



Projections of environmental impacts of biofuels across scenarios using prospective LCA

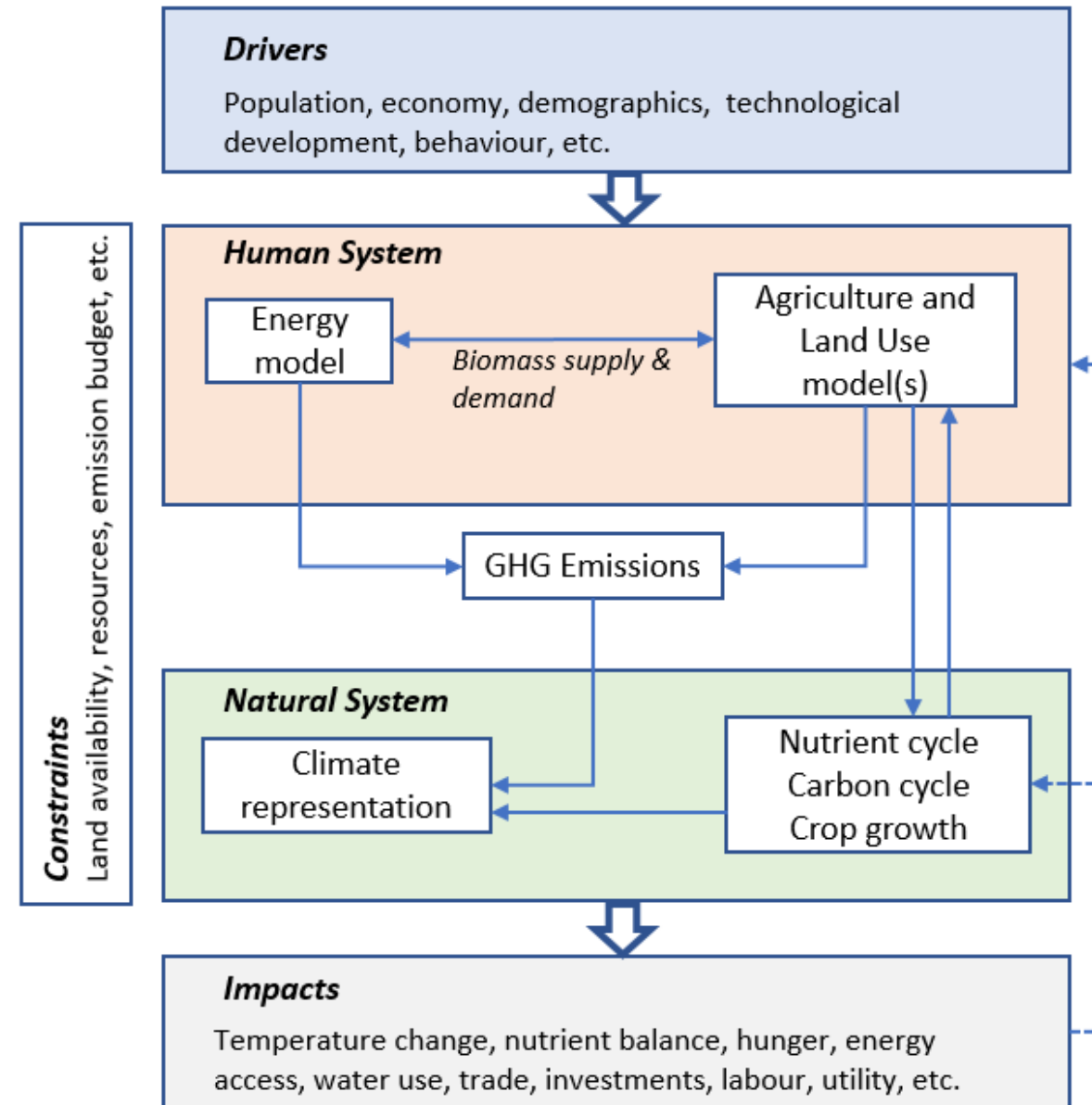
OR2022

Vassilis Daioglou, Romain Sacchi, Patrick Lamers, *et al.*

8th September 2022

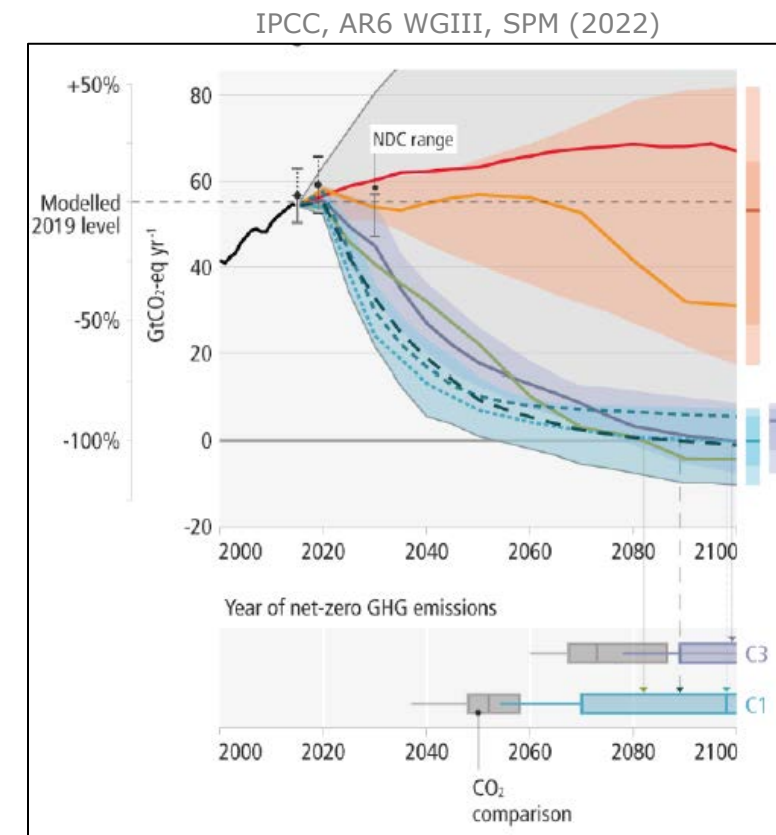
Context

- › Integrated Assessment Models (IAMs) assess the interactions between **human** and **natural** systems
- › Contain stylized representations of
 - Energy system
 - Agricultural economy
 - Climate
 - Land system
- › Bridge the Science/Policy interface
 - Scenario Analysis: *What if?*
 - What are the drivers or constraints of change?
 - How do technology and policy choices lead to different outcomes?
 - Uncertainties? Sensitivities?



Context

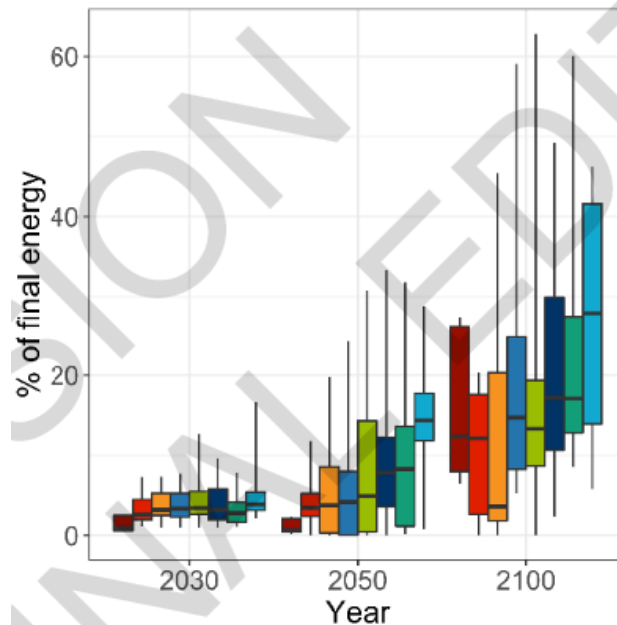
- Their focus area has been studying climate change mitigation strategies
 - Working Group III of the Intergovernmental Panel on Climate Change (IPCC)
 - Amongst others, they have highlighted the importance of biofuels



Context

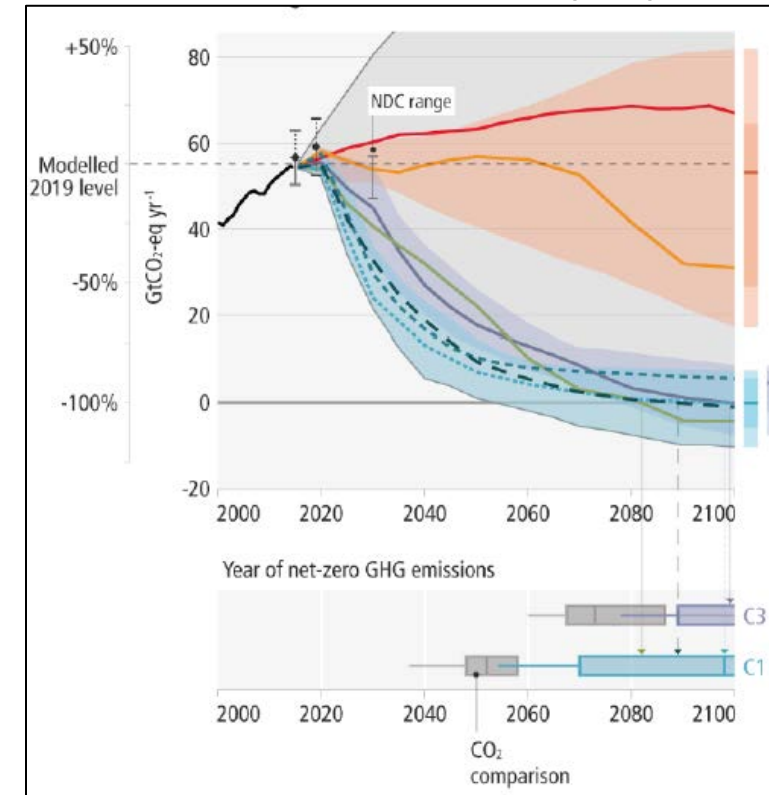
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Share of biofuels in *Transport* final energy
Colours represent increasing climate targets



IPCC, AR6 WGIII,
Fig. 3.25(2022)

IPCC, AR6 WGIII, SPM (2022)



Context

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- › Increasingly, *Sustainable Development Goals* are becoming an important guiding principle
 - But the SDGs cover a huge landscape, which IAMs do not yet cover



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- › Increasingly, *Sustainable Development Goals* are becoming an important guiding principle
 - But the SDGs cover a huge landscape, which IAMs do not yet cover
- › In order to better understand the broader implications of decarbonization strategies, need to look beyond (climate change) mitigation potential

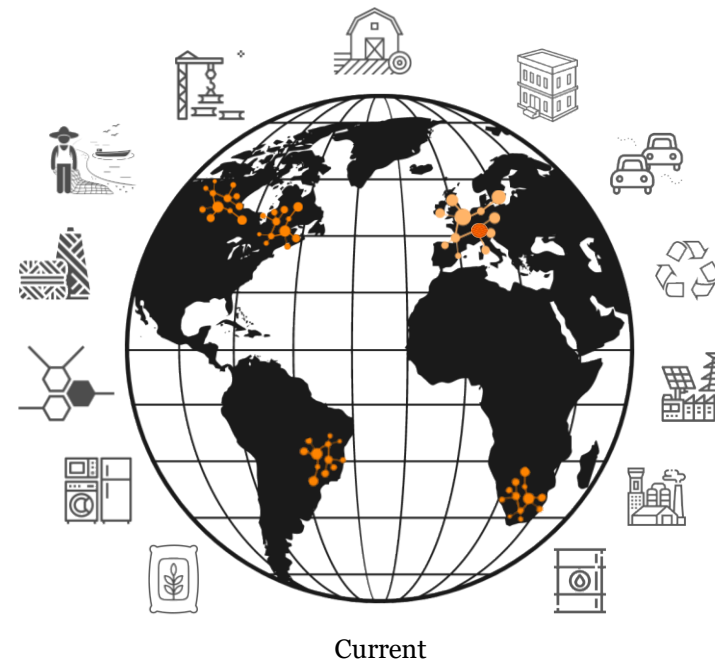
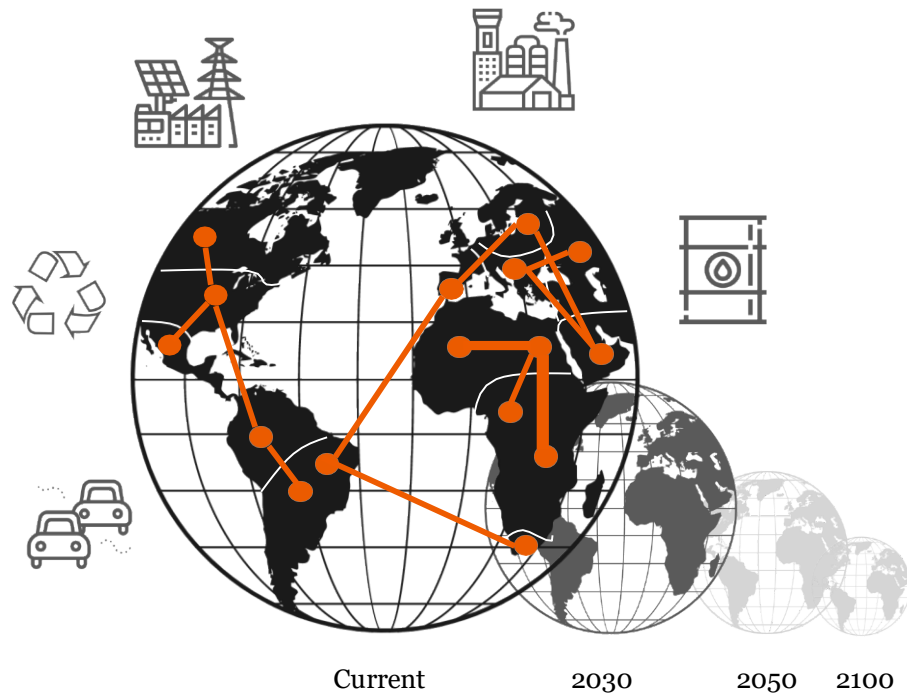
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- ***Investigate broader environmental impacts of different strategies***

Linking IAMs and LCA

> Different scopes of methods

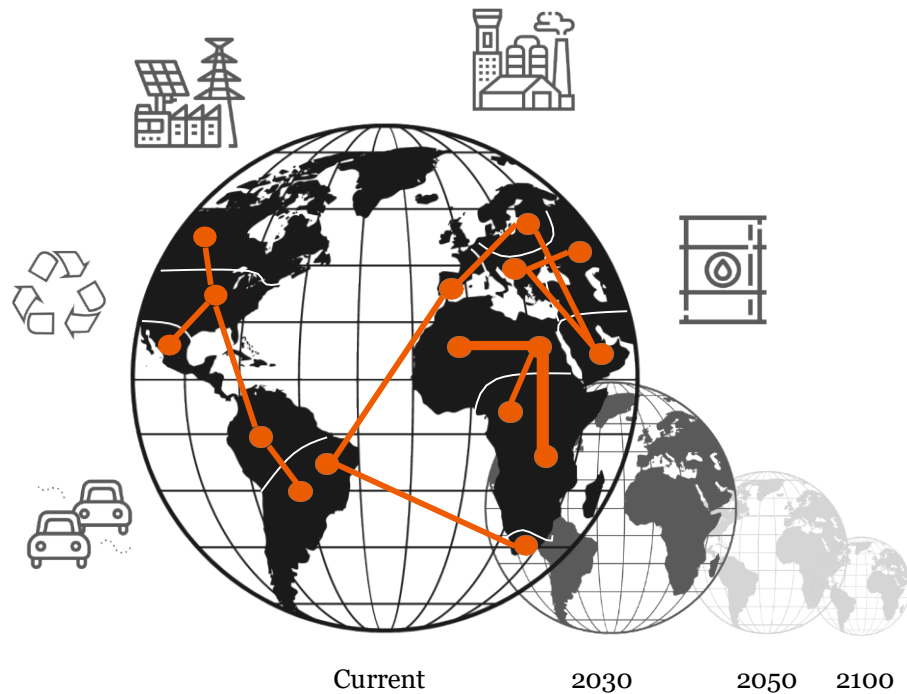
Integrated Assessment Models	Life Cycle Assessment
Forward looking	Single timestep
Projects system dynamics	Snapshot of system (energy, land, etc.)
Aggregate	High detail
Focus on costs & emissions	Multiple impact categories



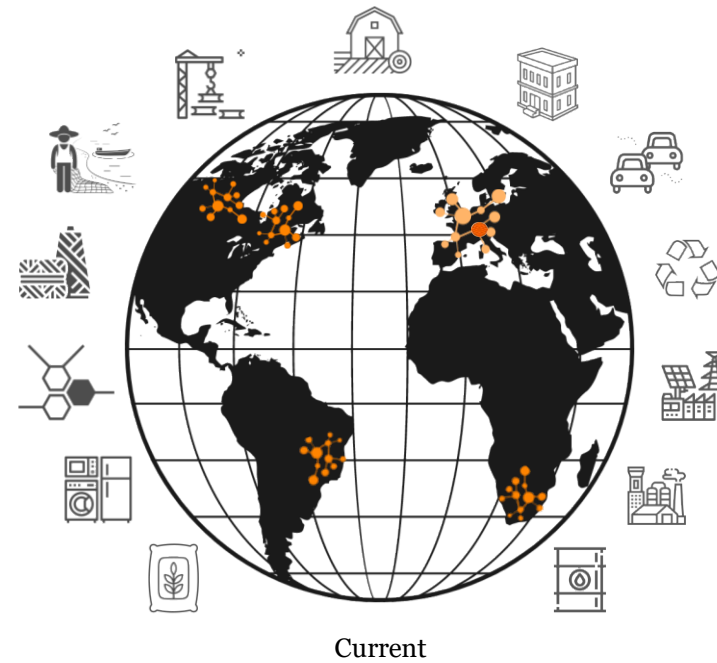
Linking IAMs and LCA

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Research Aim: Use IAM projections to make prospective LCA consistent with system-wide changes –p focusing on the case of biofuels.



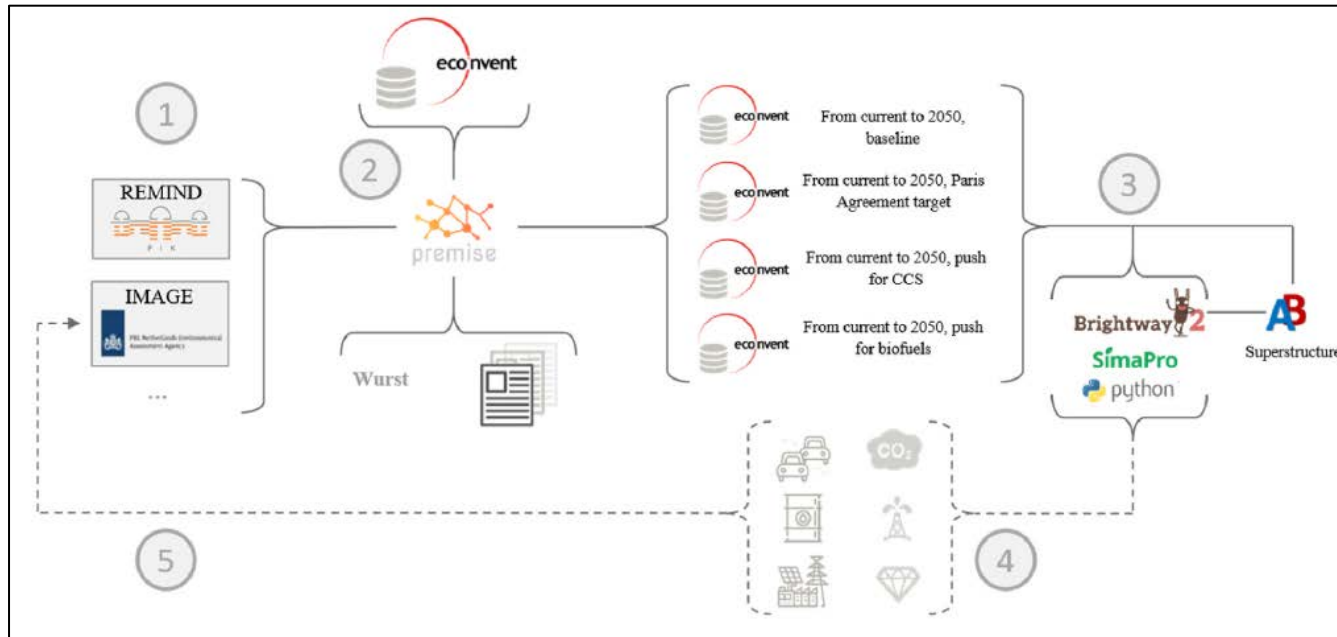
Environmental impacts of biofuels using prospective LCA



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Linking IAMs and LCA

- *premise: open-source tool that integrates IAM scenarios into Life Cycle Inventory databases*

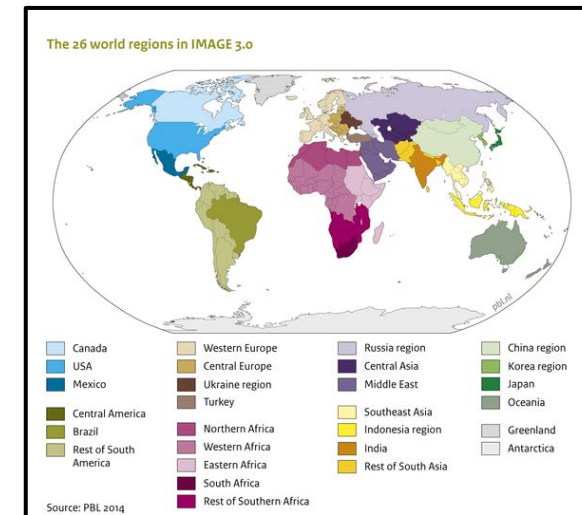


Sacchi et al. (2022)

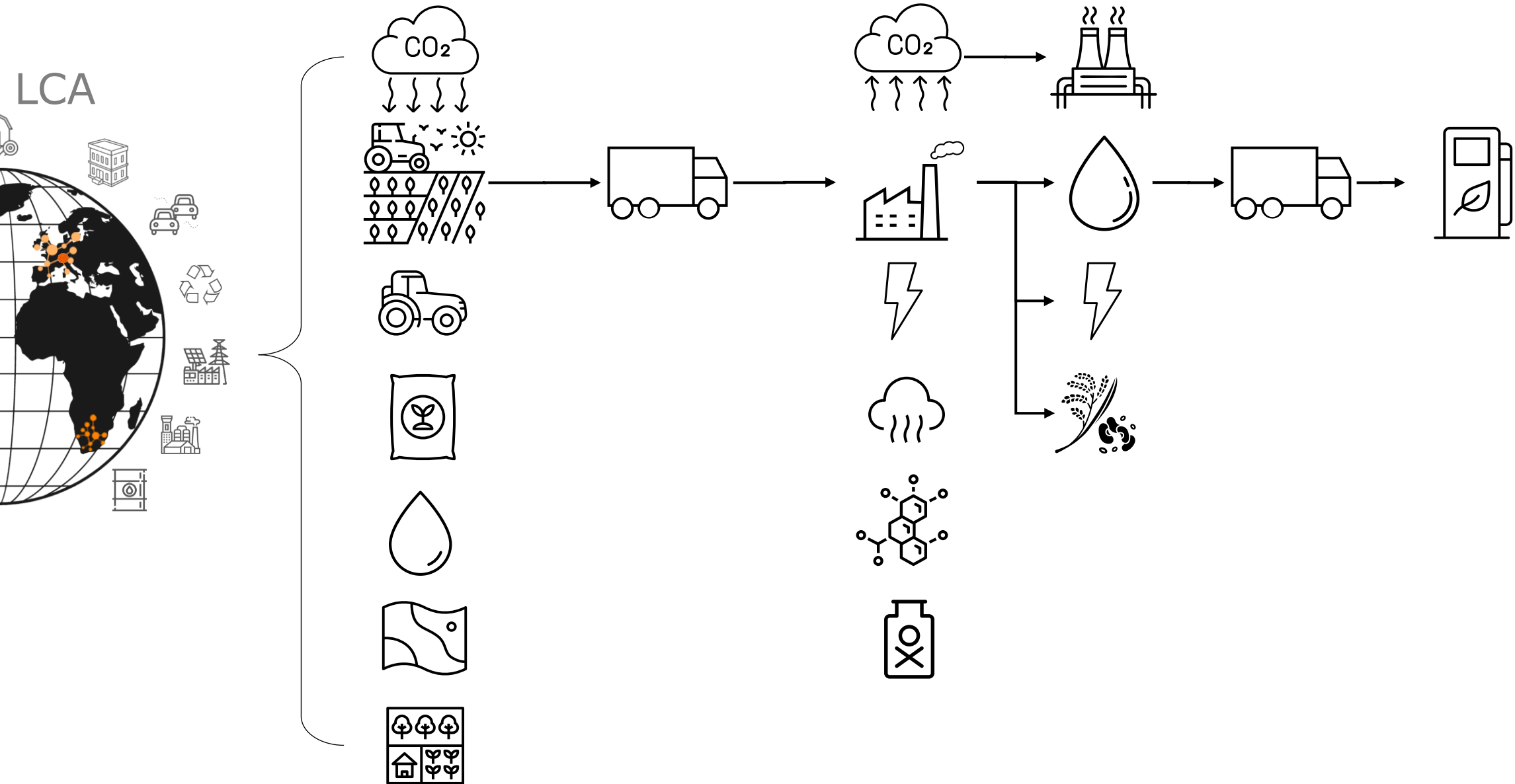
- *IAMs scenarios used as input into the LCI database (e.g., econvent)*
- *Transform LCI database, to represent the future background system (transport, industry, electricity, land use, etc.), at different timesteps*
- *Export database into common LCA software*
- *Steps 4 & 5 would return LCA indicators back into IAM decision process (work in progress).*

Method

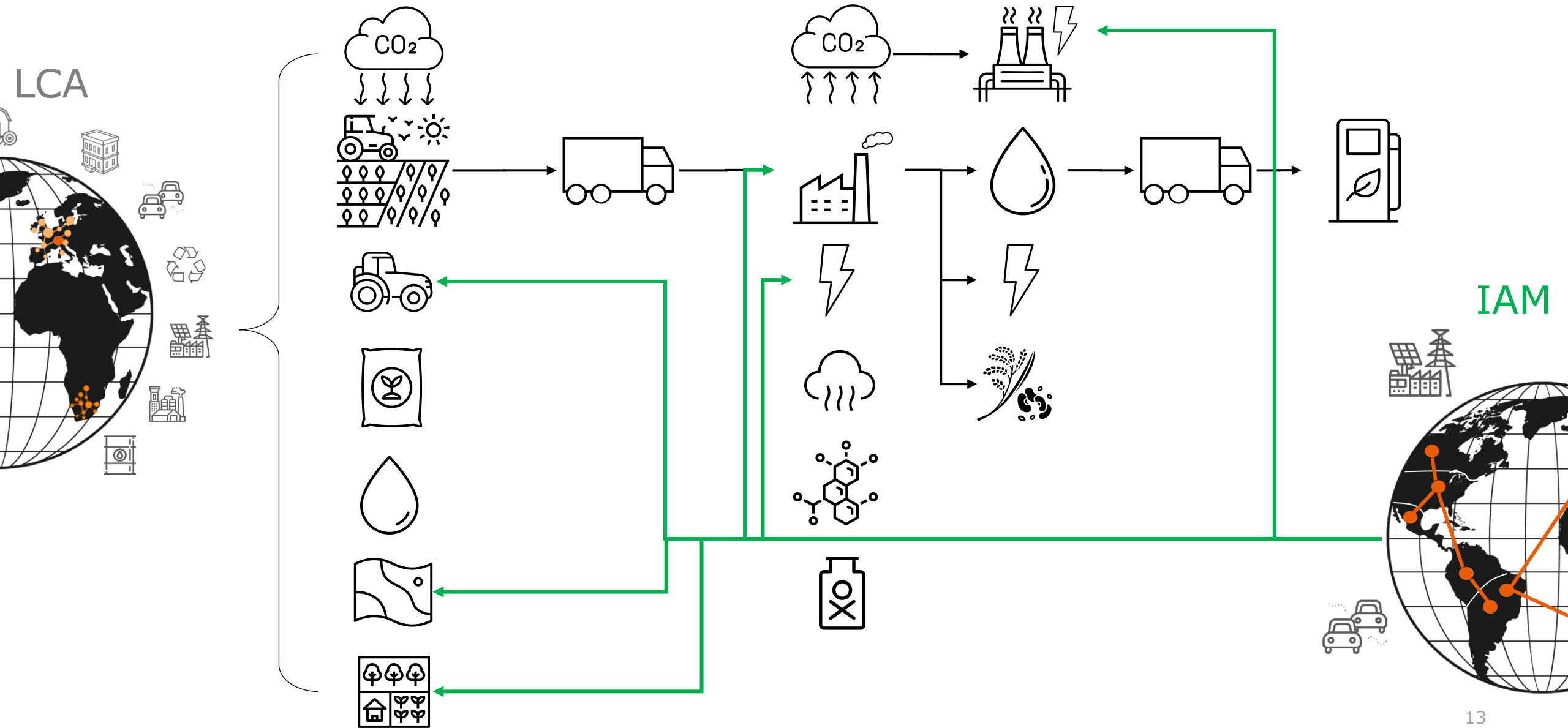
- > Use the **IMAGE** Integrated assessment model
 - Developed and maintained by the *PBL Netherlands Environmental Assessment Agency*
 - www.pbl.nl/IMAGE
- > Scenarios
 - Shared Socioeconomic Pathway 2 (SSP2) – middle of the road socioeconomic and technological developments
 - *Baseline, RCP2.6 ($\approx 2^{\circ}\text{C}$), RCP1.9 ($\approx 1.5^{\circ}\text{C}$)*
- > Model results used to transform LCI database
 - Transport & industrial energy use
 - Power system
 - Land use and agricultural system
 - 26 regions



Method



Method



Method

- › Investigate environmental impacts of bioethanol and biodiesel routes...
 - Maize
 - Sugarcane
 - Palm oil
 - Miscanthus
 - Poplar
 - Switchgrass
 - *With and without Carbon Capture and Storage*
- › ... and how these impacts change with evolving energy and land systems
 - Across geographies, scenarios and time
 - Across different environmental indicators

1st Generation

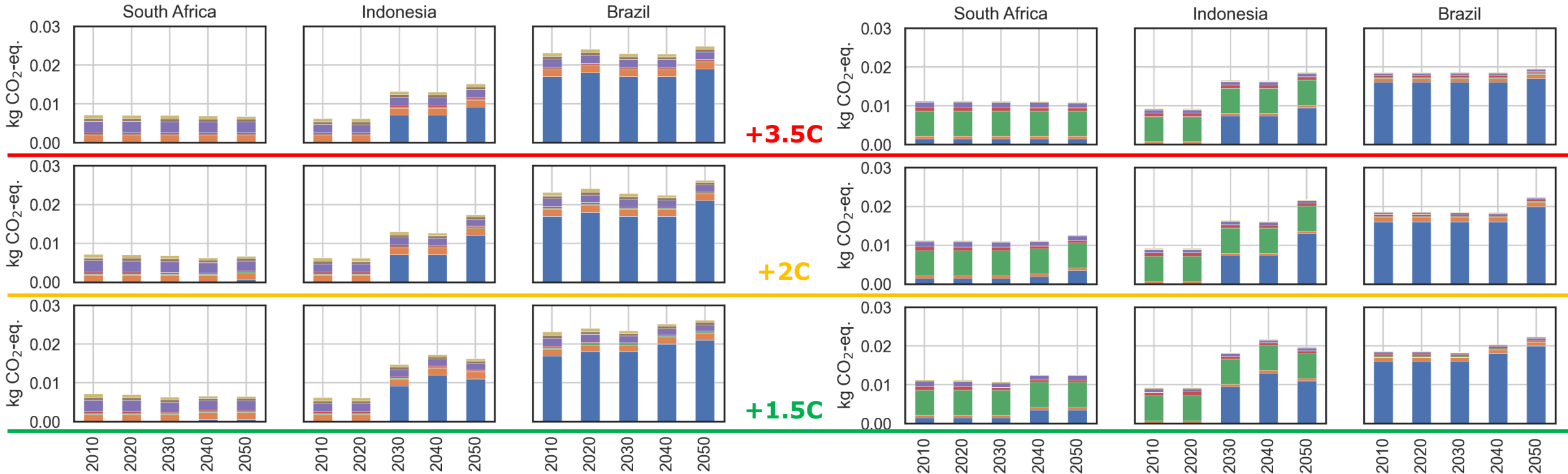
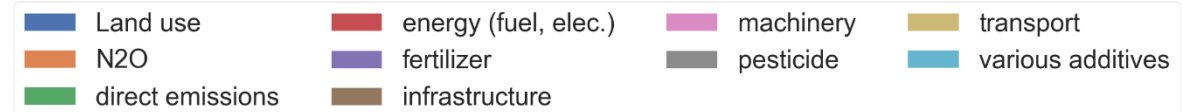
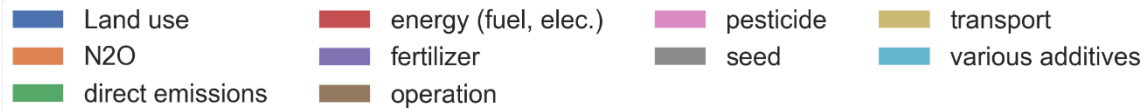
2nd Generation

Selected Results

GWP₁₀₀ | Functional Unit: 1 MJ of crop

Miscanthus

Sugarcane

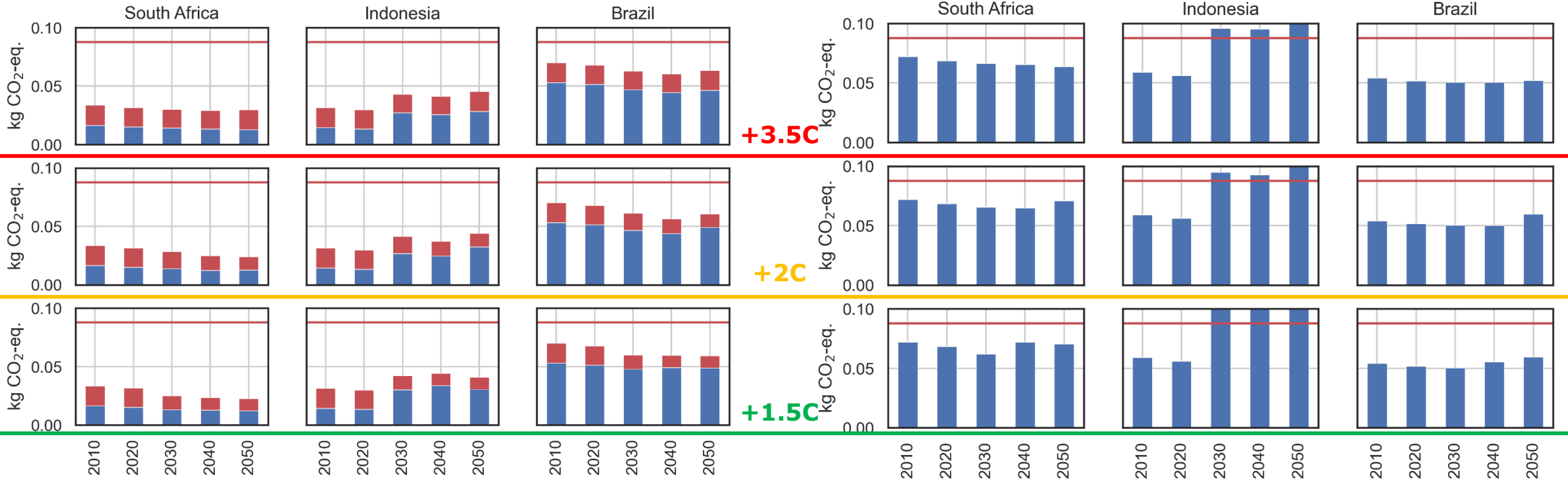


Selected Results

GWP₁₀₀ | Functional Unit: 1 MJ of ethanol

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Sugarcane

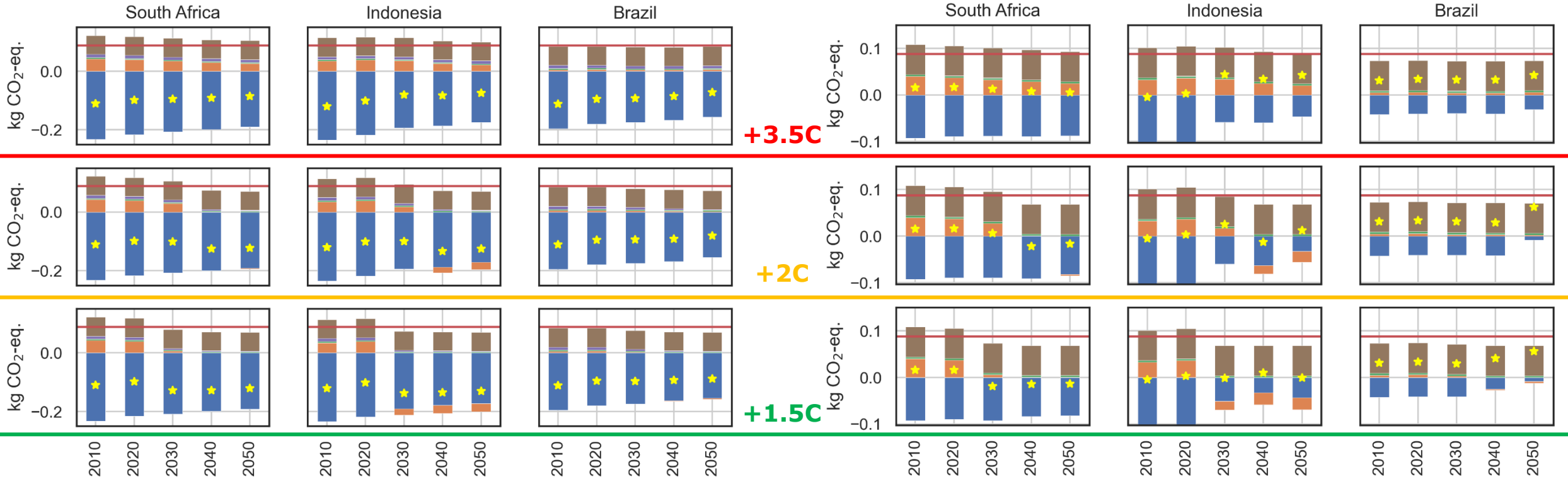


Selected Results

GWP₁₀₀ | Functional Unit: 1 MJ of ethanol with CCS

Miscanthus (w. CCS)

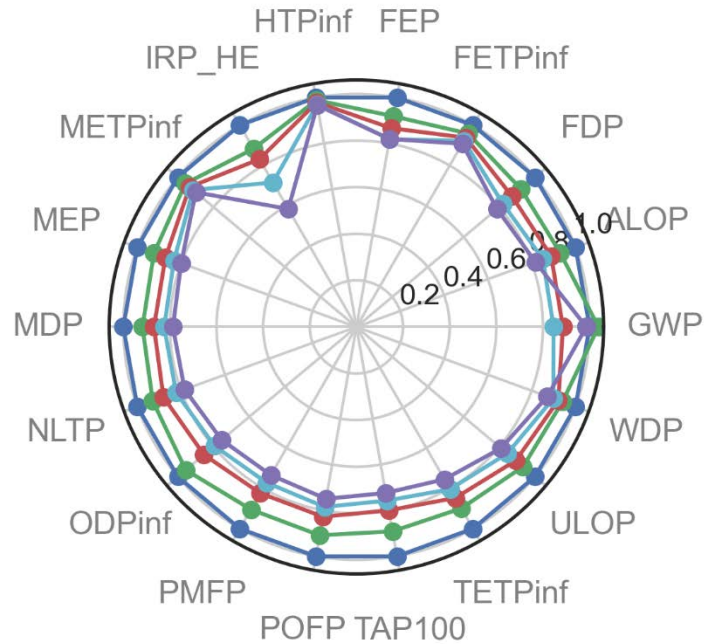
Sugarcane (w. CCS)



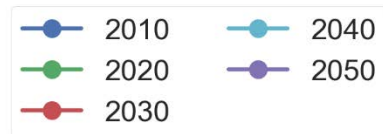
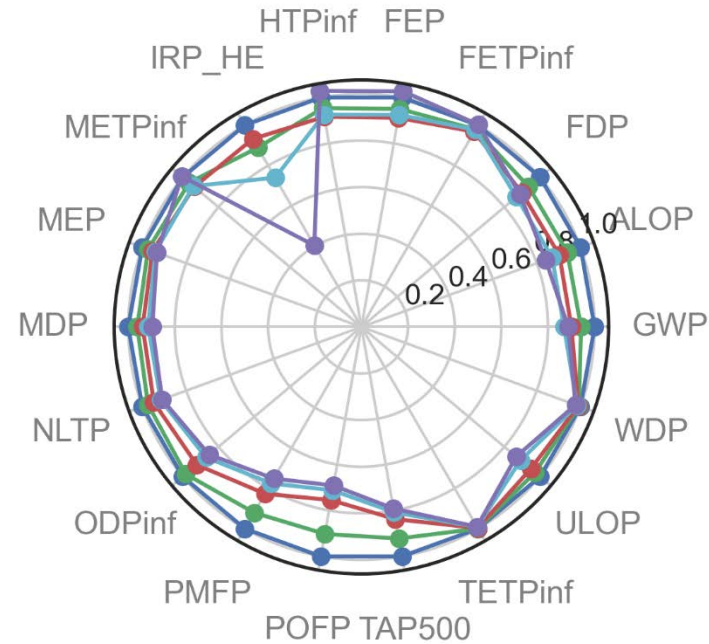
Selected Results

Functional Unit: 1 MJ of ethanol, 2010 = 1

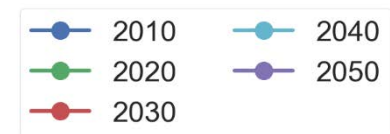
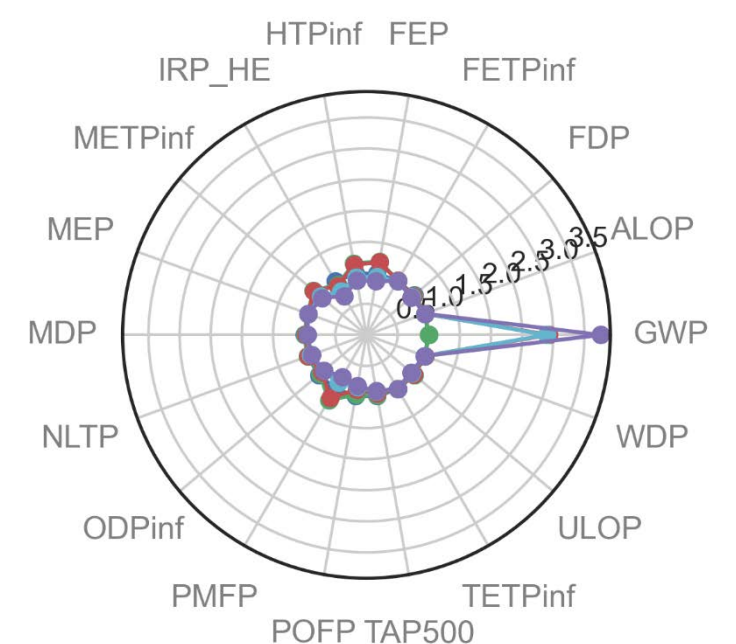
Eucalyptus, Brazil



Miscanthus, South Africa



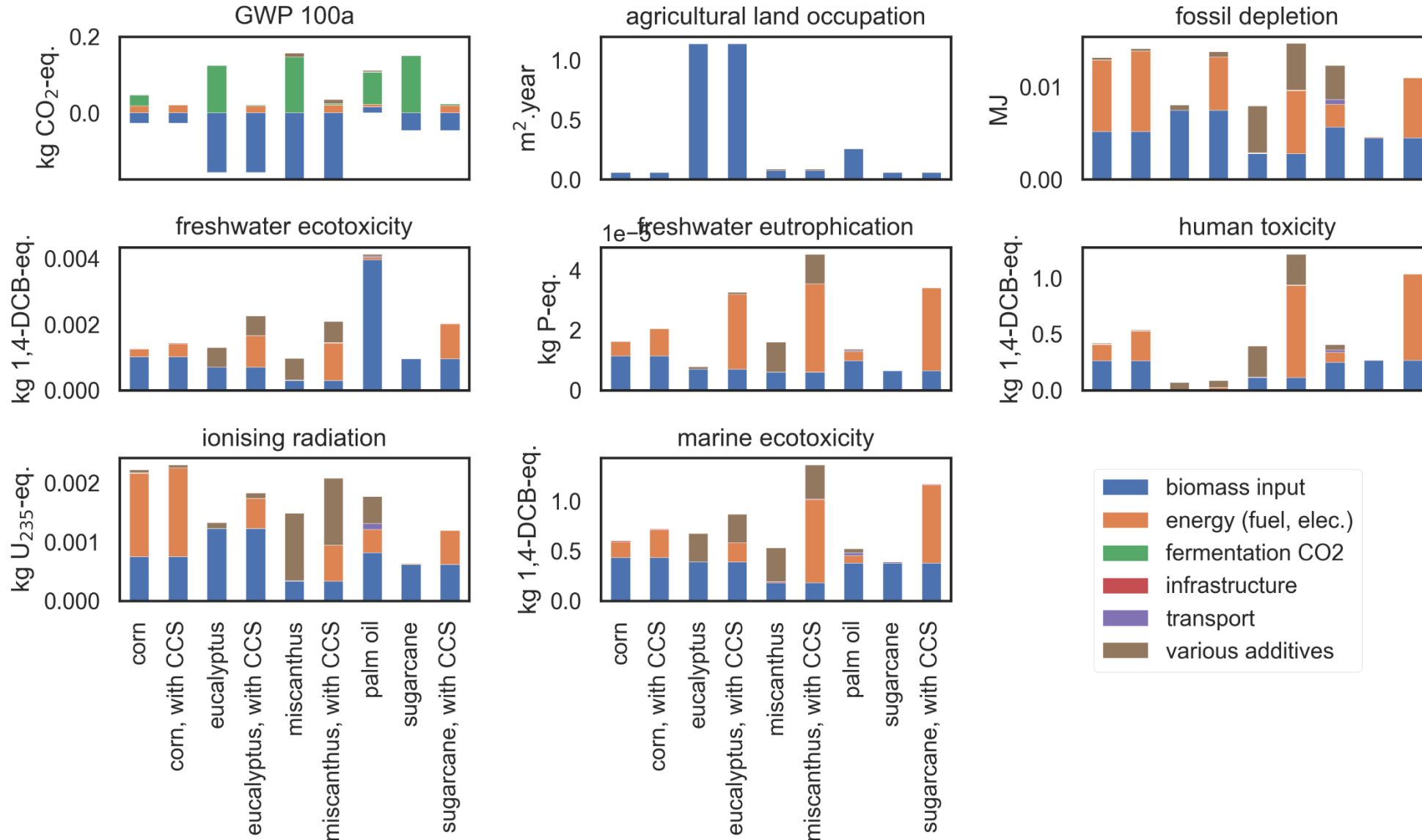
Palm oil, Indonesia



Selected Results

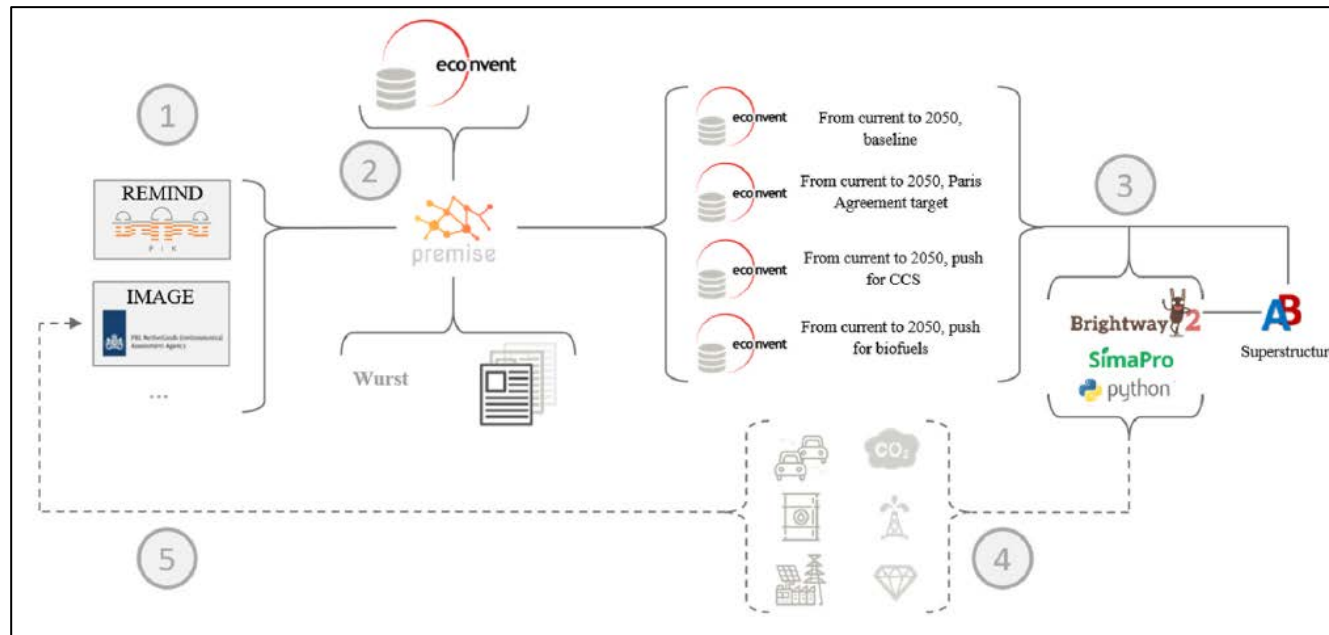
Brazil, 2050, +3.5C

Functional Unit: 1 MJ of ethanol



Further work

- › Incorporate back into IAM scenario analysis
 - Project pathways based on multiple environmental indicators (*not just CO₂ mitigation*)
 - Need to develop an appropriate *Environmental Impact* indicator
 - How to weigh different impacts?



Sacchi et al. (2022)

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- › Broaden analysis to other technologies
 - Improve understanding of environmental implications of system change
 - *Biofuels vs. fossil fuels vs. e-fuels*

- › Repeat analysis with other IAMs and broader scenario set
 - Results depend on the projections of the IMAGE model.
 - Other models may show very different pathways
 - Standardized setup of the *premise* tool allows for study to be repeated with off-the-shelf results
 - Investigate the effect of alternative scenario narratives (Green-growth, regionalization, post-growth, etc.)

Conclusions

- › Environmental impact of biofuels not static
 - Varies across time, region, scenario
 - Need to account for these changes when developing strategies aiming to meet multiple goals
- › Different biofuels types, different impacts
 - Advanced biofuels (miscanthus, poplar, switchgrass) have impacts from required *additives* (enzymes, acids, etc.)
 - Different crop productivities lead to different impacts related to land-use
 - Impacts may be further reduced with novel farming techniques reducing the need for land, fertilizers, and energy use (no-till, selection of high yielding species, selective fertilizing, etc.)
- › Synergies between climate and environmental targets
 - Movement of energy system towards renewables reduces some of the impacts of biofuel production, but mostly when CCS is considered.

Thanks!

More information:

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LCA & premise: romain.sacchi@psi.ch | @romainsacchi

This work was authored [in part] by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Bioenergy Technologies Office. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.

NREL/PR-6A20-83946