MICAT
Multiple Impacts Calculation Tool

Empirical Basis of Environmental Impacts Savings on material resources

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101000132.

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Executive summary

The Material Footprint (MF) is an aggregated indicator of raw material savings from the extraction of fossil fuels, minerals, metal ores, biotic materials as well as the extraction of materials that are not put to an economic use (unused extraction). In MICAT, the MF represents the differences (usually savings) in removing material resources from nature before and after energy-efficiency measures take effect (pre- and post-action). In some cases, the scope of the indicator is not limited to direct effects from lower energy demand (use phase) but include effects from changes in technologies (production phase). Although the measures itself can take place on a small spatial scale (e.g., a city) the extractions (or savings thereof) take place on a global scale.

MF and its sub-indicators are expressed in form of intensities (gram of material per functional unit) that are derived from the input data (e.g., mix of energy carriers for electricity) and models (e.g., material demand for producing an electric vehicle). They can usually be multiplied with the marginal changes in the system (e.g., kg of hard coal for heat) and summed up.

The data required for material savings during the use-phase (energy demand pre- and post-action) are usually included in energy efficiency scenarios like PRIMES. By including or adding additional data on the key technologies (usually products) that are necessary to achieve the energy savings, the production phase can also be included in many cases. This requires at least data on changes in product stocks and basic assumptions or technical parameters for the technologies considered (e.g., the type and size of cars exchanged).

As MF is based on bottom-up modelling (similar to life cycle assessment (LCA)) its calculation reflects the status quo or ex-post calculations. If additional data is provided, ex-ante calculations are possible to the extent that databases for life-cycle-inventories allow for it. An example for that would be the integration of future electricity mixes into the use-phase.

For monetization, both direct (embodied) material costs and indirect (external) material costs are suitable approaches. However, they are limited to certain materials (usually metal commodities) and can overlap with investment costs or energy cost savings.

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Scope of MI indicator

Definition

The Material Footprint (MF) is an aggregated indicator that quantifies the accumulation of natural material resources for providing a service or product. In the context of MICAT it is defined as "*Savings of abiotic (fossil fuels, metal ores, minerals) and biotic (not further specified) raw materials from nature; including raw materials without economic use (unused extraction)*". Further information on the indicator for resource impacts of energy efficiency measures as well as its associated impact method can be found in the literature review[1] and quantification report[2] of the COMBI project.

Relevance on EU, national and/or local level

MF is usually calculated from bottom-up models aimed at quantifying impacts on project or product level (similar to LCAs). Additional modelling steps are required when MF values are to be reported for national or regional environmental accounts. As MF was originally developed on the basis of the material-flow methodology, it is possible to report impacts that are consistent with the SDG 12 Goal[3] of reducing the MF and domestic material consumption (DMC). It is also feasible to report MF values on national or local levels, although the life-cycle approach entails material extractions from outside of the perspective system. The MF therefore is caused by and attributed to the specific actions in Europe, the country or local community but its effects (less use of natural material resources) take place on a global scale.

Impact pathway figure

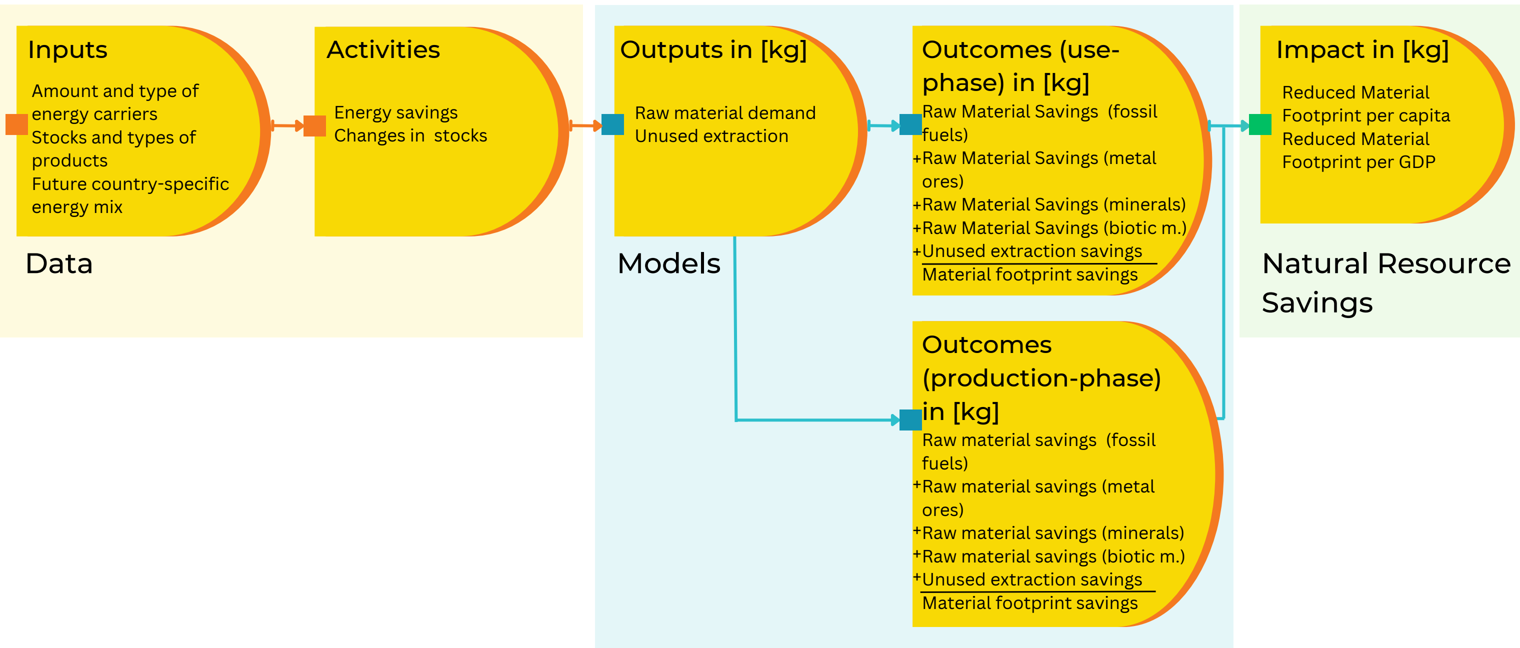

Figure 1: Logic model (theory of change) for material footprint

[1] https://combi-project.eu/wp-content/uploads/2015/09/D4.1.pdf
[2] https://combi-project.eu/wp-content/uploads/D4.4_20180321_final.pdf
[3] https://sdgs.un.org/goals/goal12

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Overlaps with other MI indicators and potential risk of double-counting

MF *correlates* with the accumulated energy demand on the input side of systems and with greenhouse gas (GHG) emissions on the output side (especially in regard to the use of energy carriers). As such, no double-counting occurs. However, there are overlaps with these types of indicators if impacts are monetized. Both energy cost savings and investment costs include partially or fully (depending on monetization method) the direct or external costs of raw materials.

Quantification method

Description

All sub-indicators (biotic, fossil fuel, metal ore and mineral raw material savings) refer to the raw materials that are extracted or permanently removed from nature from cradle-to-grave (or for MICAT from cradle-to-gate). They are summed up over the entire life cycle and expressed as material intensity in grams of resources per gram of economically used material [g/g]. This includes e.g., the residues of extracted ores but not the overburden from mining which is only included in the so-called unused extraction (UU) and only added to the overall MF.

Although it is possible to quantify MFs with the help of Input-Output Tables (IOTs) (top-down) it usually requires a bottom-up perspective (e.g., material and energy flows in life-cycle inventories). By its nature, raw material demands are very difficult to quantify for the future which is why they can be considered to be results from an ex-post assessment. Certain changes in the surrounding systems can be integrated though that result in changes in the material intensity of services. The most likely use-case for MICAT is to account for the reduced demand of different energy carriers from electricity or heat production but also e.g., changes in the material composition of vehicles from batteries compared to internal combustion machines. The changes in direct energy use are incorporated via **use-phase models** while the changes in product types and product stocks are captured by **production-phase models**.

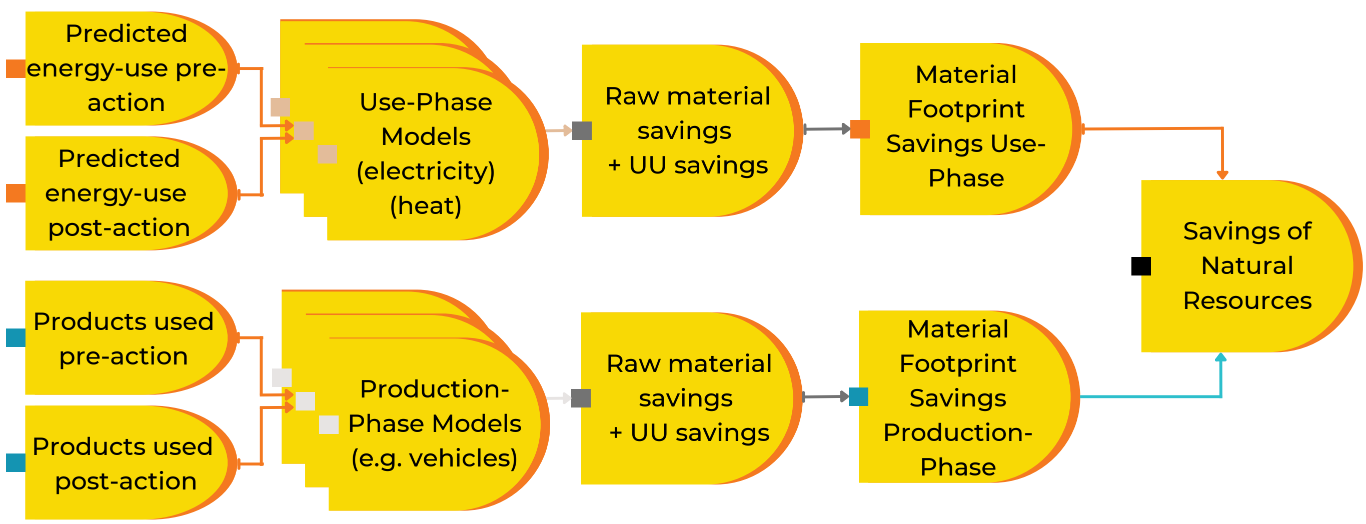

Figure 2 : Calculation steps

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Methodological challenges

Using stock data for a variety of possible current and future products is limited to available life-cycle inventories and their potential matching to product classes in the input data. A number of assumptions are necessary to represent the best-available average, or rather, generic product type. This limitation not only affects the products and their use themselves, but especially the upstream material and energy flows for the provision of materials. For some materials like metals, although a global production is assumed, differences in the material intensity of raw material exporting countries and even between mines can be very high. For local applications in particular, this might not reflect the conditions in a specific case. The existing and further developed models will try to account for that fact by using secondary sources (e.g., EUROSTAT statistics) to identify the most appropriate level of aggregation.

Data requirements

The following data is needed to calculate the MF for the use-phase (resource savings from reduced energy demand) and the production-phase (savings and trade-offs for providing key technologies).

Table 1: Quantification of the indicator aggregated energy security (supply diversity)

All phases	Use phase	Production phase
electricity & heat demand	energy carriers for electricity pre-/post-action	definition of key technologies
changes to energy systems (e.g., new technologies)	energy carriers for heat pre-/post-action	stock of products in base-case/reference scenario
		stock of products post-action/energy efficiency scenario

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Impact factor/functional relationship

All effects are based on direct or derived (modelled) intensity factors that usually can be directly multiplied with the input data (in line with e.g., Carbon Footprint Intensities). If these intensities are consistently mapped to the inputs, it should therefore be possible to calculate the MF and its sub-indicators directly from changes in the input data (linear relationship). As for spatial differentiation, it is not possible to differentiate the direct impacts within the dimension (causing the effects) from impact outside of any dimension as all material extractions take place on a global scale. However, resulting MF values can directly be attributed to different levels.

Monetisation

Two types of monetization approaches can be applied: embodied or direct costs and indirect or external costs (see also the quantification report [2] of the COMBI project for further details and monetization factors). The embodied costs can be based on market prices for processed raw materials and linked to the raw material demand. This is particularly feasible for metals and fossil fuels. The indirect material costs are externalized costs of societies that occur if raw materials deplete in the future and additional investments are necessary to provide them in the same quality. The eco-cost model provides such future costs for metals by using historic data and assuming fixed developments for scarce metal prices as well as the growth of population and economies.

Double-counting can occur for embodied material costs if material costs are not excluded from investment costs.

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Aggregation

MF impacts (or midpoints) should not be aggregated with other inputs or outputs, even if the unit is nominally the same. The aggregation within the method is formulated as a sum of all sub-indicators as follows:

Material Footprint (MF) = Fossil Fuel Demand +Metal Ore Demand + Mineral Demand + Biotic Raw Material Demand + Unused Extraction

Conclusion

This indicator shows the material usage in the production phase and use-phase. Thus, it shows how much material has to invested and is saved over the time period the measure is introduced. The MF is calculated in a Bottom-Up approach, which makes it difficult to combine with the Top-Down approach of the measures. Therefore, just a few production-phase MFs will be included. The Use-Phase can be integrated easily and can maybe also be monetized.