



University of Natural Resources
and Life Sciences, Vienna

Department of Economics and Social Sciences
Institute of Social Ecology

Modelling economy-wide material stocks and flows for 14 materials, 177 countries and 200 years: the ODYM-MISO-2.0 model

Dominik Wiedenhofer & Jan Streeck

Barbara Plank, Doris Virág, Helmut Haberl, Fridolin Krausmann



European Research Council
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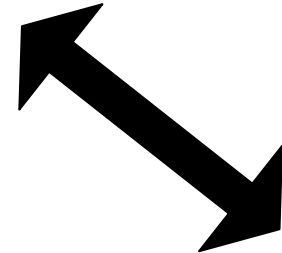
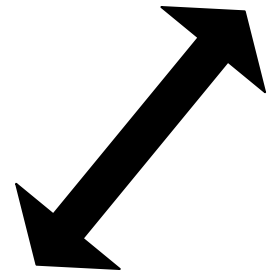
Understanding the Role of Material Stock Patterns for the Transformation to a Sustainable Society: the Stock-Flow-Service Nexus

→ <https://matstocks.boku.ac.at>



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Stocks Buildings, infrastructure, machinery



Flows
Energy, materials, Waste, emissions



Services
Contributions to social well-being

Sustainability Transformations require a re-configuration of **stock-flow-service nexuses** to achieve higher wellbeing for all, at much lower levels of resource use and emissions.

Research within the project across spatio-temporal scales, using a variety of (inter)disciplinary approaches and methods



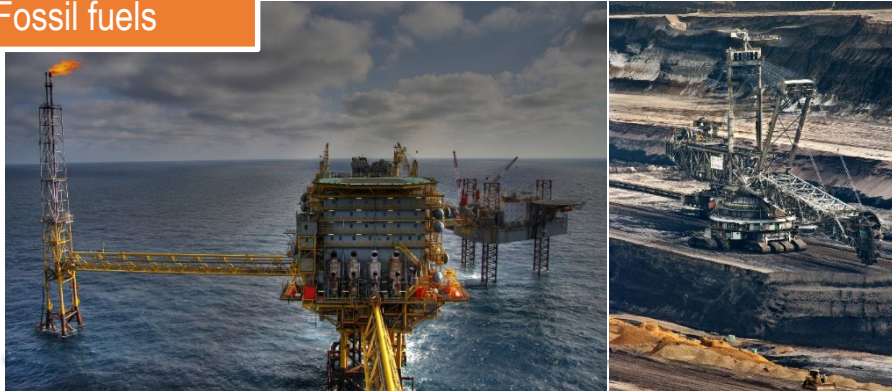
Haberl, Wiedenhofer, et al. 2019, *Nature Sustainability*. <https://doi.org/10.1038/s41893-019-0225-2>
Kalt, Wiedenhofer, et al. 2019, *Energy Research & Social Science*. <https://doi.org/10.1016/j.erss.2019.02.026>
Haberl, Wiedenhofer, et al 2017. *Sustainability*, <https://doi.org/10.3390/su9071049>

Observing and modelling the socio-economic metabolism of nations through economy-wide material and energy flow analysis



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Fossil fuels



Biomass



Metals:
ores & waste rock



Non-metallic minerals:
Construction & industrial



Krausmann et al. (2017) *Annual Review of Environment and Resources*. <https://doi.org/10.1146/annurev-environ-102016-060726>

Haberl, Wiedenhofer, et al. (2019) *Nature Sustainability*. <https://doi.org/10.1038/s41893-019-0225-2>

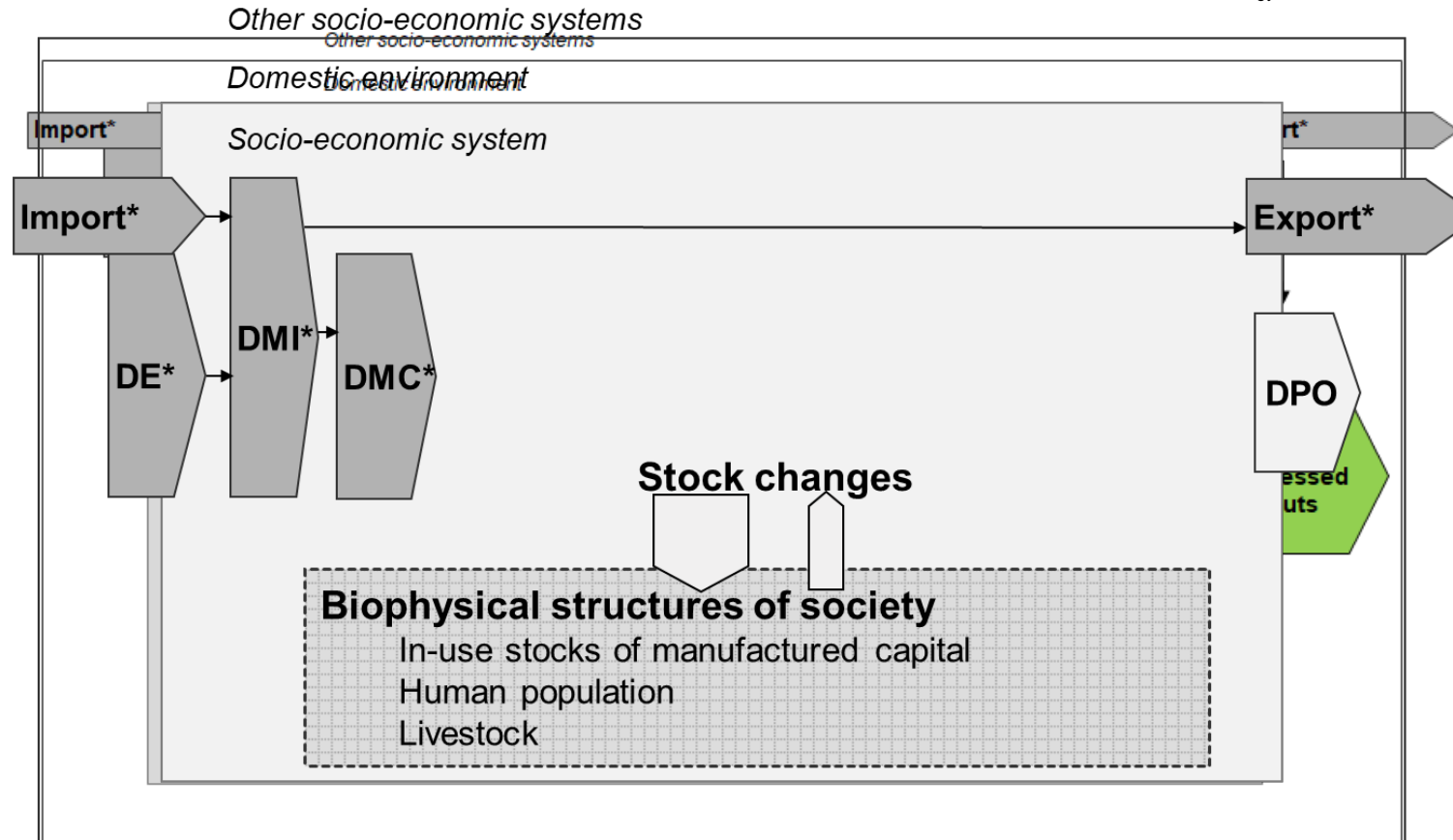
Wiedenhofer et al. (2019) *Ecological Economics*. <https://doi.org/10.1016/j.ecolecon.2018.09.010>

First steps towards integrating material stock dynamics and opening the black box in economy-wide material and energy flow analysis



Dynamic Material Inputs, Stocks and Outputs: MISO-1.0

- Fully consistent extension of economy-wide MFA
- Combines mass-balanced accounting with inflow-driven dynamic MFA modelling principles
- Implemented in Matlab
- Sensitivity testing of model parameters
- Monte-Carlo Simulations to propagate uncertainty
- Global Sensitivity Analysis: attribution of the sources of model output uncertainty to model input parameters



A number of global to world-regional investigations based on MISO 1.0 dynamic MFA modelling



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Global socioeconomic material stocks rise 23-fold over the 20th century and require half of annual resource use

Fridolin Krausmann^{a,1}, Dominik Wiedenhofer^a, Christian Lauk^a, Willi Haas^a, Hiroki Tanikawa^b, Tomer Fishman^{b,c}, Alessio Miatto^b, Heinz Schandl^d, and Helmut Haberl^a

Global Environmental Change 52 (2018) 131–140



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Resources, Conservation & Recycling 161 (2020) 104960

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Full length article

Stock-flow relations in the socio-economic metabolism of the United Kingdom 1800–2017

Jan Streeck*, Dominik Wiedenhofer, Fridolin Krausmann, Helmut Haberl

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Resources, Conservation & Recycling 163 (2020) 105076

Contents lists available at ScienceDirect

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journal homepage: www.elsevier.com/locate/resconrec



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Full length article

Spaceship earth's odyssey to a circular economy - a century long perspective

Willi Haas*, Fridolin Krausmann, Dominik Wiedenhofer, Christian Lauk, Andreas Mayer

Institute for Social Ecology, Department for Economic and Social Sciences, University of Natural Resources and Life Sciences (BOKU), Schottenfeldgasse 29, 1070 Vienna, Austria

From resource extraction to outflows of wastes and emissions: The socioeconomic metabolism of the global economy, 1900–2015

Fridolin Krausmann*, Christian Lauk, Willi Haas, Dominik Wiedenhofer

Global Environmental Change 61 (2020) 102034



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Growing stocks of buildings, infrastructures and machinery as key challenge for compliance with climate targets

Fridolin Krausmann*, Dominik Wiedenhofer, Helmut Haberl

Towards the country-level using ODYM-MISO-2.0



Aim: Develop comprehensive long-term estimates of the major (bulk) material cycles, differentiate end-uses and the dynamics of socio-economic material stocks of nations

Objectives:

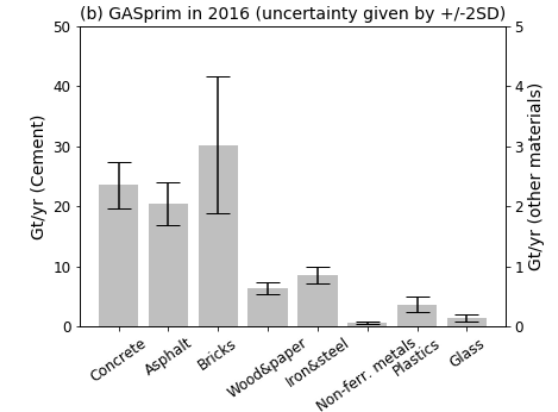
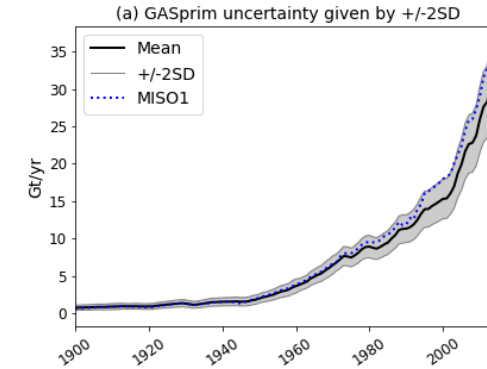
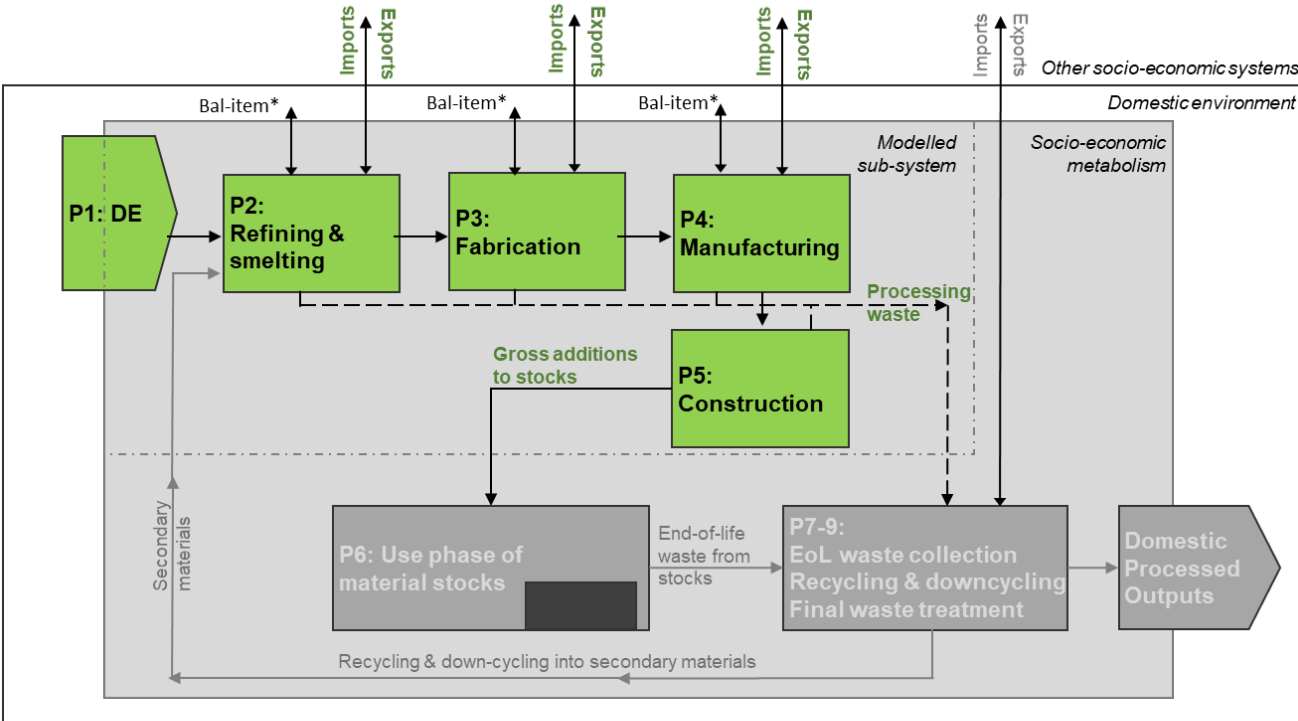
- **Step 1:** develop a robust, transparent and comprehensive database on primary material cycles for 14 materials, 177 countries and 200 years, incl. systematic uncertainty assessment (Plank et al., in prep)
- **Step 2:** develop robust, transparent and transferable methods to discern end-uses of final product stocks in inflow-driven dynamic MFA (Streeck et al., in prep)
- **Step 3:** Build on ODYM framework to develop „**ODYM-MISO-2.0**“
 - a) Including several specific sub-modules from **MISO-1.0** model
 - b) Specify technical systems definition for modelling & data work
 - c) Implement Monte-Carlo Simulations to propagate and quantify uncertainty (as in **MISO-1.0**)
 - d) Model stocks-flows for all 14 materials, an intermediate number of end-uses, across space & time



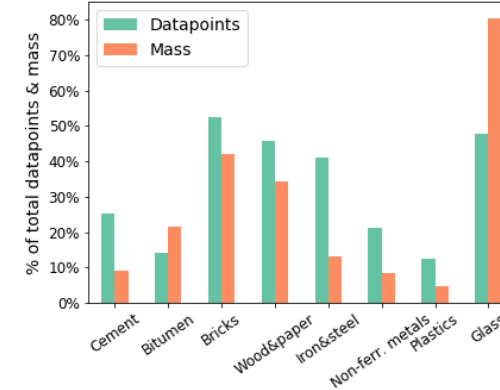
Step 1: robust and transparent primary materials database, incl. uncertainty assessment



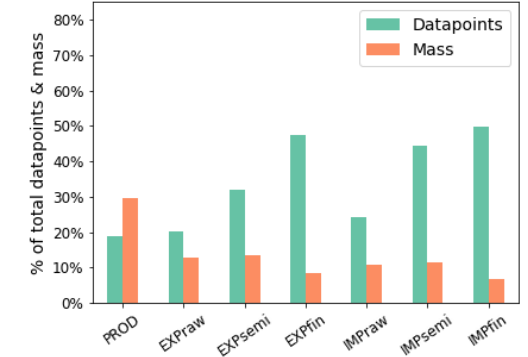
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(c) Estimate share of total datapoints & mass of GASprim 1900-2016



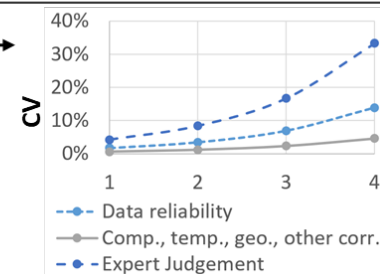
(d) Estimate share of total datapoints & mass of GASprim 1900-2016



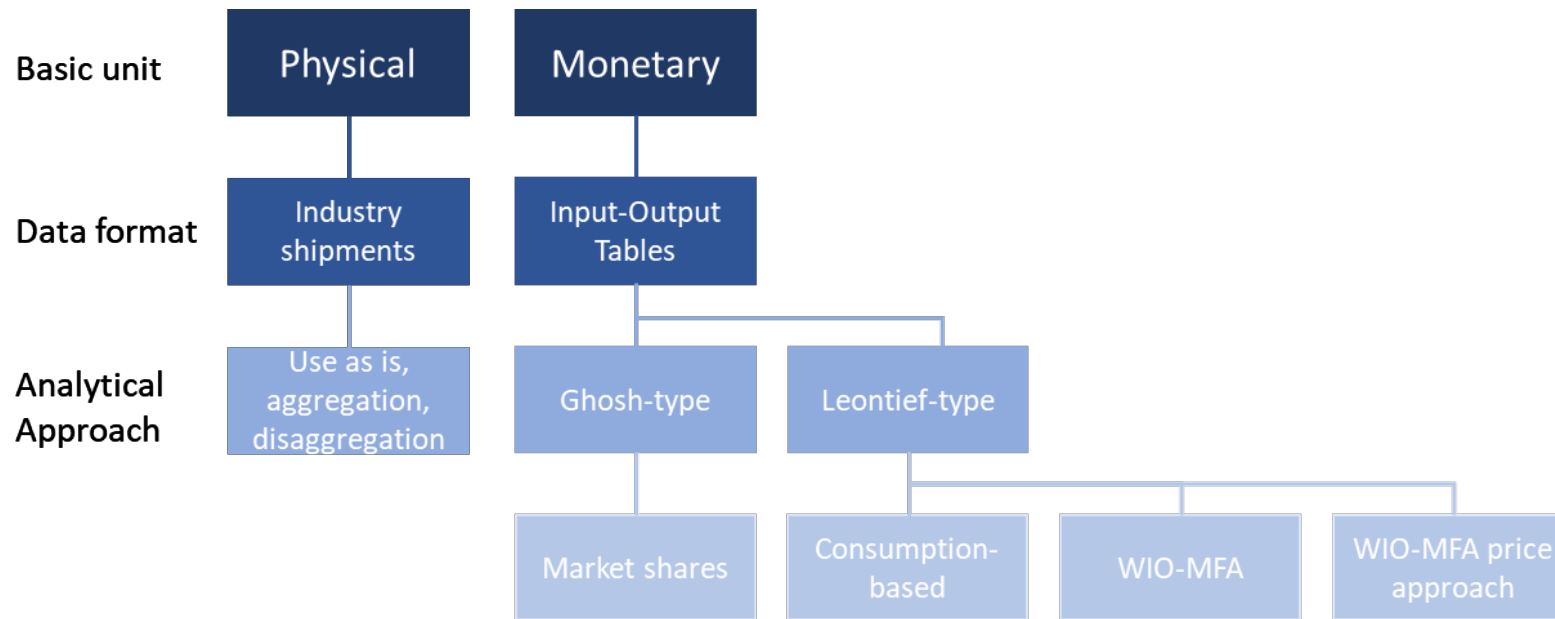
Scope:

- Economy-wide
- 14 materials
- 177 countries
- 1900-2016
- Systematic uncertainty assessment

Criteria	Scores based on databases			
Data reliability	1	2	3	4
Completeness	1	2	3	4
Temporal correlation	1	2	3	4
Geographical correlation	1	2	3	4
Other correlation	1	2	3	4
Expert judgement	1	2	3	4



Step 2: towards robust and transferable methods to derive product end-uses in inflow-driven dynamic MFA



- Currently running method comparison for USA as data-rich case
- Transfer to EXIOBASE for global coverage → rather coarse end-use sectors
- Potentially combination of different data/methods to derive more detailed product split

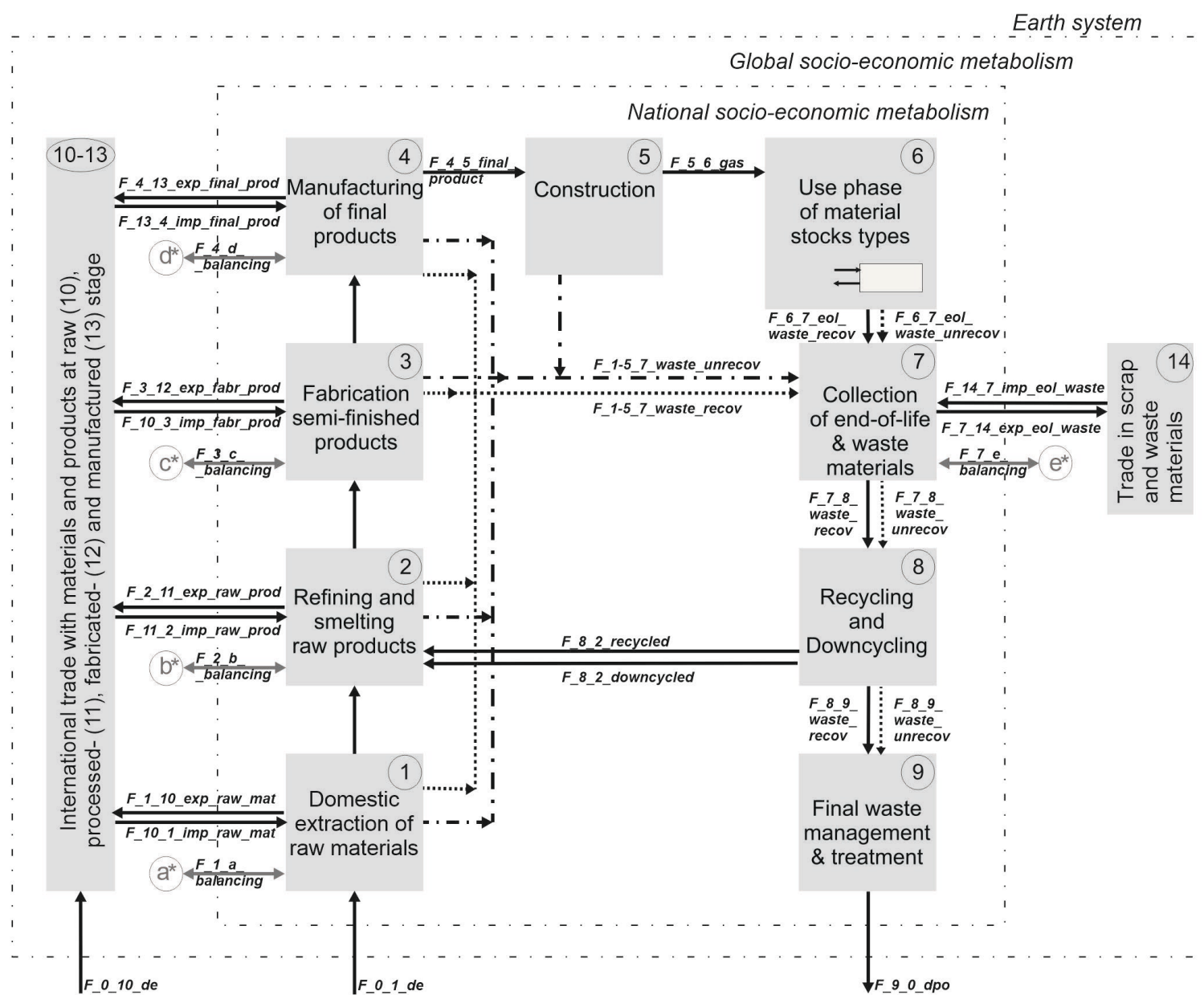


Step 3a:

from conceptual ew-MFA definitions

towards more technical and specific systems definition

for ODYM-MISO-2.0



Step 3b: Adapting & implementing ODYM-MISO-2



Use of ODYM Modeling Framework (Pauliuk & Heeren 2020)

- Object definition, data loading and formatting according to modeling backbone:
ODYM_Classes & ODYM_Functions
- Inflow-driven modeling via ODYM_dynamic_stock_model

ODYM-MISO-2 framework needs include several sub-modules developed previously (Wiedenhofer et al. 2019; Laner et al. 2014))

- Dynamic modelling of foundation- and sub-base requirements
- Physical demand-supply module for virgin aggregates versus recycled & downcycled materials
- Input of semi-quantitative uncertainty assessment of datapoints and translation to coefficients of variation
- Monte-Carlo Simulations to propagate and quantify uncertainty



Ongoing work ...



- Implementing Monte-Carlo Simulations (MCS) into **ODYM-MISO-2.0**
 - Many thanks to the original developers and contributors of ODYM
 - Many thanks to Christoph Helbig for sharing some ODYM-MCS code and his reflections on using it
 - Inclusion of various probability distributions for lifetimes and MCS
 - optimize for reasonable computing time for 14 materials, 177 countries, 200 years and $>10^3$ MCS
- Developing an energy & GHG emissions module to address materials-energy-emissions nexus
- Developing “our” specific sub-modules far enough, to provide as sub-modules for general ODYM use
- Publish intermediate steps, results and developed methods in peer-reviewed journals, as feasible in #OpenAccess & #OpenData





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Thanks for your attention!

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[Matstocks.boku.ac.at](https://www.matstocks.boku.ac.at)

<https://www.researchgate.net/project/MAT-STOCKS-Understanding-the-Role-of-Material-Stock-Patterns-for-the-Transformation-to-a-Sustainable-Society>

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