the water footprint network:

- individual person,
- a process,
- a product's entire value chain or for a business,
- a river basin
- a nation

For details how the indicators should be calculated is refered to the Water footprint network site http://waterfootprint.org/en/water-footprint/ and the Global Water

Footprint Assessment Standard,which lays out the internationally accepted methodology for conducting a Water Footprint Assessment.
http://waterfootprint.org/en/standard/global-water-footprint-standard/

Water footprints may be broken down into three different sub indicators. The blue water footprint refers to consumption of blue water resources (surface and groundwater) along the supply chain of a product. 'Consumption' refers to loss of water from the available ground-surface water body in a catchment area. Losses occur when water evaporates, returns to another catchment area or the sea or is incorporated into a product. The green water footprint refers to consumption of green water resources (rainwater insofar as it does not become run-off). The grey water footprint refers to pollution and is defined as the volume of freshwater that is required to assimilate the load of pollutants given natural background concentrations and existing ambient water quality standards. (WFN, 2011)

3. Land footprint

Land footprint is expressed in units of surface (m2, ha or km2). Depending on the system definition it will relate to one years consumption of a nation or individual, or the to the cradle to gate/grave chain of a unit (e.g. kg, piece etc.) of product.

4. Materials footprint

Material footprints are expressed in kg Raw Material Equivalents. Depending on the system definition it will relate to one years consumption of a nation or individual, or the to the cradle to gate/grave chain of a unit (e.g. kg, piece etc.) of product.

5. Carbon footprint

Carbon footprints are expressed in kg CO_2 Equivalents. Depending on the system definition it will relate to one years consumption of a nation or individual, or the to the cradle to gate/grave chain of a unit (e.g. kg, piece etc.) of product.

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

1. Ecological Footprint, some Limitations
p.m.

2. Water footprint from waterfootprint network

In the water footprints of the waterfootprint network not much attention is given yet to the uncertainty of data and models used.

3. Land footprint

4. Materials footprint

Material footprints are based on Economy Wide Materials Flow Accoounts (EW-MFA) for uncertainty related to this method see the factsheets EW-MFA.

5. Carbon footprint

Carbon footprints are mostly based on EE-IOA or LCA methodology. For uncertainty related to these methods see the respective factsheets.

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

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

Given the consumption perspective of the footprint indicators, methodologies like Life Cycle Assessment (LCA) and Environmental Extended Input Output Analysis (EEIOA) can be used to calculate footprint indicators. For details see factsheets on LCA and EEIOA. Giljum et al (2013) describe three types of methodologies to calculate footprint-type indicators based on IOA, LCA or a hybrid of these two methods. The report also gives an overview of databases that are useful to derive footprint indicators for materials, water, land and carbon (Giljum et al., (2013).

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**

Water footprint from waterfootprint network

The Waterfootprint network provides different tools to calculate the water footprint, like

- Water Footprint Assessment Tool
- National water footprint explorer
- Product gallery
- Personal water footprint calculator

http://waterfootprint.org/en/resources/interactive-tools/

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

1. National Ecological Footprint

The most widely used methodology for calculating national Footprints are the National Footprint Accounts by the Global Footprint Network. The Global Footprint Network (GFN) is the organization that promotes the application of Ecological Footprint accounts and is supported by more than 90 partner organizations. The National Footprint accounts are calculated annually for more than 150 countries. The Global Footprint standards (GFN 2009) have been initiated by the Global Footprint Network to reach consensus on a common calculation method for the Ecological Footprints. Partners of the Global Footprint Network are required to comply with the most recent Ecological Footprint standards.
http://www.footprintnetwork.org/en/index.php/GFN/

2. Water footprint from waterfootprint network

The **Water Footprint Network** is an international learning community (non-profit foundation under Dutch law) that serves as a platform for connecting communities interested in sustainability, equitability and efficiency of water use. The organization has two work programmes: a Technical Work Programme and a Policy Work Programme. In addition, there is a Partner Forum which offer partners of the WFN a way of receiving, contributing and exchanging knowledge and experience on water footprint. http://waterfootprint.org/en/

3. Land footprint

p.m.

4. Materials footprint

Material footprint accounts for the European Union are drafted by EUROSTAT.
http://ec.europa.eu/eurostat/statistics-explained/index.php/Material_flow_accounts_-_flows_in_raw_material_equivalents

Materialfootprint from materialfootprint network

http://materialfootprint.org/materialfootprintnetwork_eng.html#objectives

5. Carbon footprint

p.m.

Carbon footprints of nations are mostly calculated using EE-IOA, see factsheet EE-IOA.

Three standards for carbon footprinting have been already published, including the PAS 2050 standard (BSI, 2008), the Product Life Cycle Accounting and Reporting Standard by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD) (WRI & WBCSD, 2011), and the International Organisation for Standardisation developed the ISO 14067 on the Carbon Footprint of Products (ISO, 2012).

Glossary of acronyms /abbreviations used	-> Definition