# Why regional detail is key for consequential LCA and how to improve it –
the case of biogas and rail transport

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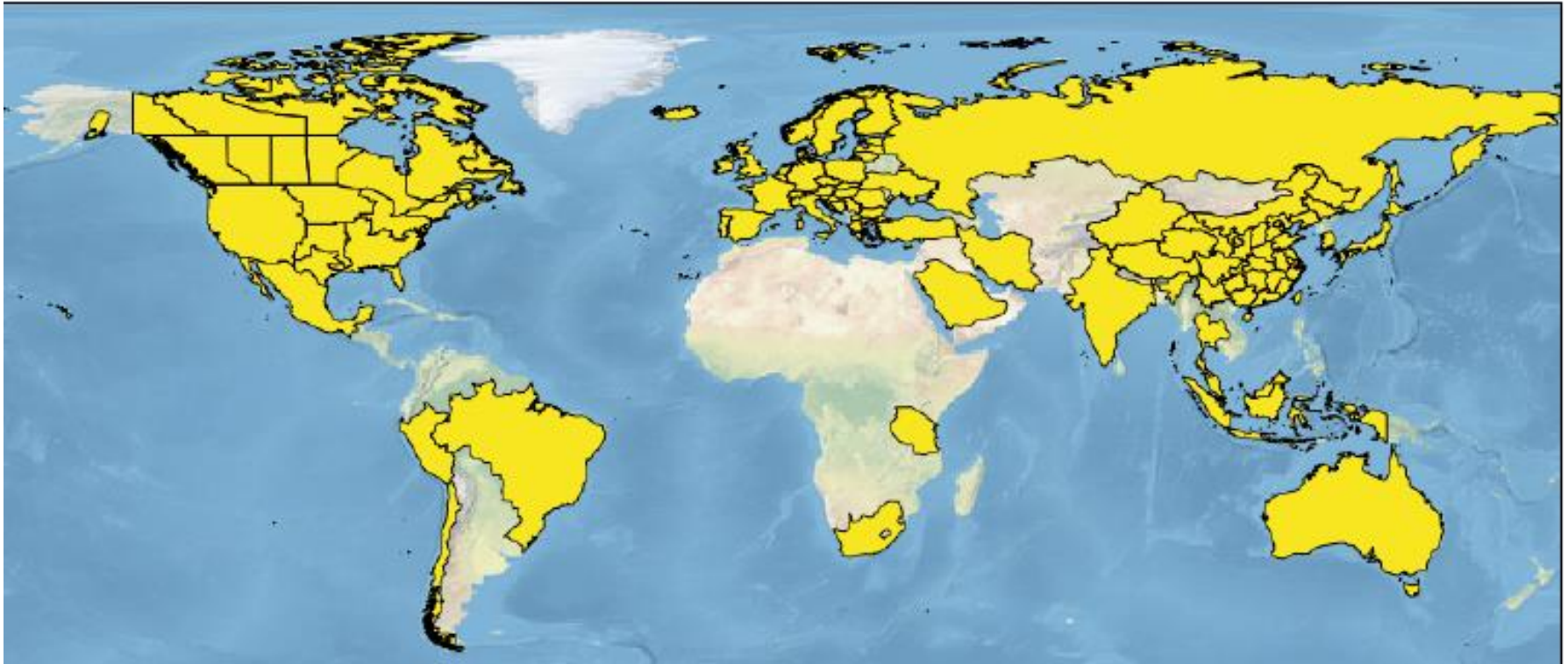
Regional aspects

- Consequential assessment requires representation of markets
  - Regional markets differ largely
  - Global marginal technology not representative
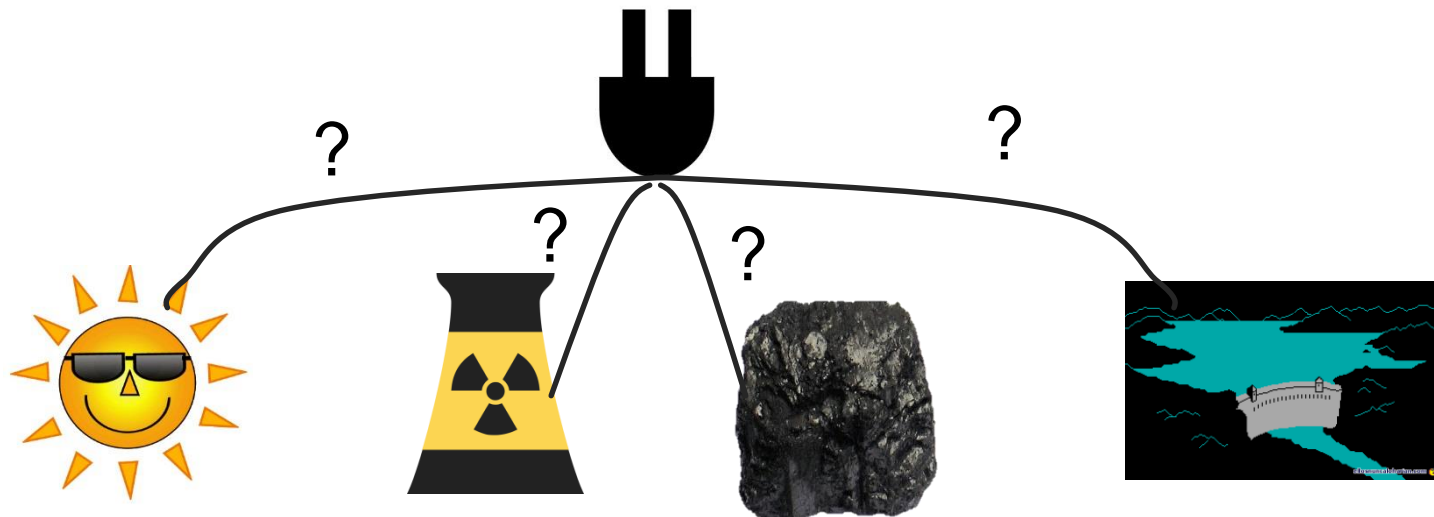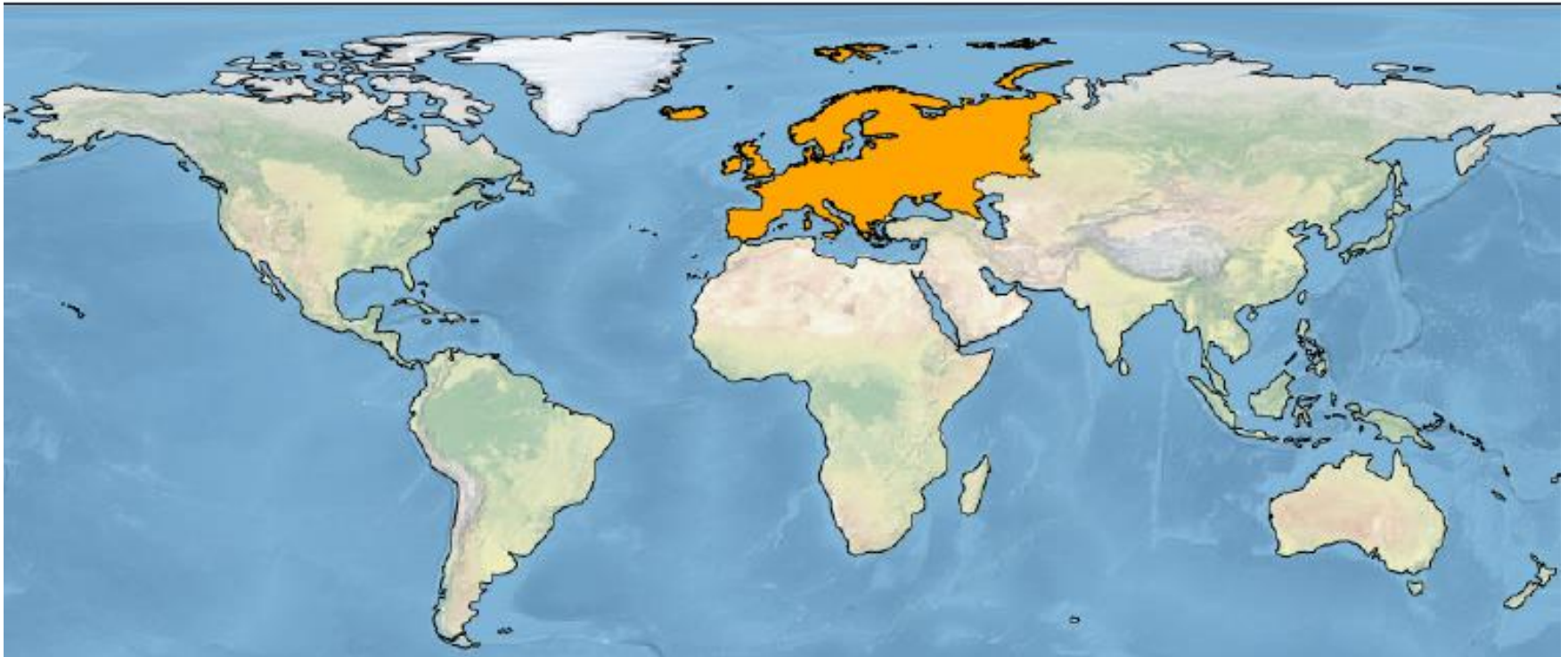
Current Situation ecoinvent

electricity sector

Current Situation ecoinvent: European datasets
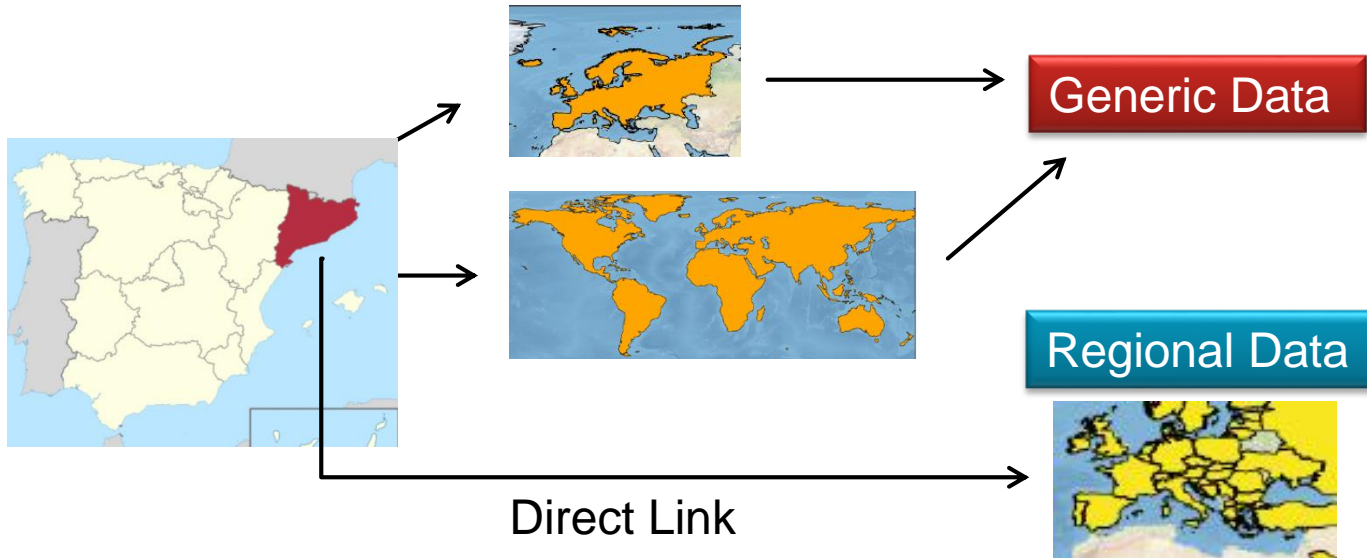
30% of transforming activities

Current Situation ecoinvent: Global datasets

20% of transforming activities, 90% of market activities
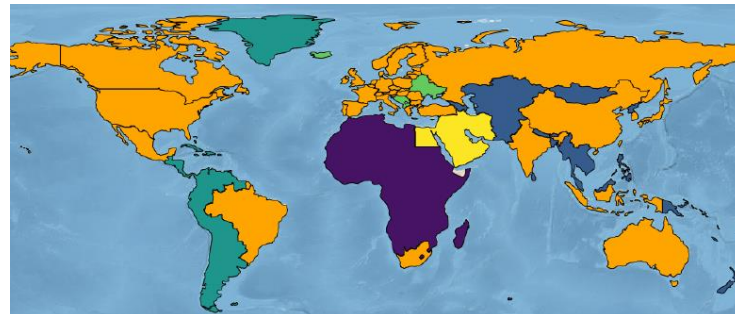
Current Situation ecoinvent: Global datasets

- Markets are mainly global
  - Supply chain is modeled as global
  - Real consequential results not accessible

Generic Data

Regional Data

Direct Link

Approach: Combine MRIO and LCI

Ecoinvent and Exiobase

- Ecoinvent 3.3 life cycle inventory database
- Exiobase 2.2 global multi-regional input-output database

Combining the database

- Combine information:
  1. Create dataset for every Exiobase region (copy of best match)
  2. Replace aggregated markets (RoW, GLO) with Exiobase "market"
  3. Create integrated hybrid matrix

- Rest of the world and global datasets get eliminated
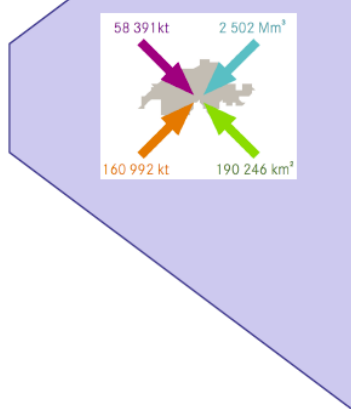 - At least regional resolution for all markets and processes (exiobase regions)

Combining the database

Ecoinvent technosphere matrix
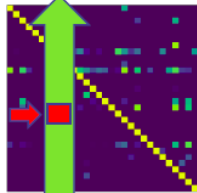
12k x 12k activities

Regionalized technosphere matrix
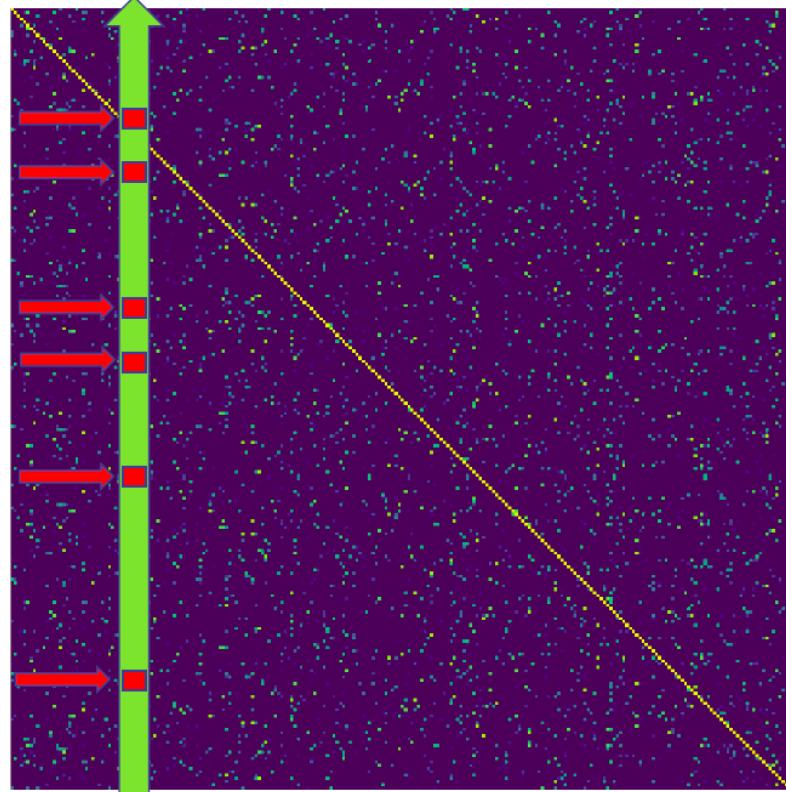
307k x 307k activities

Biogas Example

- ## Ecoinvent v3.3
  - ### Swiss Biogas: Methane 96%, CH
    - Biogas from global market
    - Biogas global:
      - >99% RoW (rest of the world) Biogas
      - <1 % Swiss Biogas

➡️ **Results ~ identical to RoW dataset**

- ## Hybrid model (with exiobase v2.2)
  - ### Swiss Biogas
    - 7 % RoW (rest of the world) Biogas
    - 93 % Swiss Biogas
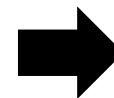
➡️ **93% specific Swiss conditions included**

Transport Example

- Ecoinvent v 3.3 Train (freight):
  - Global: 40% RoW, 31% US, 22% CN, 7% Europe
    - **RoW: 100% Electric**
    - **US: 100% Diesel**
    - China: 70% Diesel, 29% Electric, 1% Steam
    - Europe: ~50% Diesel % 50% Electric
  - Overall **Global: ~50% Diesel % 50% Electric**
- Choice of RoW or GLO
  - 100% Electric vs. 50% Electric/50% Diesel

When Supply chain of US, Europe and China get a RoW or global market input (90% of markets 20% of activities), local information is lost

Conclusions

- Economic data from global multi-regional input-output (GMRIO) increases regional resolution of LCI
  - Utilize available regional detail by disaggregating global markets
  - Apply region-specific marginal technologies throughout supply chain

- Geographically explicit inventory facilitate regionalized impact assessment of marginal technologies

- GMRIO data developed for consequential modeling should be applied in future, to increase the representativeness

- Computational problems are not limiting

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Stephan Pfister | 07.05.2018 | 12

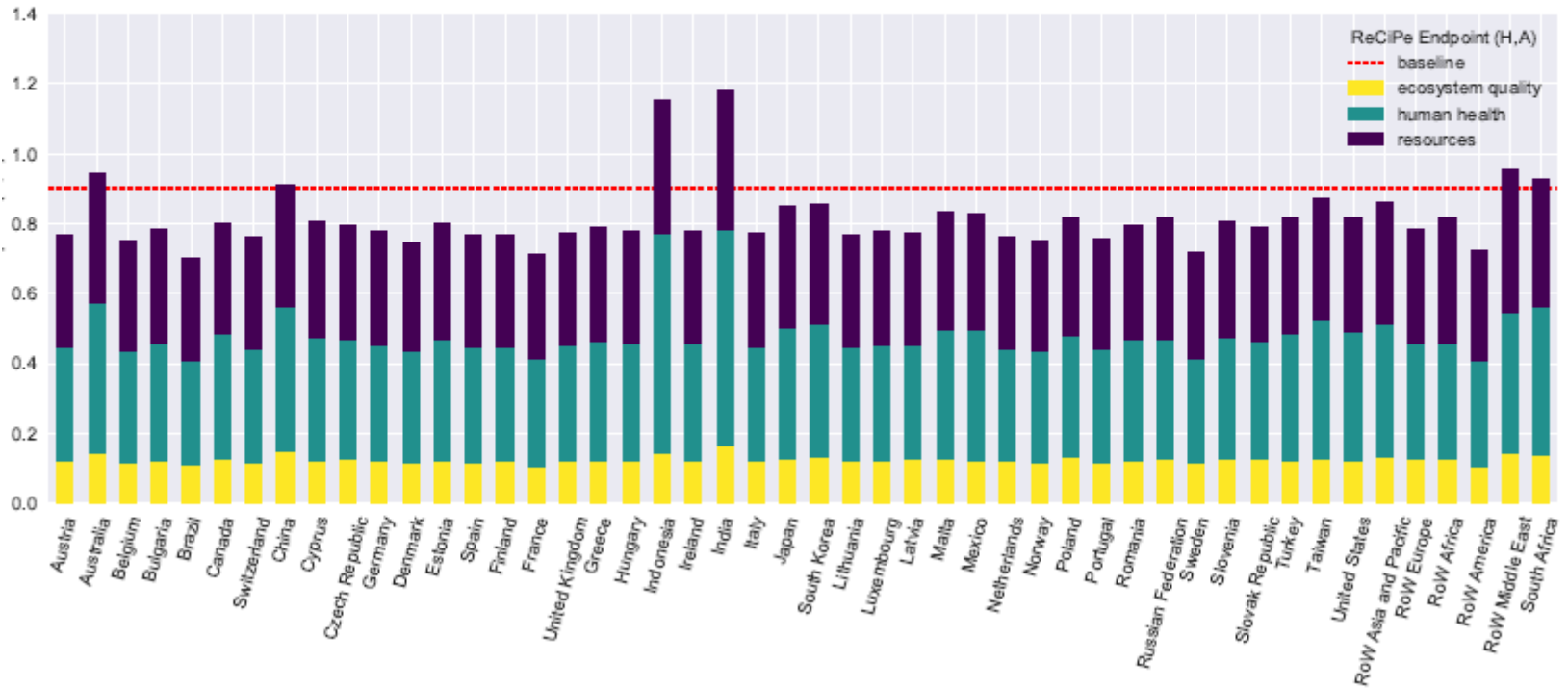# Thank you for your attention!

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Backup Slides

Result car production

Passenger car production, petrol/natural gas
ReCiPe Endpoint (H, A)

Regionalized inventory

- Passenger car production in **Germany**
- Geographically explicit impacts along the supply chain
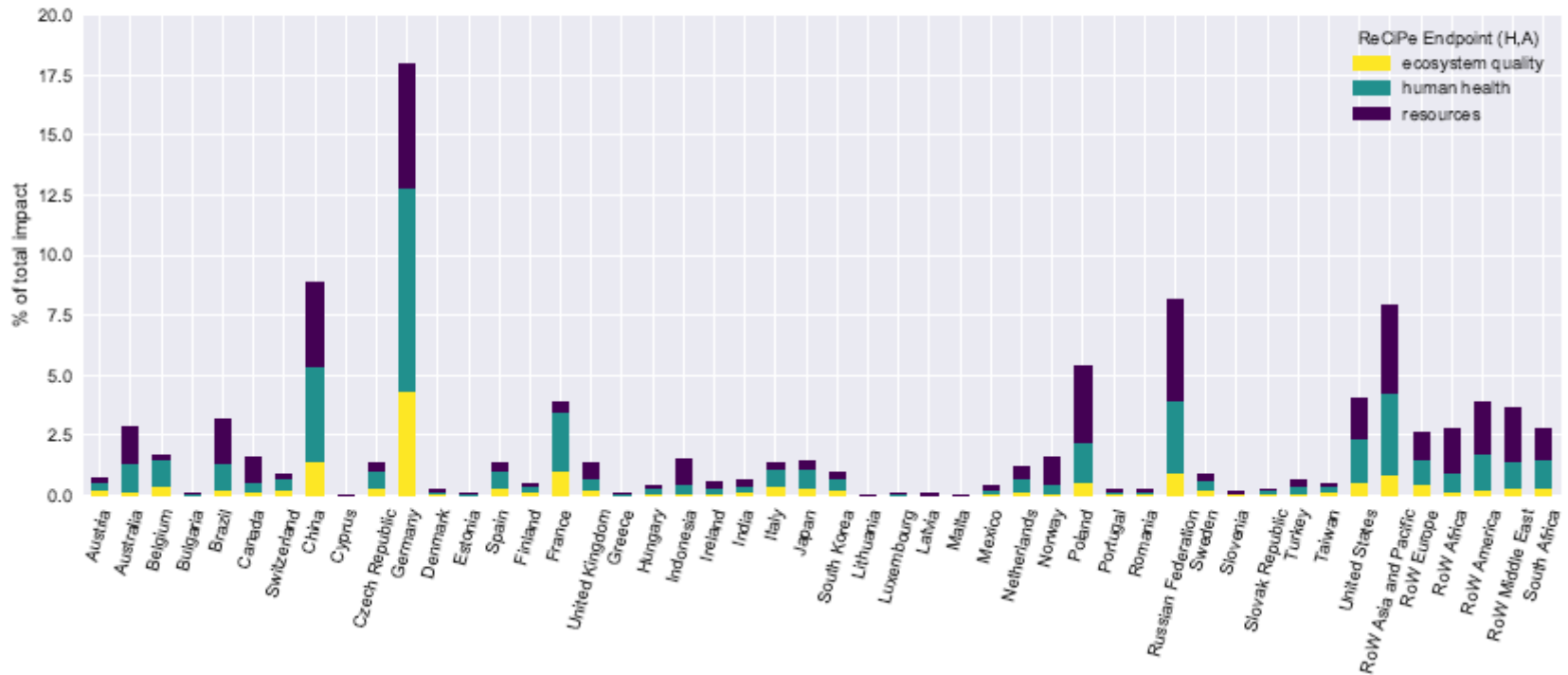
UNEP-SETAC recommended LCIA methods

- characterization factors on country level

High

Low

Water consumption
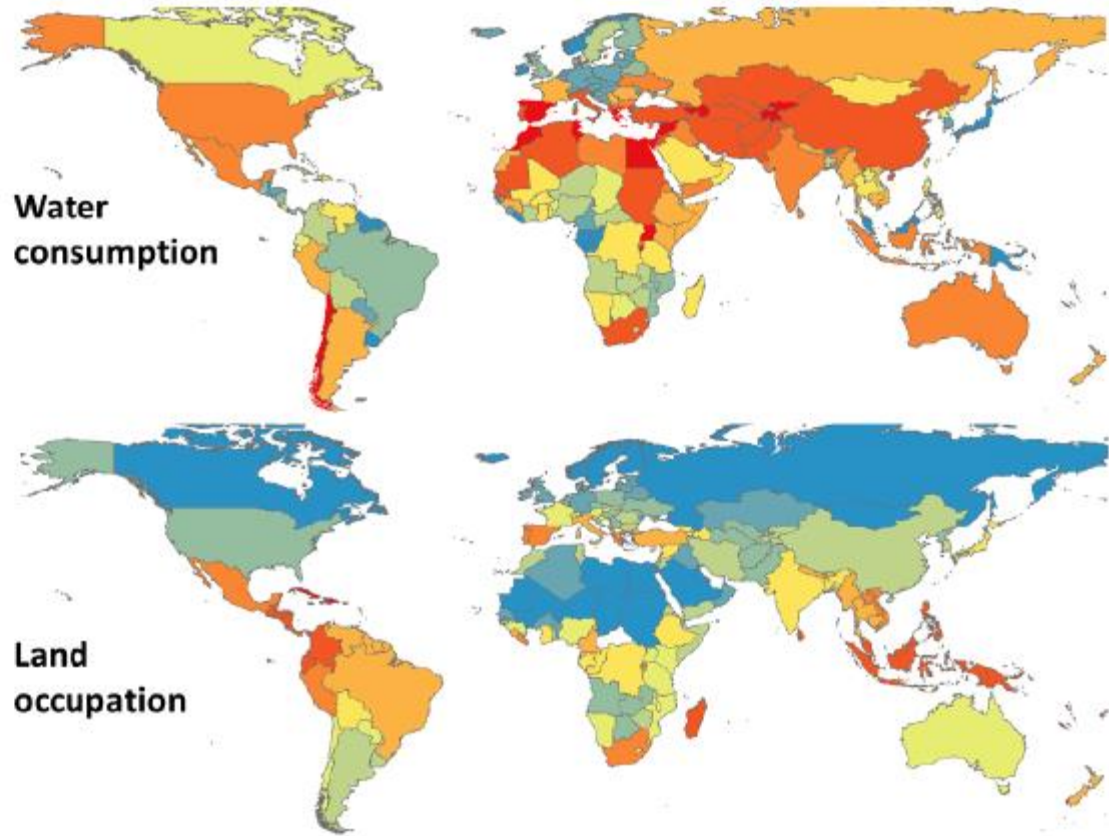
Land occupation

Reference:
Frischknecht R, Jolliet O (eds) (2017) **Global Guidance for Life Cycle Impact Assessment Indicators - Volume 1.**

Water consumption

- market for textile, woven cotton

Land occupation

- market for textile, woven cotton

Situation

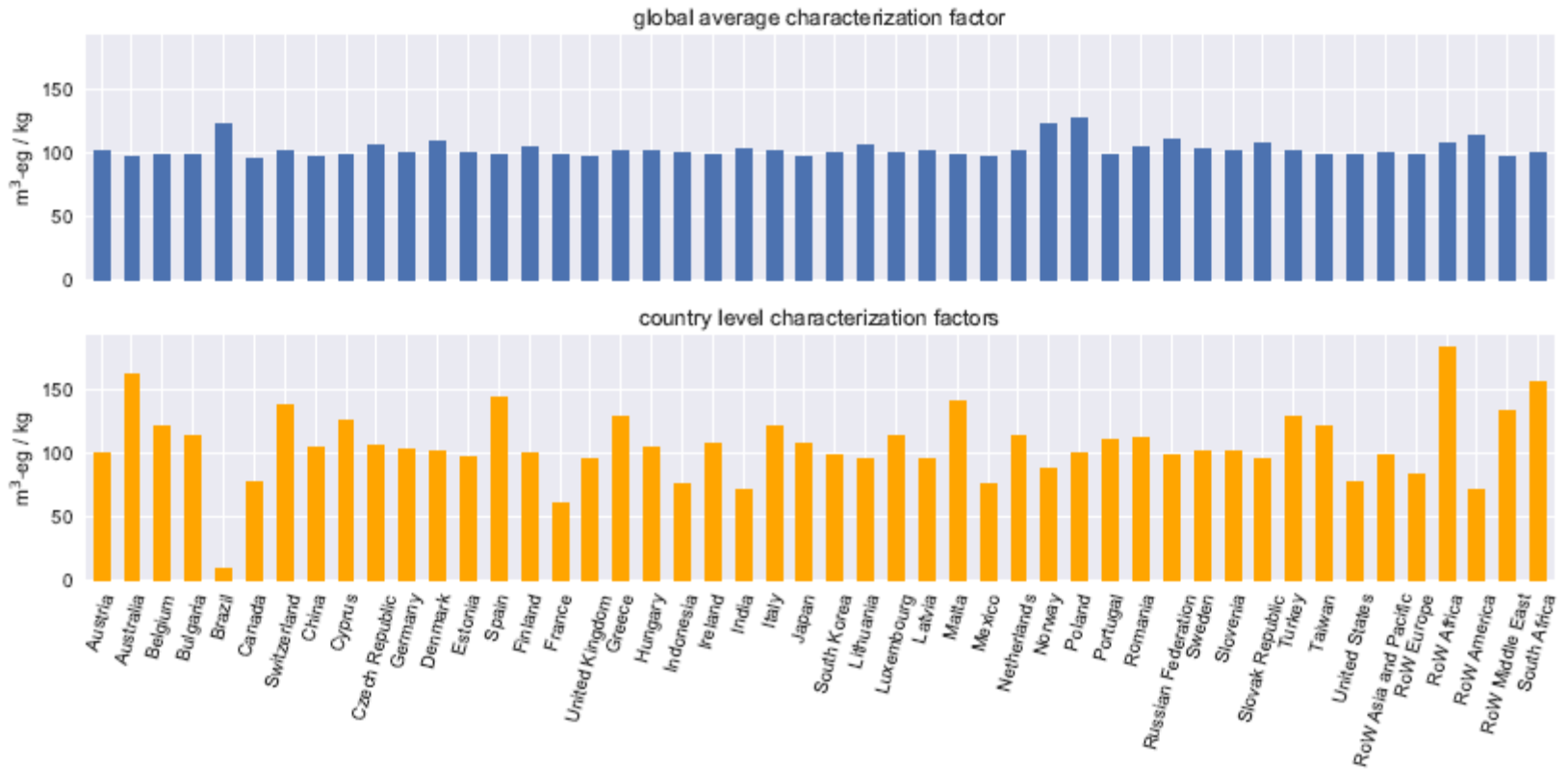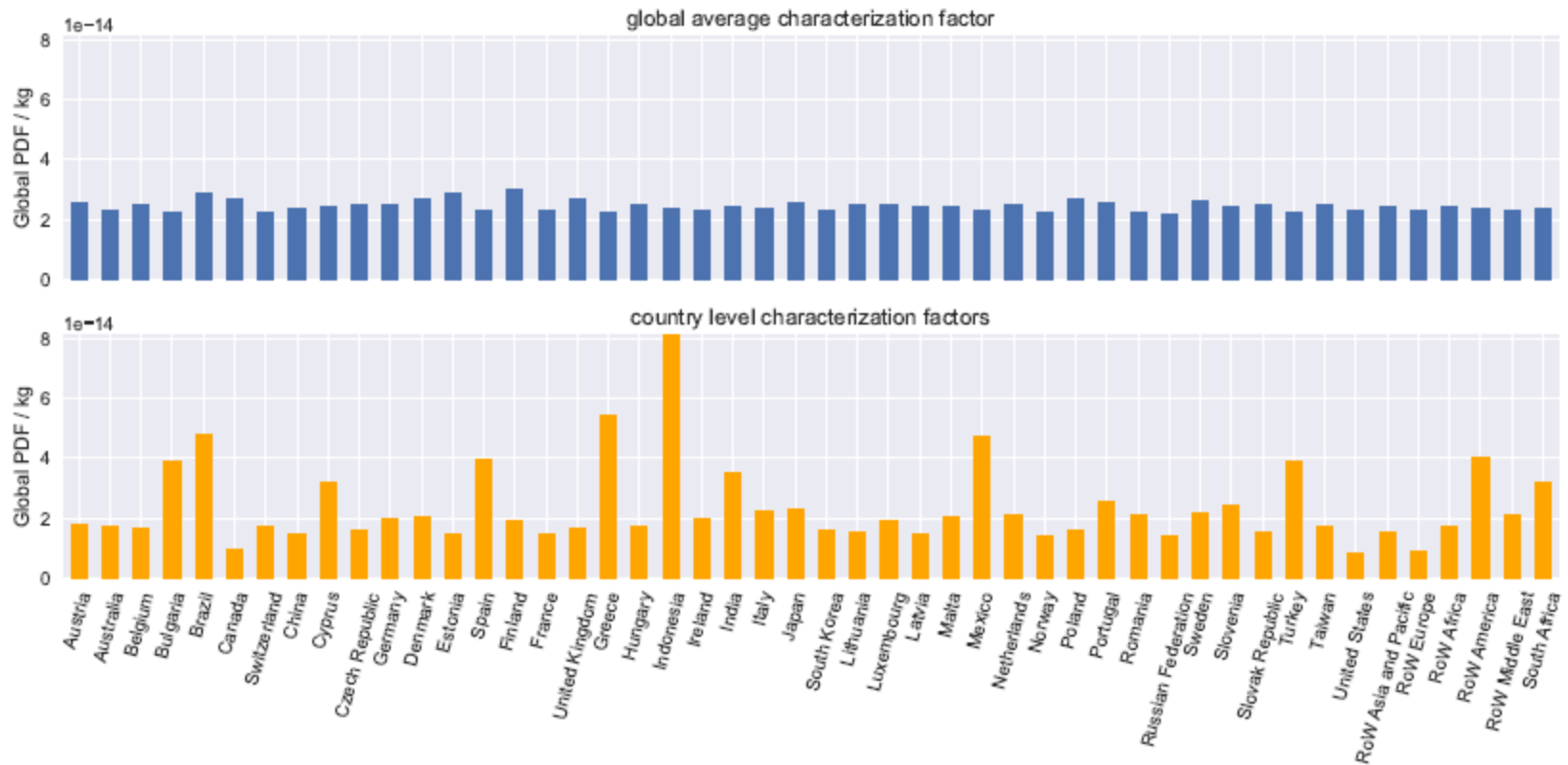- Consequential LCA depends on identification of marginal technology use as a function of a demand. In the past, spatial detail has been widely neglected in LCI development, but it is essential for consequential LCA, since marginal technology is highly depending on the region: e.g. Additional electricity in Germany might be nuclear, while in China coal and hydropower. Even if some products are highly globalized, important processes such as energy and transport systems are not.

- Modern Life Cycle Inventory (LCI) databases like the ecoinvent database [1] have a global coverage, but generally a low regional resolution, except for electricity markets. However, in ecoinvent, Industrial activities are connected by "market activities", which are based on the production volumes of the producing activities. Apart from the electricity sector, where extensive regionalization efforts have been undertaken, market activities in ecoinvent are predominantly modelled as global markets. This also results in the fact that electricity inputs to most processes in from a global and not country specific market.

- On contrary global multi-regional input-output (GMRIO) databases like Exiobase [2] can be used to improve market activities, since they are based on trade analysis, even if they are not representing marginal changes in demand

Method

- In this study the industry-by-industry input-output-table of the Exiobase database [2] is used to increase the regional resolution of the ecoinvent LCI database. New LCI unit process datasets are created for all regions in Exiobase, based on corresponding dataset in the ecoinvent database. The unit process datasets are matched to their encompassing industry sector using the International Standard Industry Classification (ISIC) [3]. The economic relation between the industry sectors from Exiobase is then employed to re-link the newly created unit process datasets.

- The described procedure yields a new LCI database with high regional resolution, where economic relations from Exiobase are merged into the structure of the Ecoinvent 3.2 LCI database [1]. This approach can be considered a Hybrid approach, where GMRIO data is used to estimate international markets and therefore origins in the supply-chain, without changing the detailed, process specific exchanges from ecoinvent. It means that all processes in ecoinvent are allocated to respective regions in Exiobase and in case without direct match, the processes from aggregated regions are copied for all Exiobase regions within these regions (e.g. RoW and RER) as depicted in Figure 1. Because every process in the resulting "technosphere" matrix therein has a clearly defined location, the supply chain includes origins of input processes as reflected by multiregional exchanges in Exiobase. Consequently regionalized marginal technologies can be utilized – if available directly from ecoinvent or alternatively manually.

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Hybrid System

- The combination of the two databases extends the dimension from ~12'000 x 12'000 to ~307'000 x 307'000 (Figure 1). This is a huge increase and leads to difficulties solving the system to get the results. Calculating an inverse is not realistically feasible and other techniques have been applied. With our custom-built solver the initial run lasts about 15 minutes and the all following take approximately 30 seconds on a powerful modern PC.)

Hybrid System *Figure 1: The scheme illustrates how the ecoinvent technosphere matrix (left side) is expanded to a merged Exiobase-ecoinvent database, where all Exiobase regions have region-specific processes (right side). The same ecoinvent RoW process (indicated as red cell), is copied and re-linked for 6 regions in this illustration.*
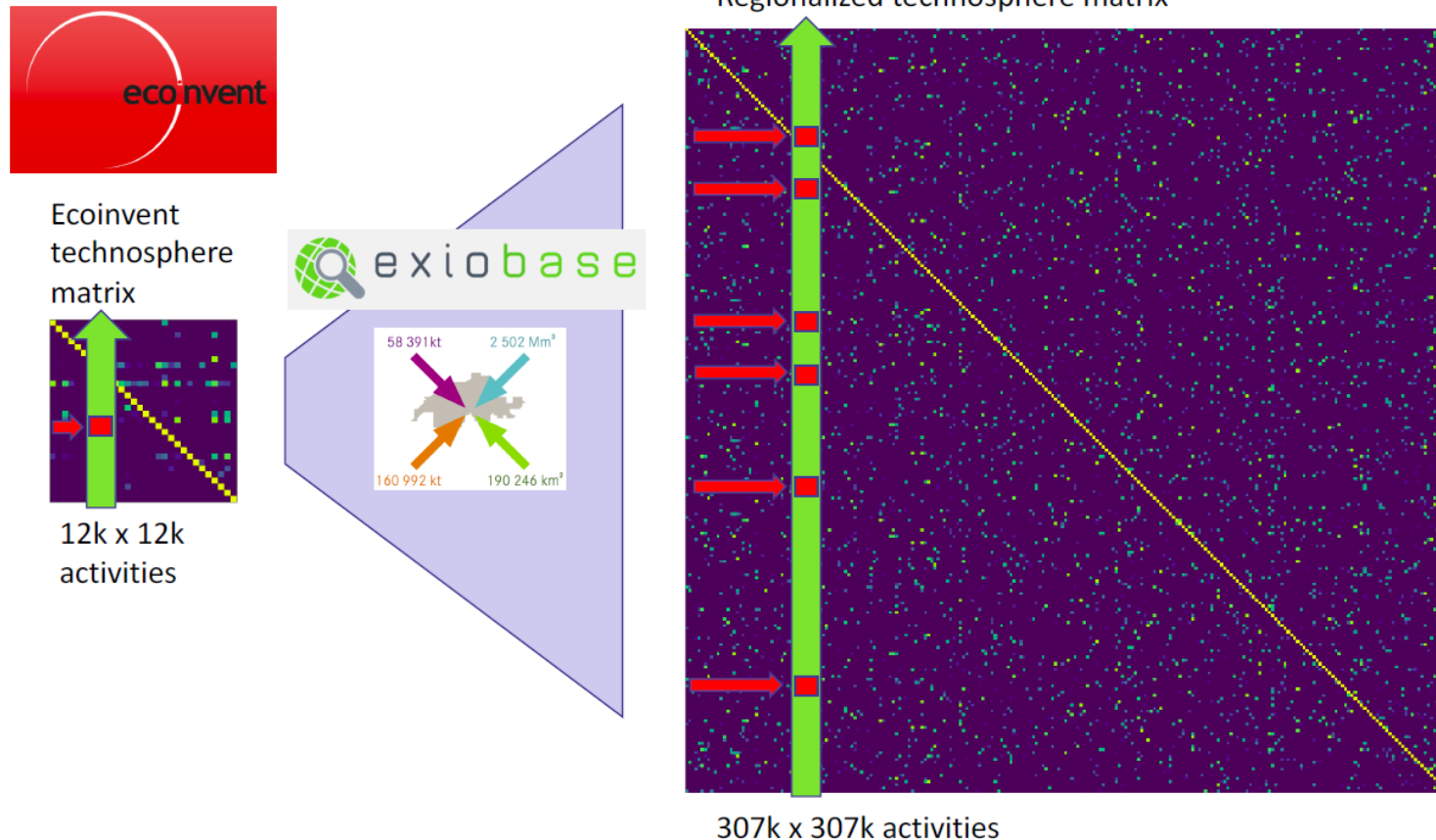
Comparison default consequential and hybrid consequential ecoinvent

- There are two main effects of the coupled model:

- A) By default, RoW or GLO datasets are used if no region-specific datasets are available. The new model replaces the input processes and full supply chain based on the specific region of interest. A prominent example is transport, e.g. by train, where only few country-specific processes exist in ecoinvent. The electricity input in the consequential model of the RoW dataset is a mix of all global electricity produced, which is not meaningful, since electricity from grid is not exported beyond connected electricity grids. In the new model, the process "inherits" the location distribution based on Exiobase data and represents inputs form countries connected to the same grid. In the case of RoW train, e.g. a Japanese train has global electricity mix in ecoinvent, which in reality might be consequential Japanese electricity mix. This is represented in the suggested consequential hybrid model.

- B) While the first case could be treated manually, all existing processes will be improved deeper in the supply chain, whenever the ecoinvent process relates back to a RoW or GLO process. An example for this is Swiss biogas use ("Methane, 96% by Volume"), where the market mix relates to global production and only a small share of biogas comes from Switzerland, which is in contrast to reality. The hybrid model improves such issues throughout the database.

Conclusions

- Economic data from global multi-regional input-output (GMRIO) databases like Exiobase can be used to increase the regional resolution on the inventory level, which then in turn allows to apply the region-specific marginal technologies throughout the supply chain. In order to improve the quality for consequential assessments, GMRIO data developed for consequential modeling should be applied in future, as it will increase the representativeness of the approach.

Outlook

- Improve MRIO input data (especially RoW regions)
  - GTAP 9 most consistent high resolution
  - EORA highest resolution – very low in some countries

- Improve spatial detail of LCIA methods

- Test sensitivities (automatic procedure)
  - Risk scale
  - Selection of risks
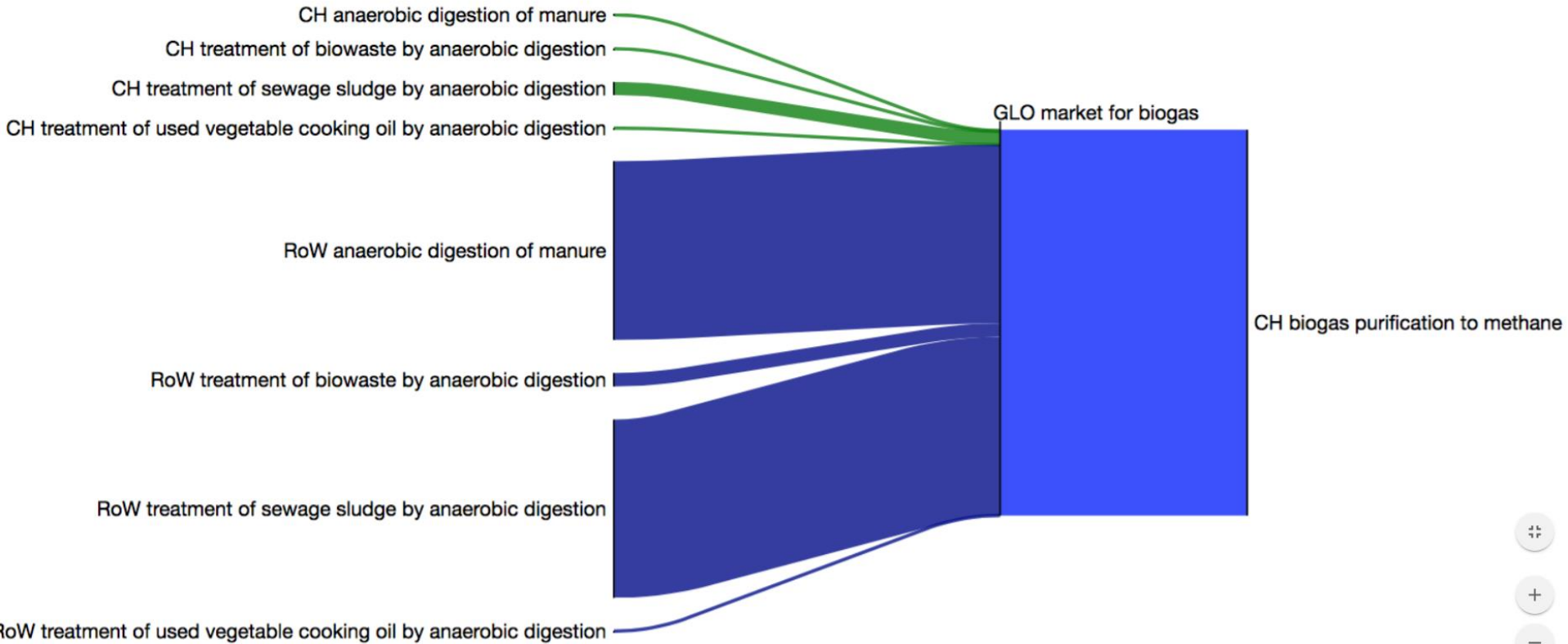 - Selection of environmental impacts
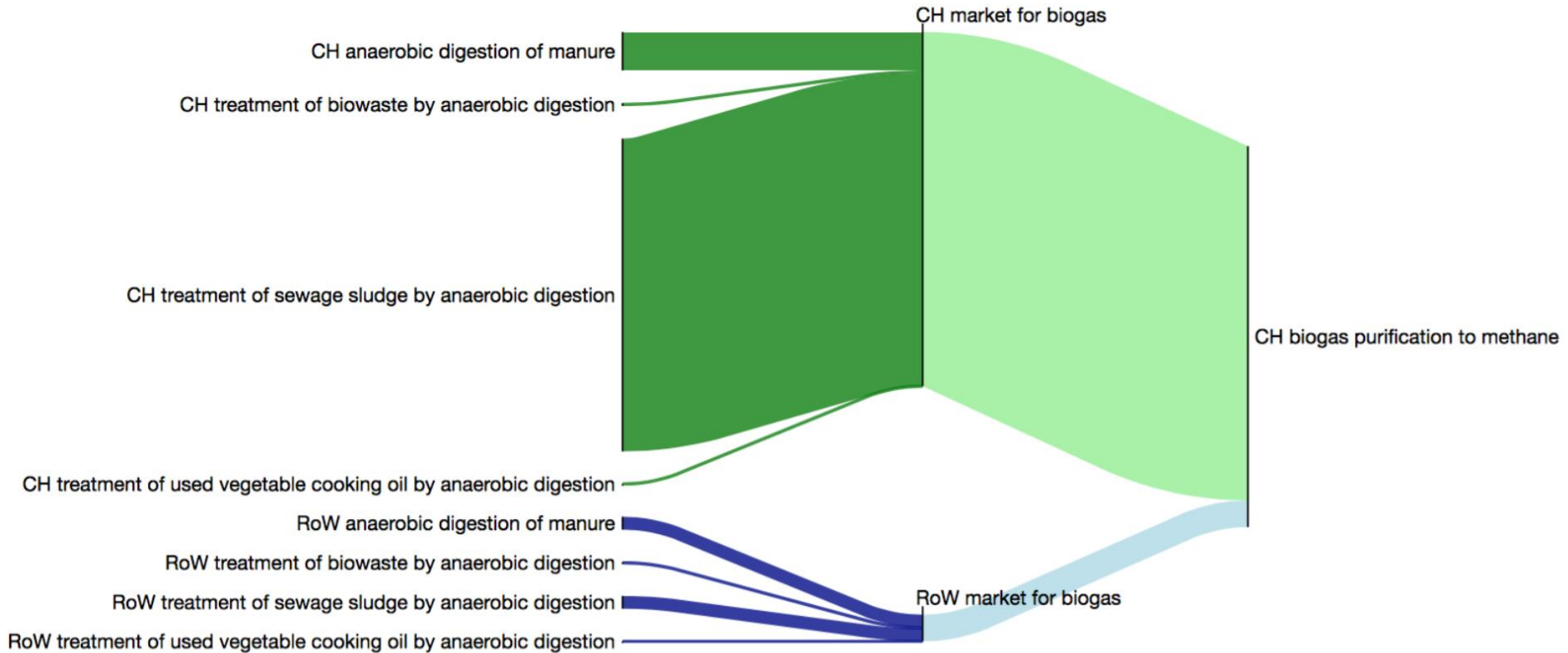
Exiobase Resolution

43 countries (>95% World GDP)
5 Rest of World regions (RoW)
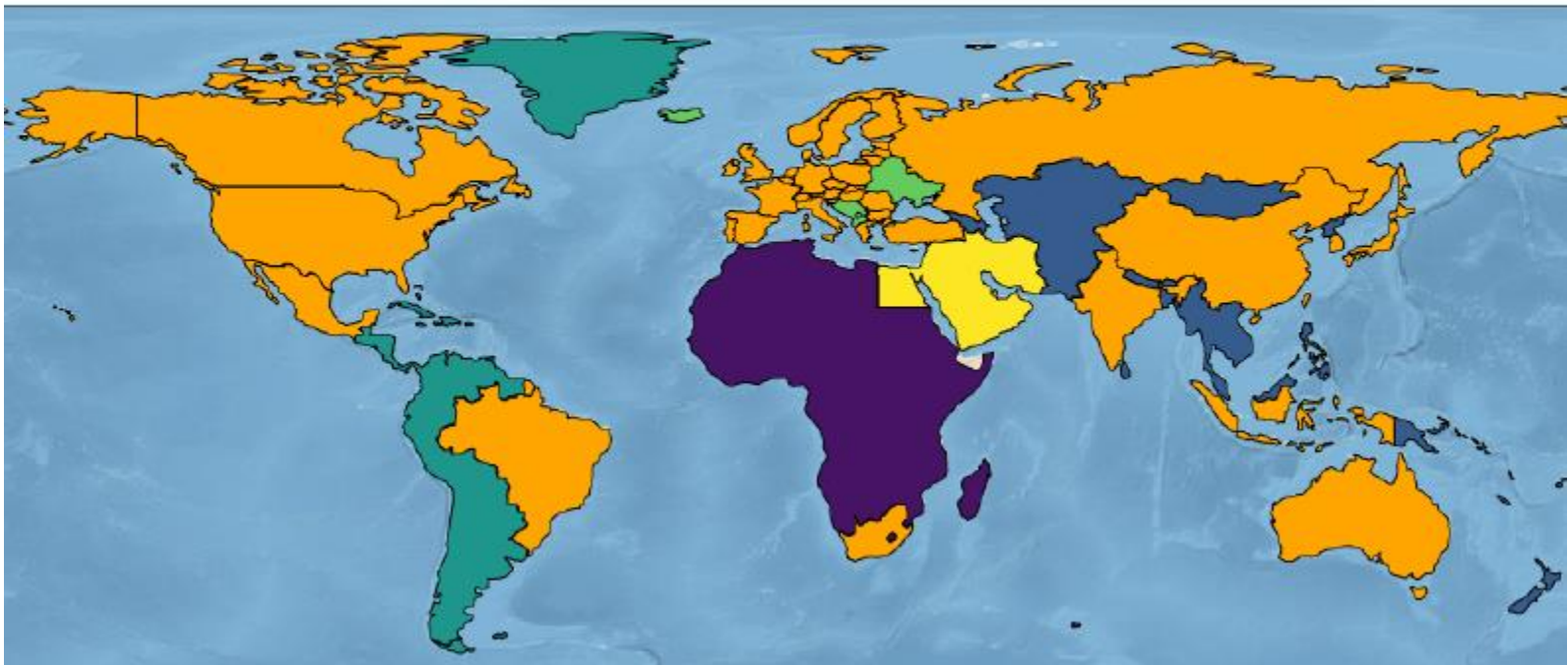
Biogas ecoinvent

Biogas Hybrid

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