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Integrated assessment modeling and life cycle assessment

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U.S. DEPARTMENT OF ENERGY BATTELLE

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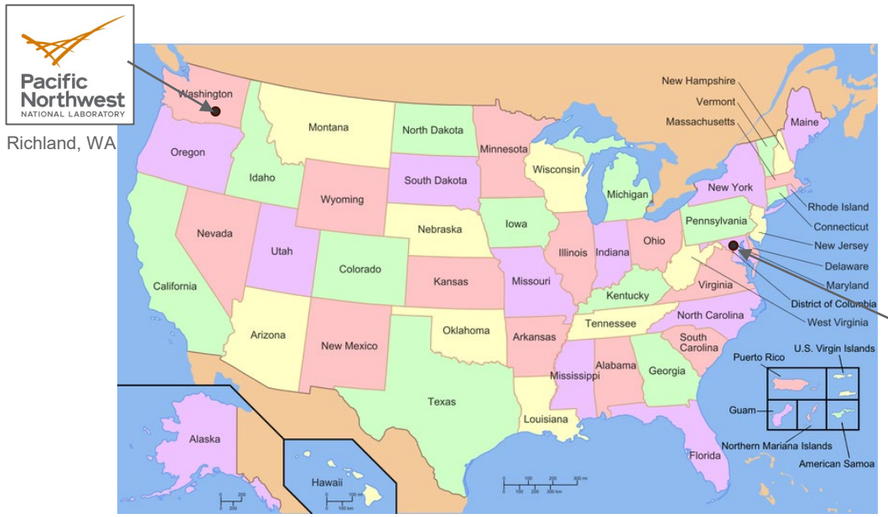
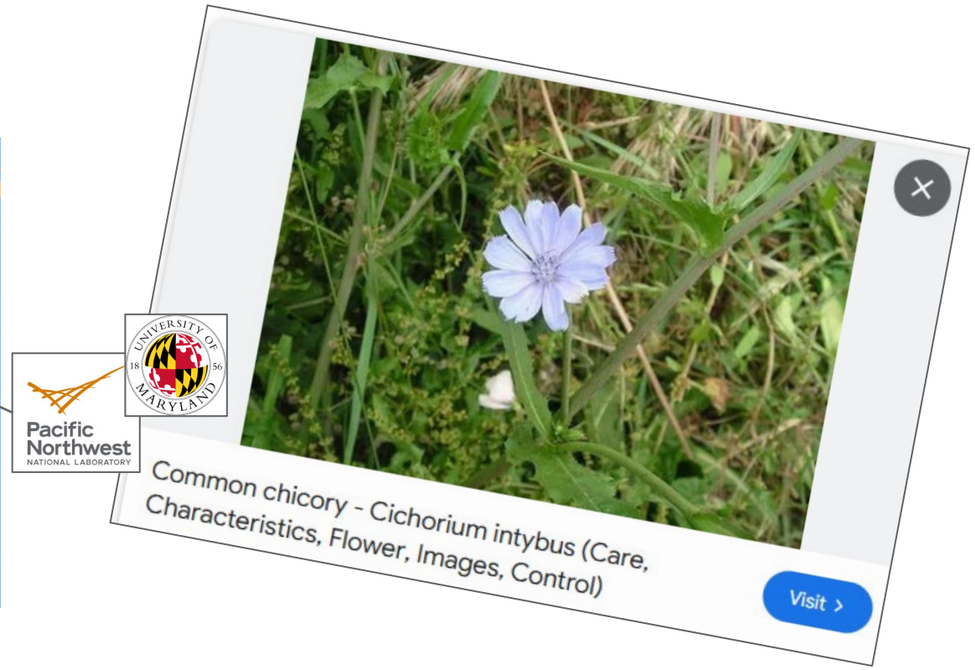
Outline

1. Refresher: What is LCA?
2. What is IAM?
3. Why combine LCA and IAM?
4. Examples

Intro

- from Dresden, Germany (near Berlin)
- came to US for a PhD in 2016
- now Earth Scientist at JGCRI (Joint Global Change Research Institute) (near DC)





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What is your experience with LCA and / or IAM so far?

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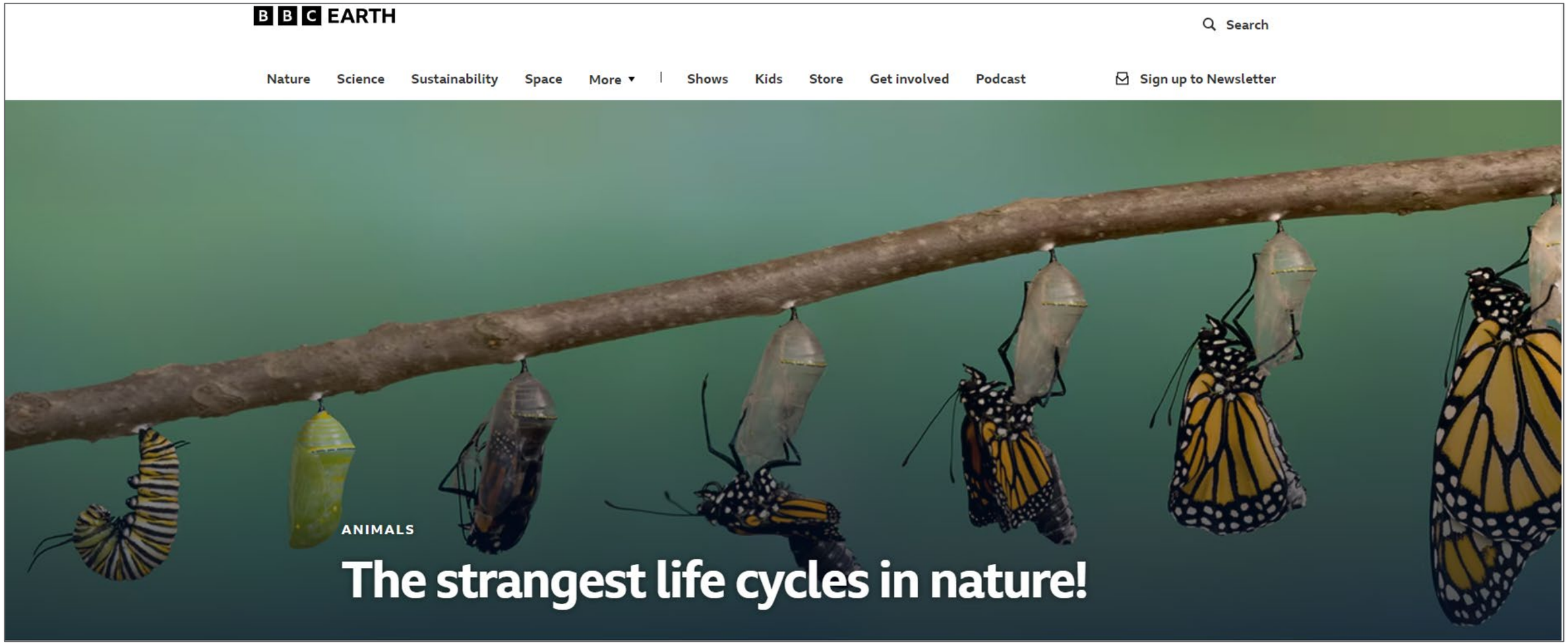
Refresher: What is LCA?

What is LCA?

- systematic analysis
- environmental impact
- entire life cycle of a product, material, process, or other measurable activity

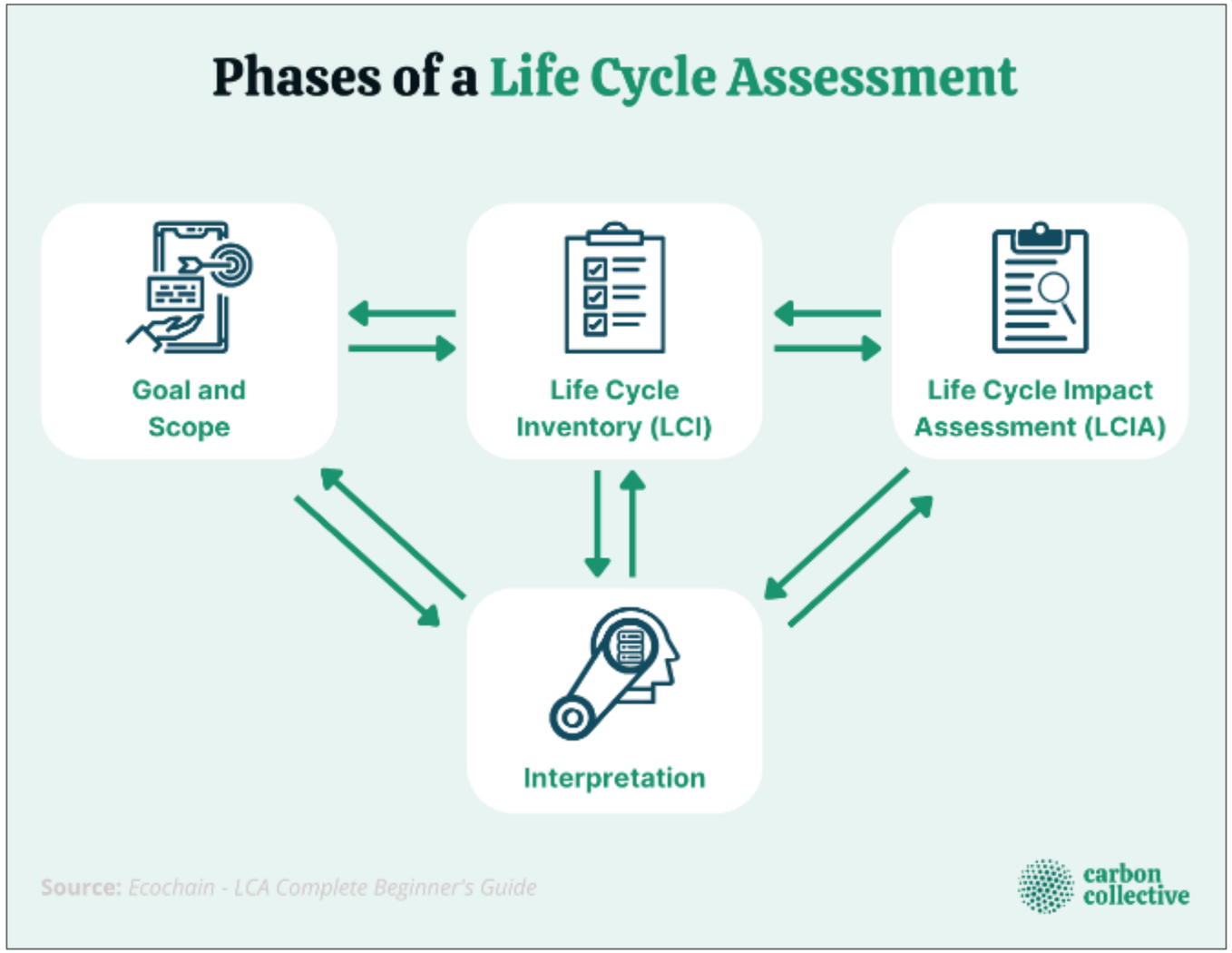
Examples of life cycle stages:

Example of life cycle stages in nature



https://www.bbcearth.com/news/the-strangest-life-cycles-in-nature

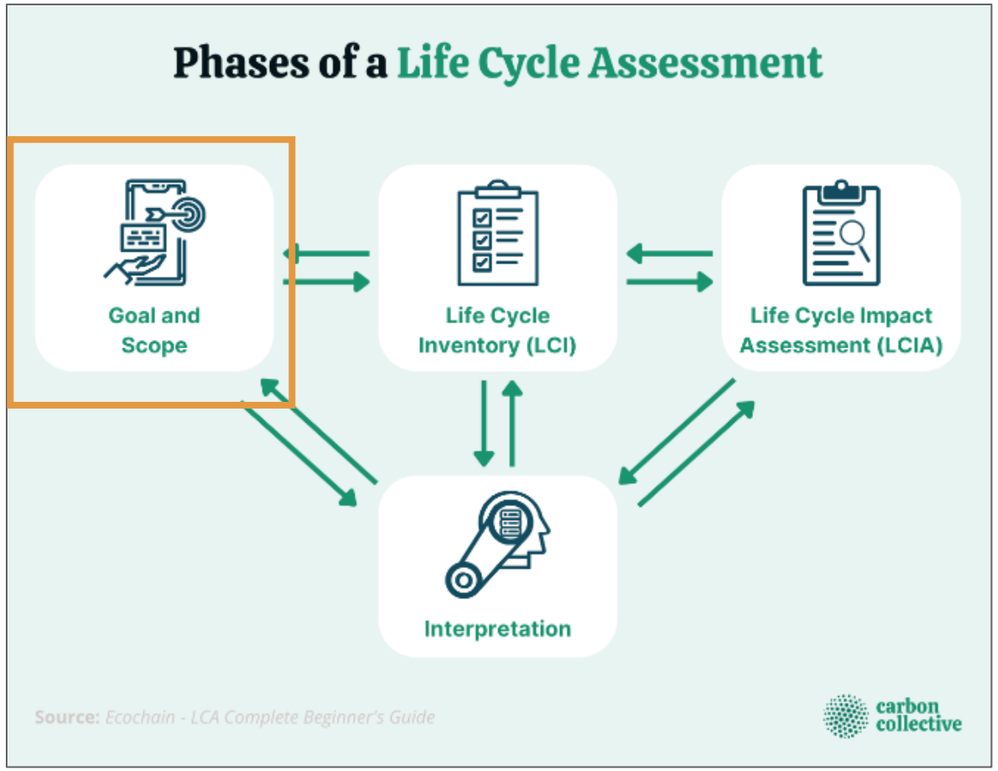
Phases of LCA



https://www.carboncollective.co/sustainable-investing/life-cycle-assessment-lca

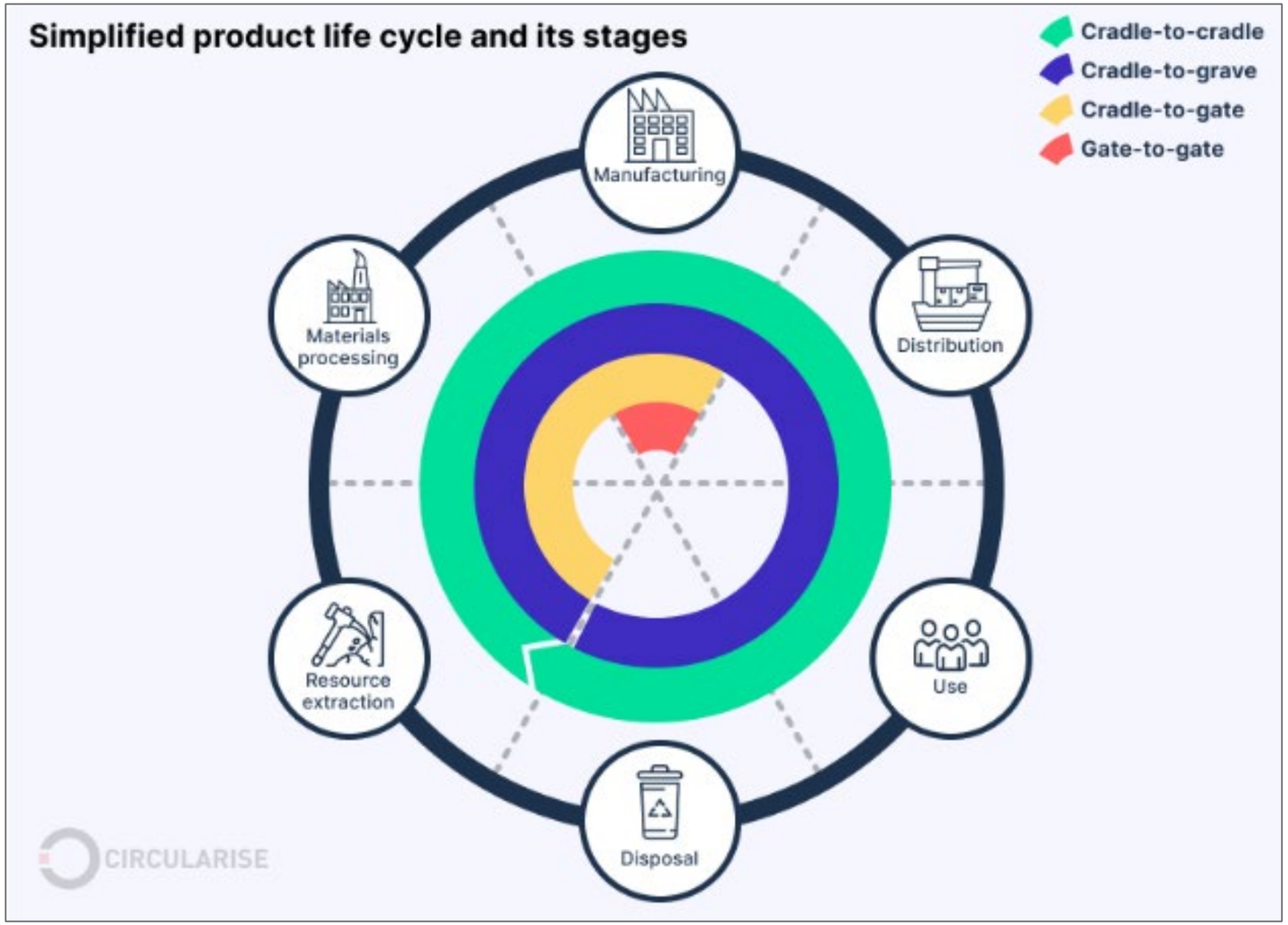
Phases of LCA: Goal and Scope

- Goal and Scope:
  - Goal:
    - ✓ Compare products?
    - ✓ Basis for design, corporate or policy decisions?
    - ✓ Comply with regulation?
    - ✓ Customer demand?
  - For whom?
    - ✓ Stakeholders?
    - ✓ Customers?
    - ✓ The public?
  - Scope:
    - ✓ Functional unit
    - ✓ **System boundaries**
    - ✓ Method
      - Standard (ISO + regional standards)
      - Impact assessment method
      - Database



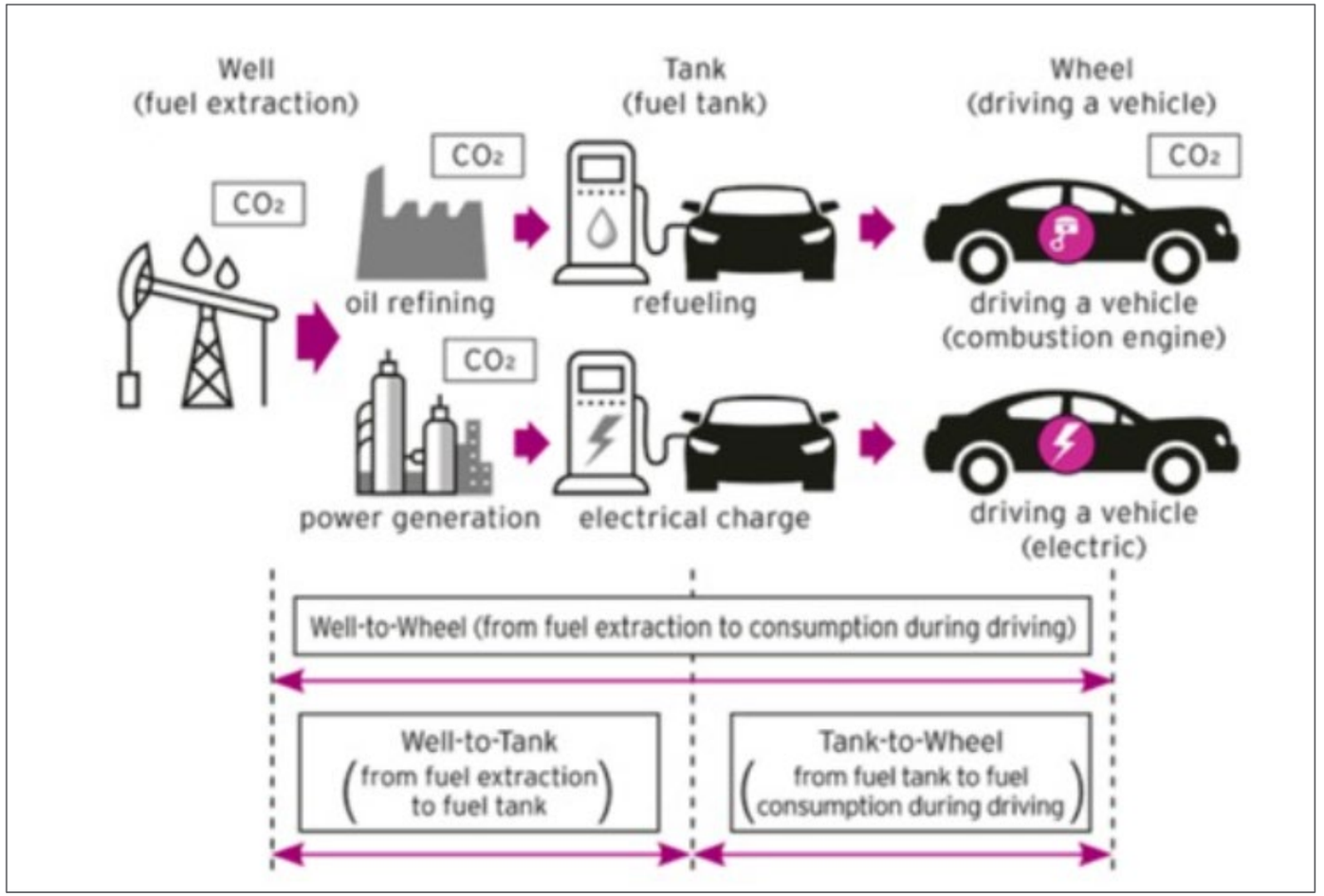
https://ecochain.com/blog/how-to-define-the-goal-scope-of-your-lca/

System boundaries



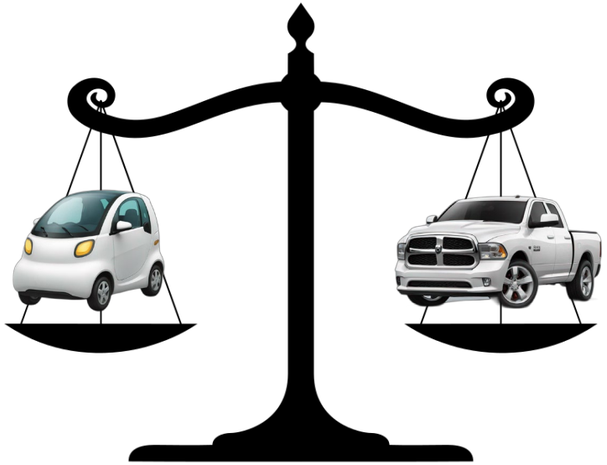
https://www.circularise.com/blogs/what-is-life-cycle-assessment-lca

LCA stages: fuels



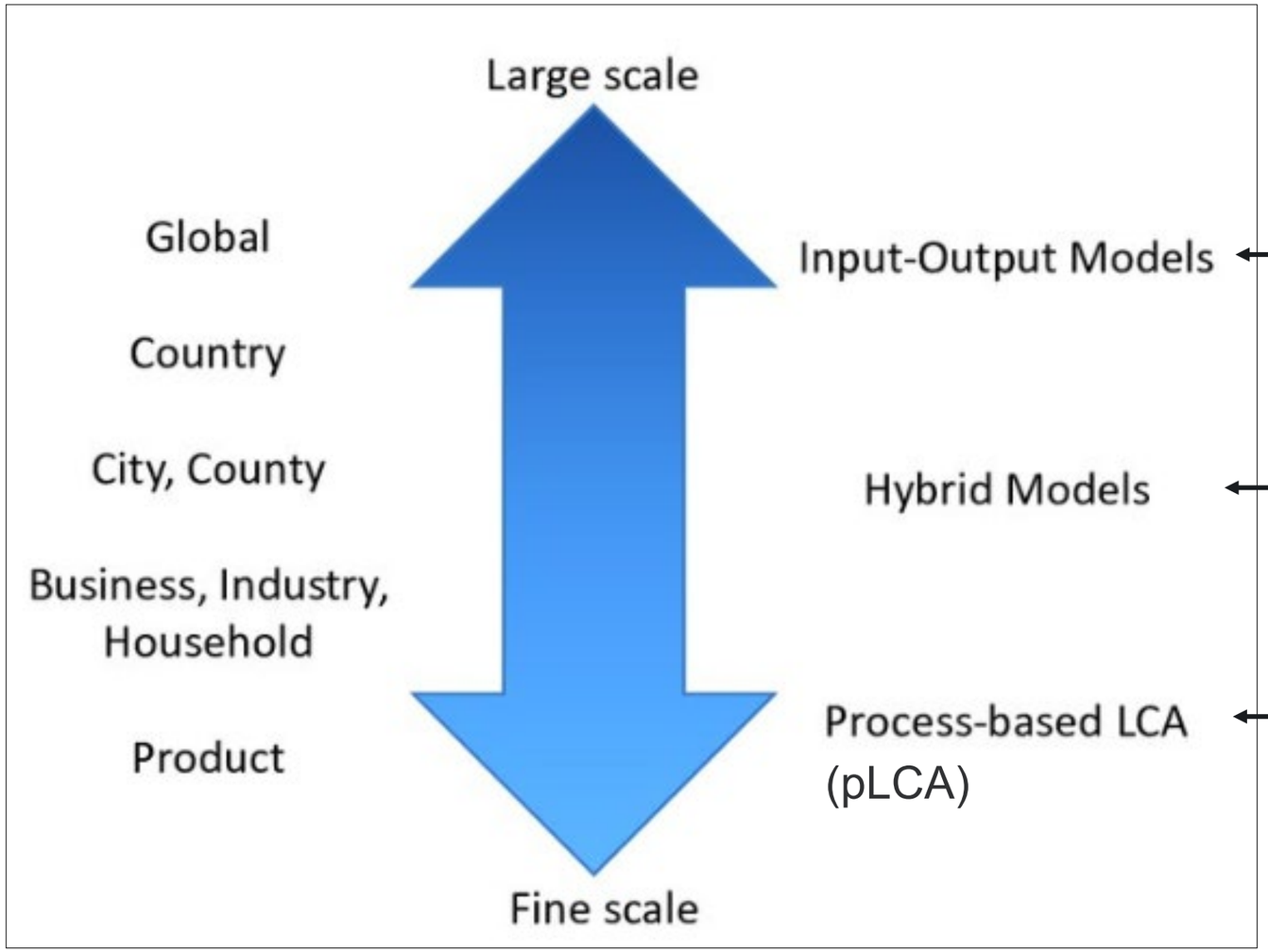
https://kleebinder.net/future-smartmobility-needs-sustainable-cleanenergy/

LCA: possible research questions



- Are tomatoes from Spain or Mexico less impactful on the environment?
- Should I buy an organic cotton T-shirt or a regular cotton one?
- What is the total environmental impact of an electric vehicle (EV) manufactured in China, and driven in India over the entire vehicle lifetime?
- What is the impact of GHG emissions from 1 kWh of electricity generation in India?
- How does a conventional vehicle compare to an EV driven in the US in terms of CO2 emissions?
- How big a share of renewable energy do we need in the electricity grid for the carbon footprint of electric vehicles to become smaller than the footprint of gasoline-powered vehicles?
- …

Types of LCA: process-based versus economic



production- vs. consumption-based accounting of emissions; often country level

avoids truncation errors of pLCA; can facilitate regionalization

usually comparing 2 alternatives; often product level

Adapted from https://www.sciencedirect.com/science/article/pii/S187734351000369#fig1

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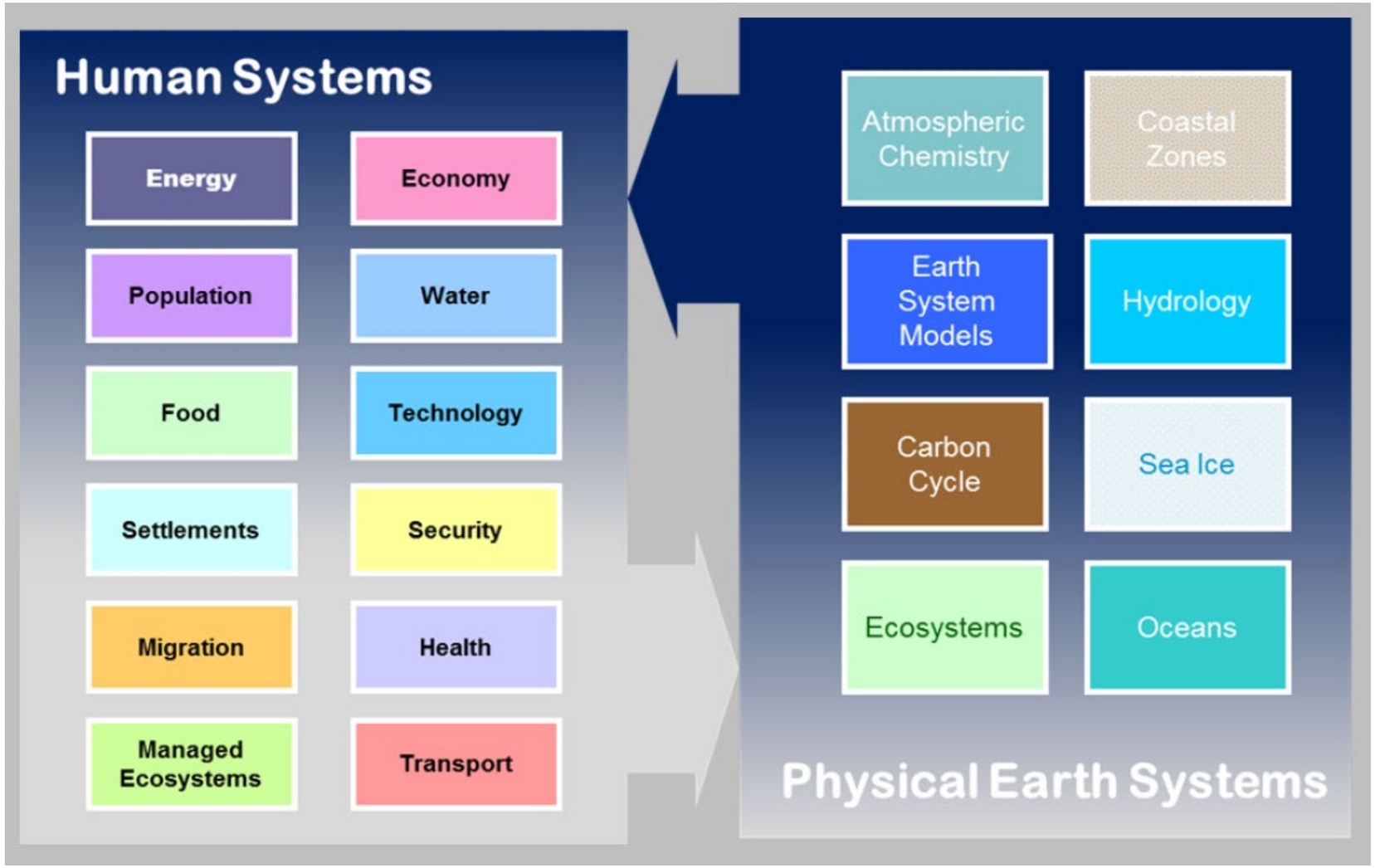
What is integrated assessment modeling (IAM)?

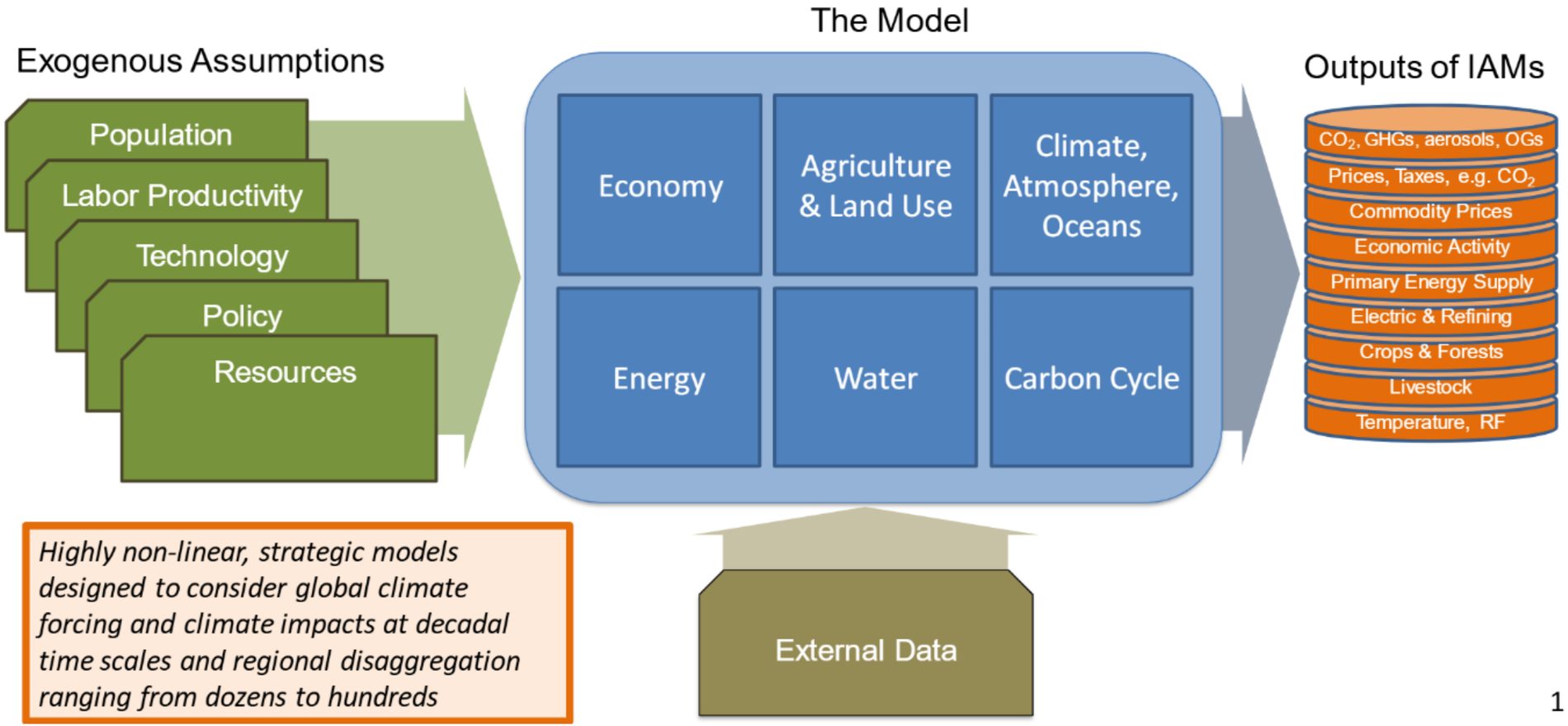
What is IAM?

- integrate human + Earth system
- insights not available from disciplinary research alone
- own discipline



https://github.com/JGCRI/gcam_training

IAM example: GCAM



Highly non-linear, strategic models designed to consider global climate forcing and climate impacts at decadal time scales and regional disaggregation ranging from dozens to hundreds

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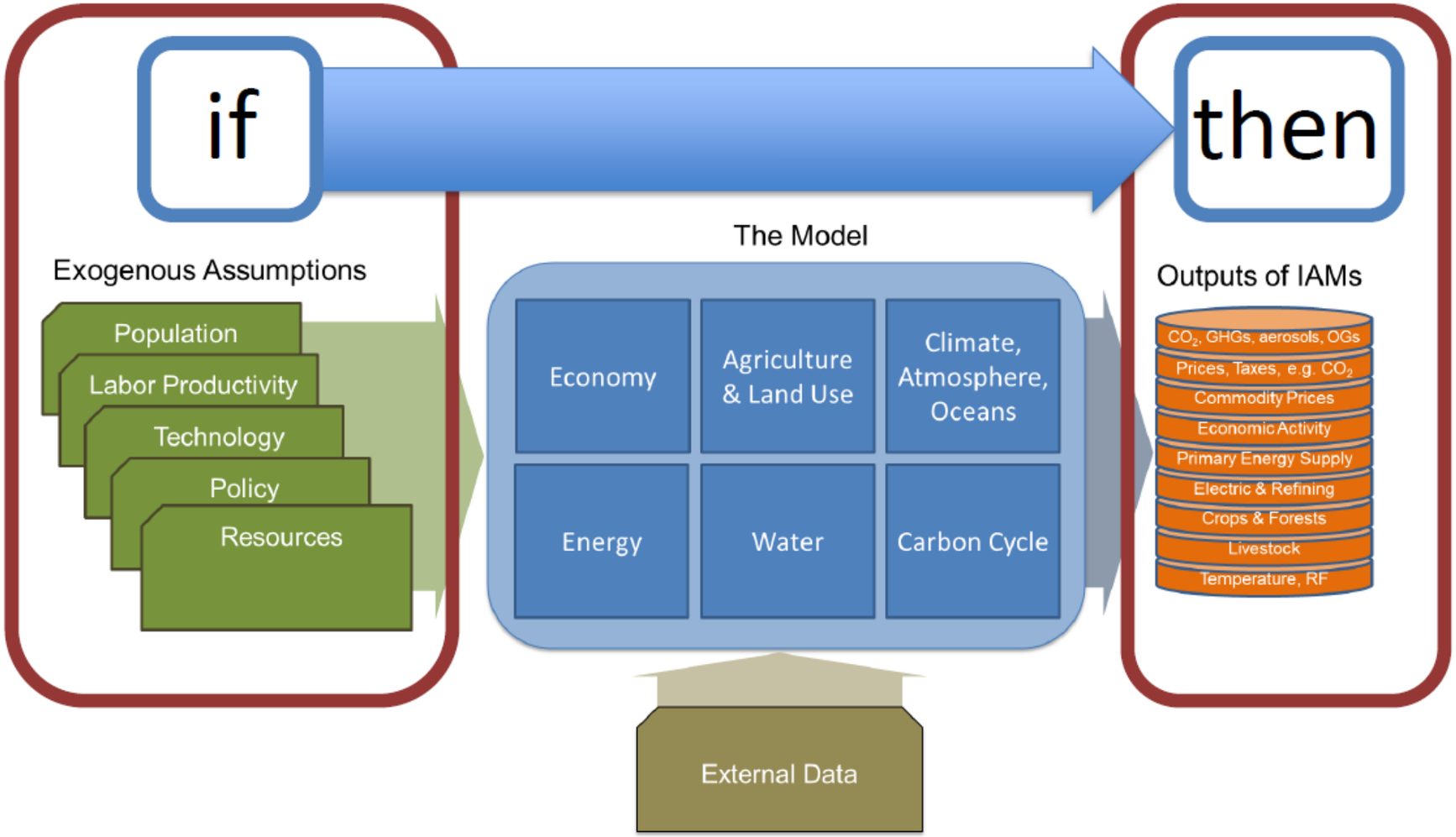
- (FYI, GCAM is fully public!)

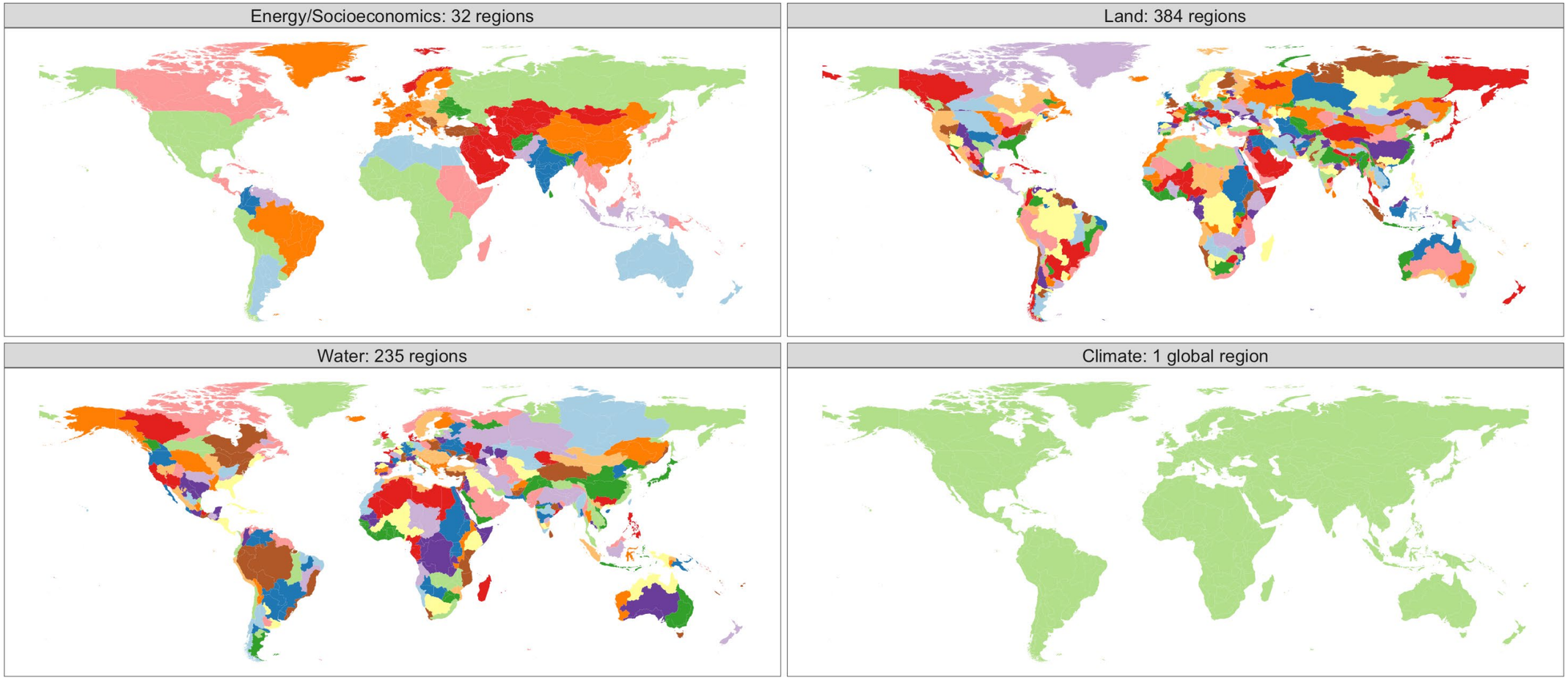
https://github.com/JGCRI/gcam_training

IAM-based scenarios



https://github.com/JGCRI/gcam_training

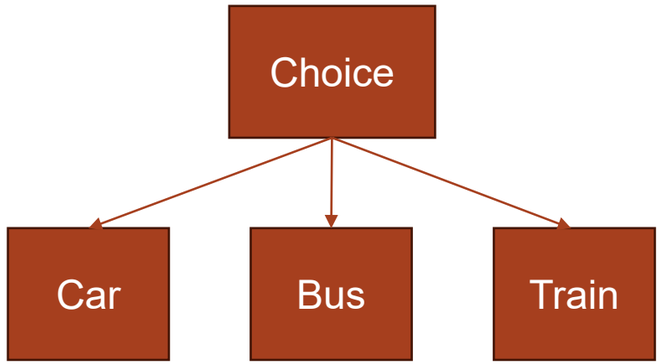
GCAM's regional resolution



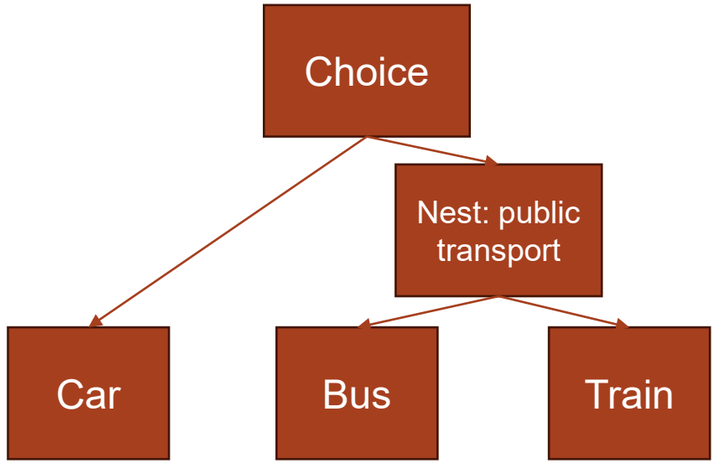
- also country-specific versions such as GCAM-USA, GCAM-China, GCAM-Canda etc.
  https://gmd.copernicus.org/articles/12/677/2019/gmd-12-677-2019.pdf

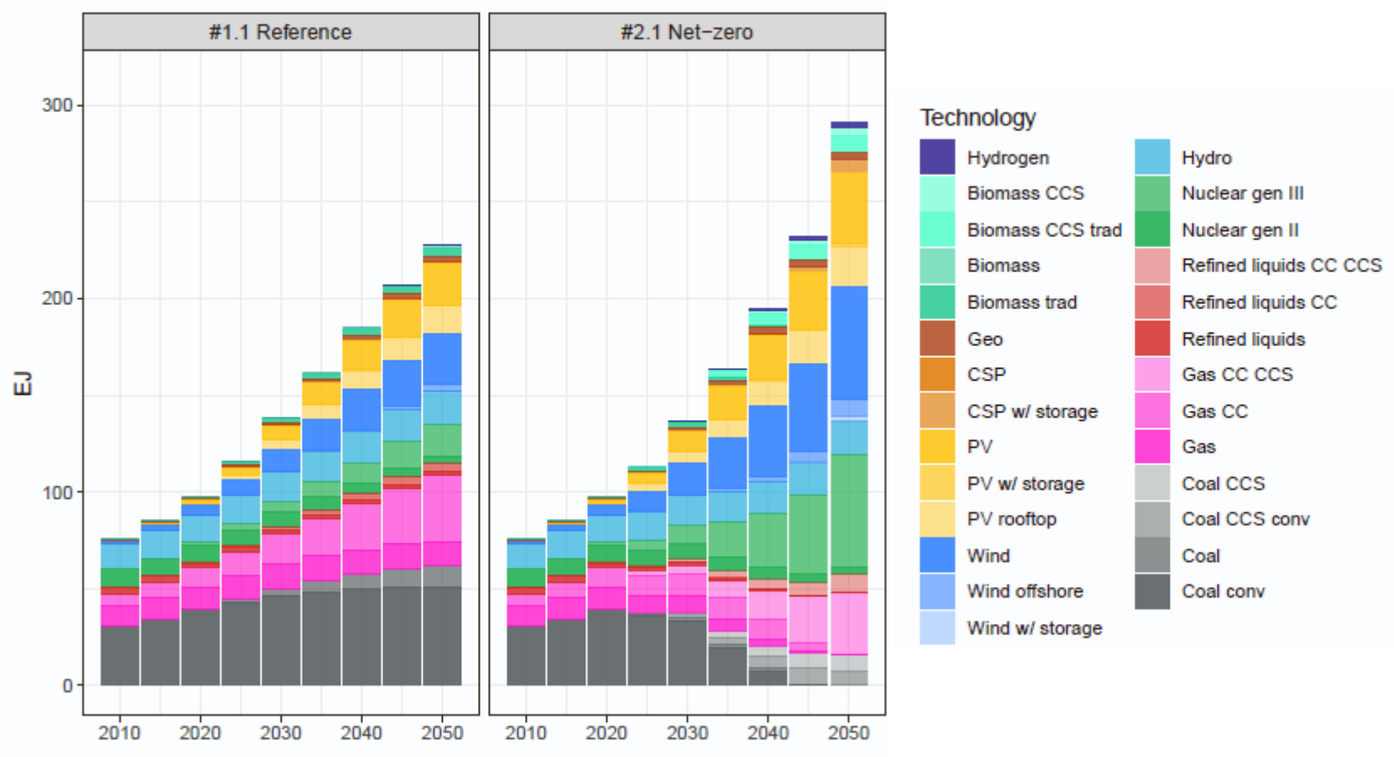
Logit choice: technology competition

- No “winner takes all” (unlike strict optimization)



- Nested:





https://www.sciencedirect.com/science/article/pii/S2590332224002021

IAM: possible research questions

- What role will hydrogen play in the future globally or in certain countries?
- How can we stay within 1.5C?
- How much will it cost to reach “net-zero”?
- How will the power sector adapt to future climate targets?
- Which sectors strongly react to climate policies, which ones less?
- How does a carbon price affect the price of gasoline?
- How do biofuels, ammonia fuels, etc. affect food prices?
- …

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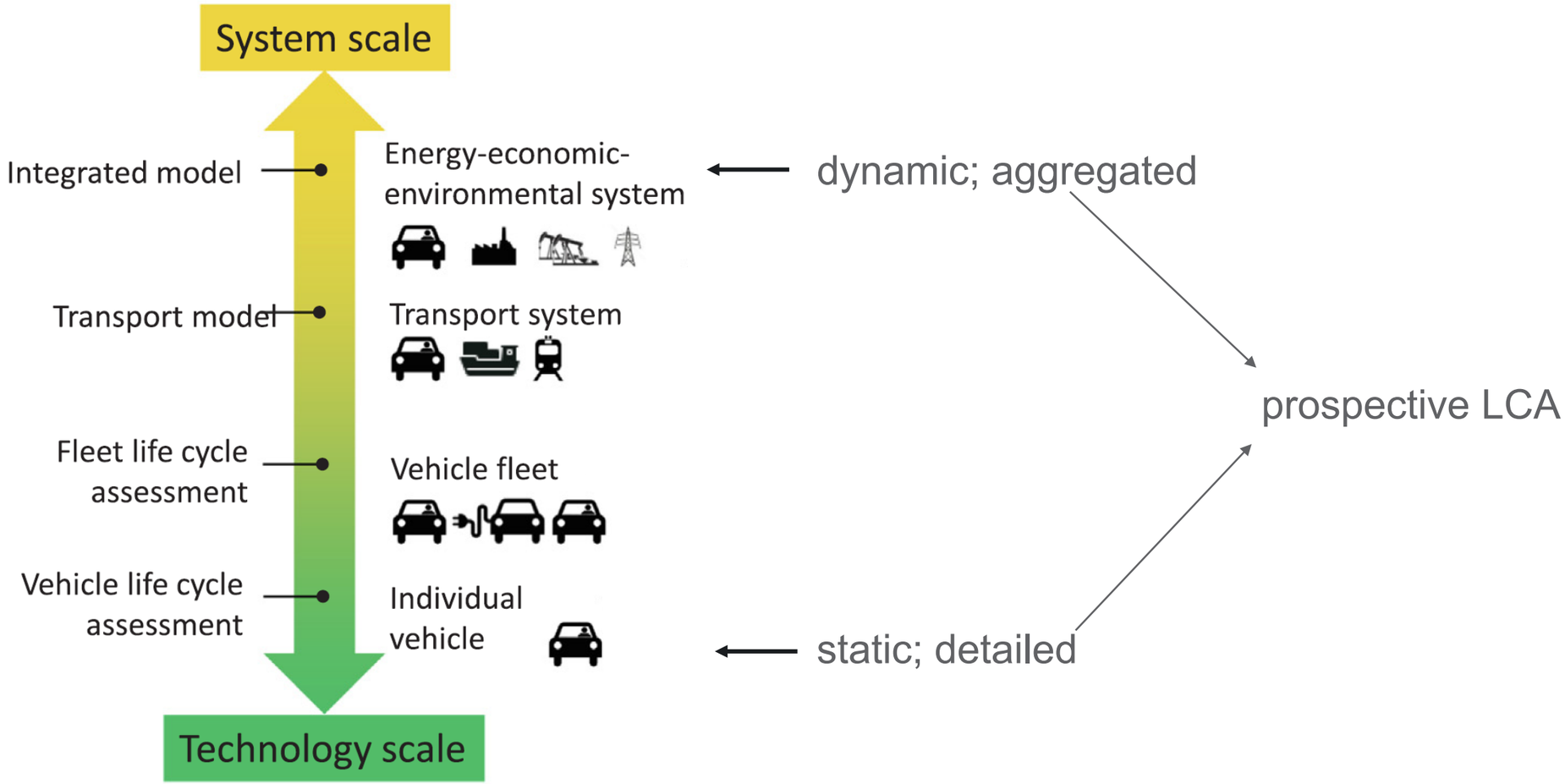
Why combine IAM and LCA?

Types of assessment: static versus dynamic



https://www.sciencedirect.com/science/article/pii/S1361920919300513

Why combine IAM and LCA?

- Combine the strengths of both
  - LCA:
    - ✓ additional pollutants and impact categories
    - ✓ more technological detail (e.g. battery chemistry)
    - ✓ more detailed supply chain processes
  - IAM:
    - ✓ market mechanisms (balancing of supply and demand)
    - ✓ prices facilitate technology competition
    - ✓ larger system boundary / whole economy
- To generate new insights for sustainability/climate policy

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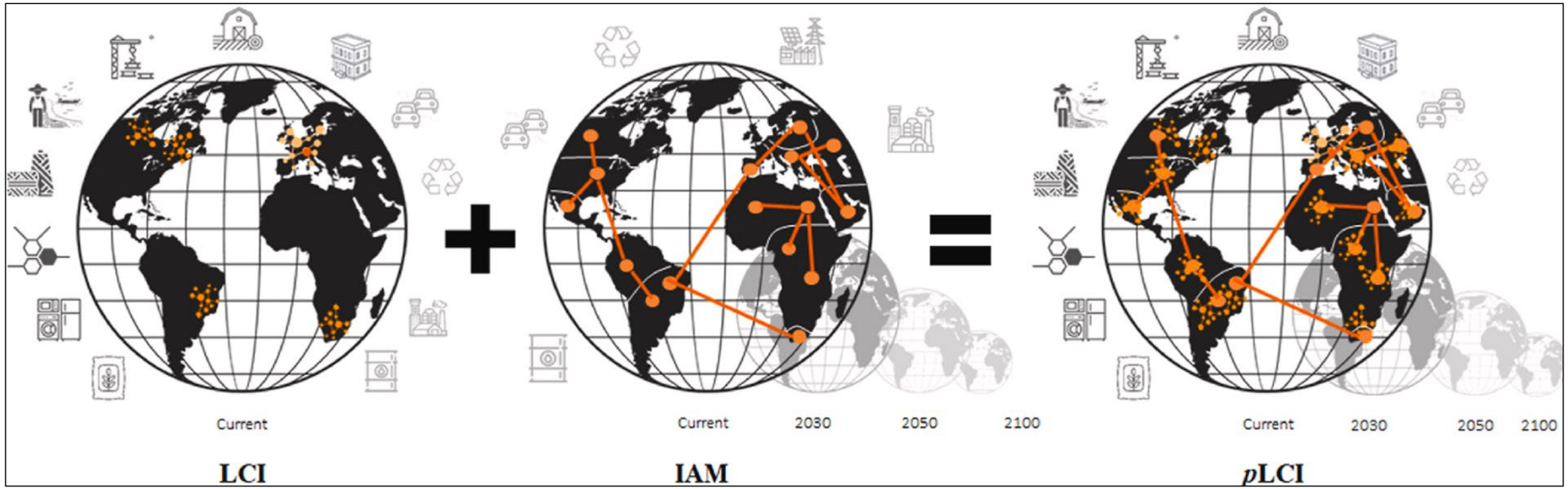
Examples

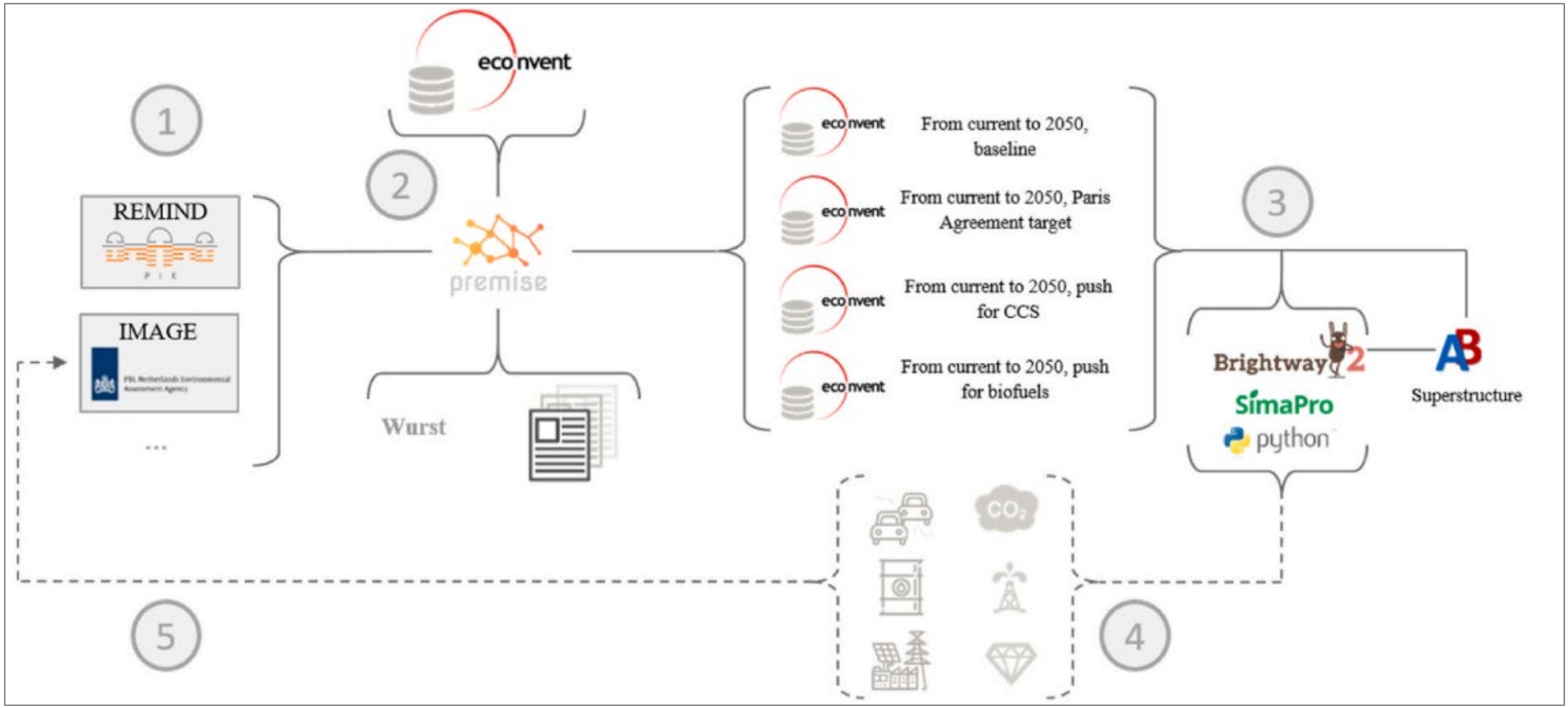
Example: prospective LCA

- Often an LCA that uses outputs from an IAM, most commonly electricity mix, more lately also main industrial, transport and refining processes
- E.g. *Premise* tool: “Premise is a tool that streamlines the generation of prospective inventory databases for LCA by integrating scenarios generated by Integrated Assessment Models (IAM).”



https://www.sciencedirect.com/science/article/pii/S136403212200226X

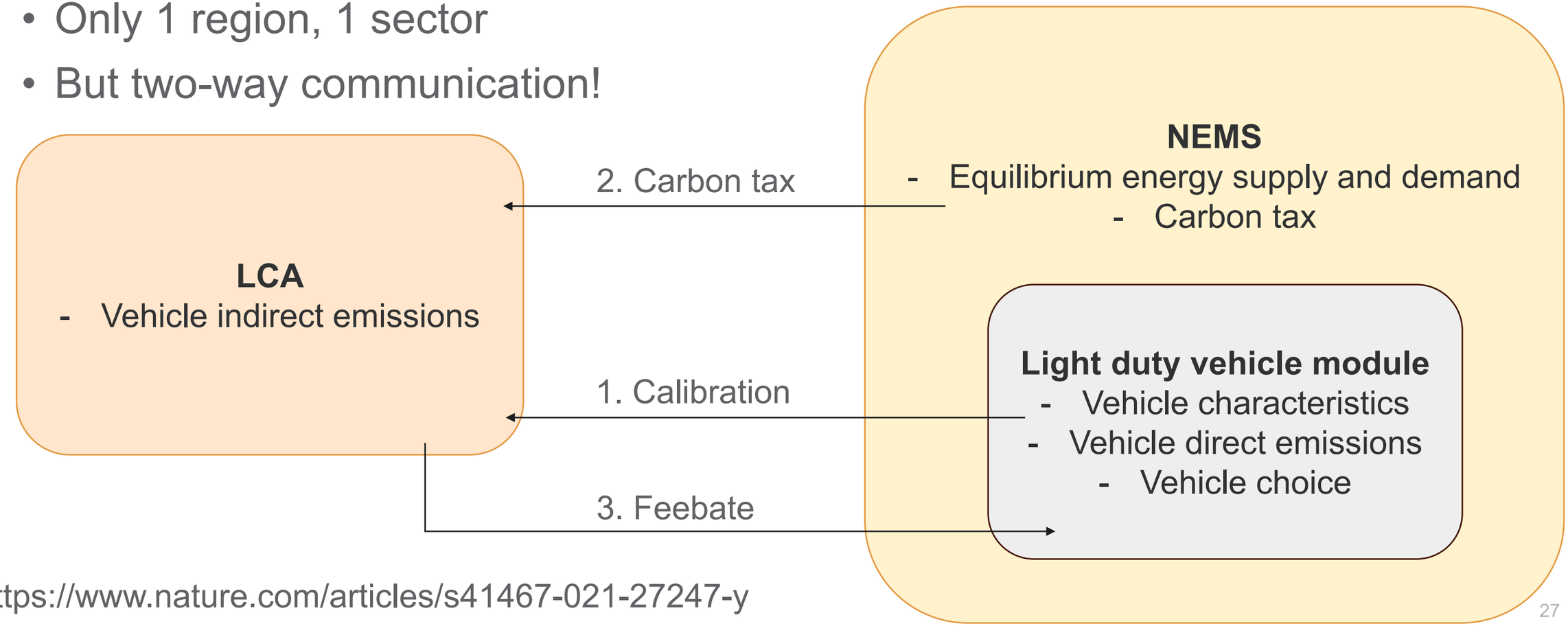
Example: constructing a prospective LCA



https://www.sciencedirect.com/science/article/pii/S136403212200226X

Example: another prospective LCA

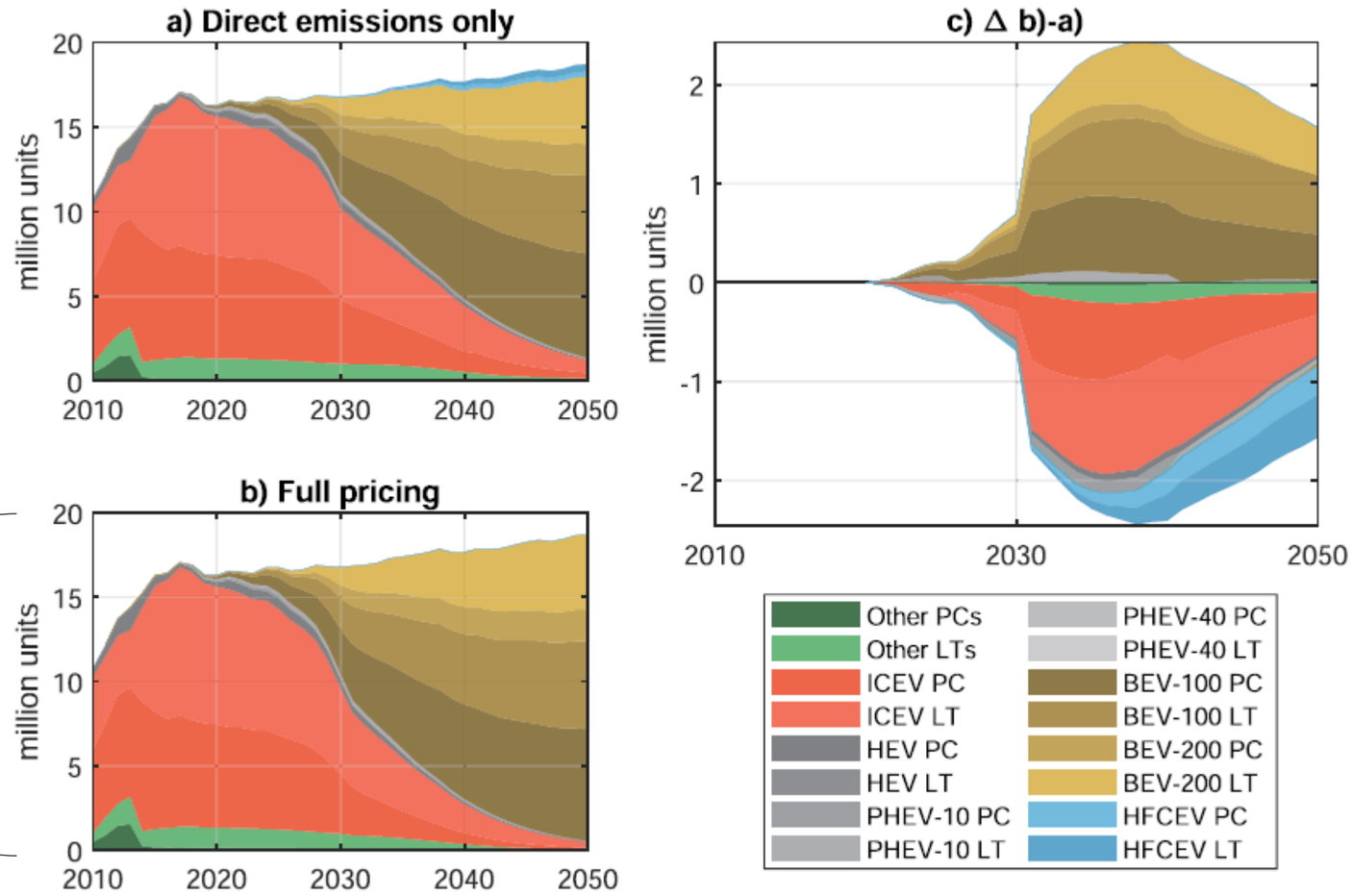
- Soft-linking of LCA and NEMS (not an IAM but still a systems model)
- Less automated
- Only 1 region, 1 sector
- But two-way communication!



https://www.nature.com/articles/s41467-021-27247-y

Example: Insights from prospective LCA

- Integrating LCI coefficients into vehicle choice procedure does affect optimal vehicle choice pathways, see difference between a) and b)



Integrated LCA results

https://www.nature.com/articles/s41467-021-27247-y

Example: “GCAM LCA” tool

- Tool “swims” upstream from end-use sector to primary energy carrier
- Production of equipment and/or infrastructure not included

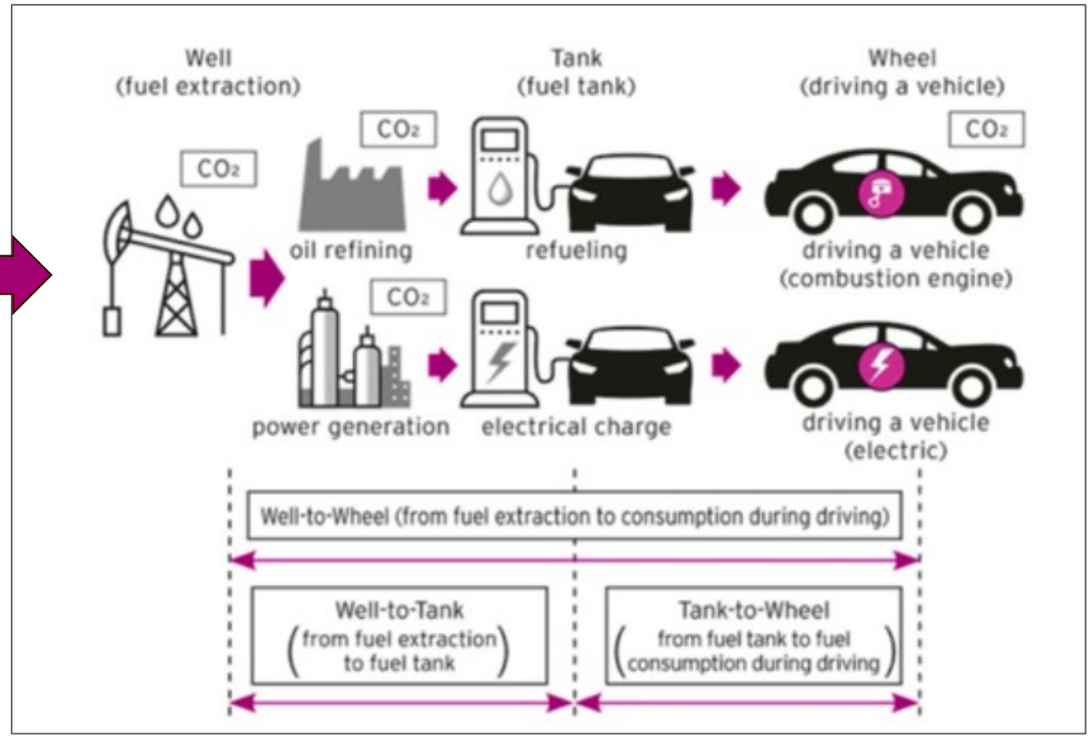
Solar

Oil

Biomass

Natural gas

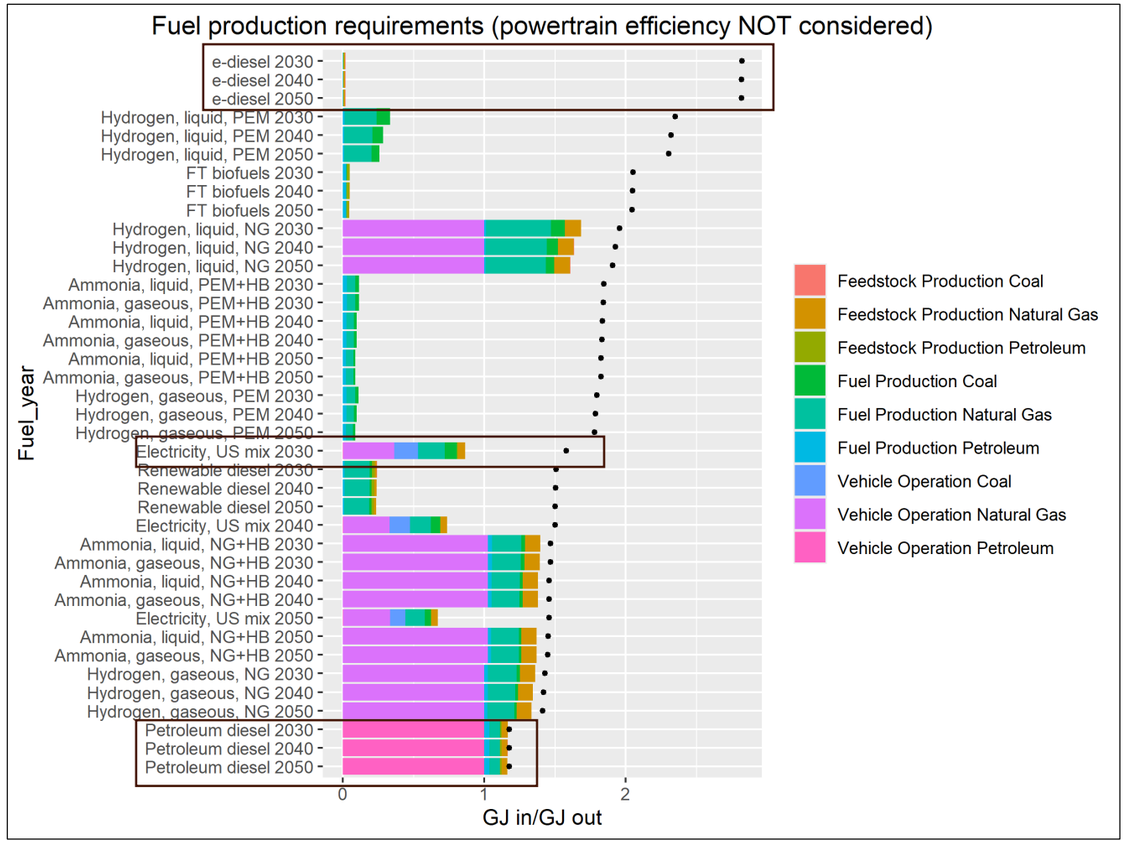
…



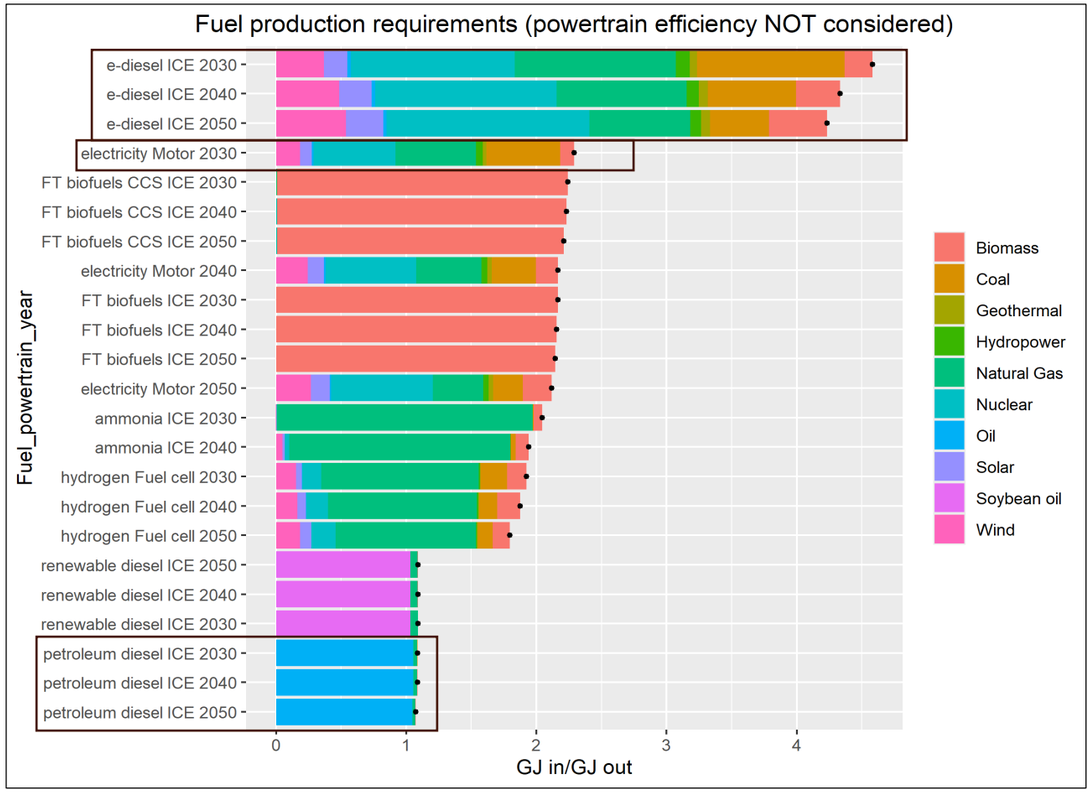
https://kleebinder.net/future-smartmobility-needs-sustainable-cleanenergy/

Example: Comparison of GREET and “GCAM LCA”

- Very preliminary results!
- GREET:



- GCAM:



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Acknowledgements

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