A METHODOLOGICAL APPROACH TO PROSPECTIVE LIFE CYCLE ASSESSMENT FOR THE HARMONIZATION OF THE FOREGROUND AND BACKGROUND SYSTEMS

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DLR

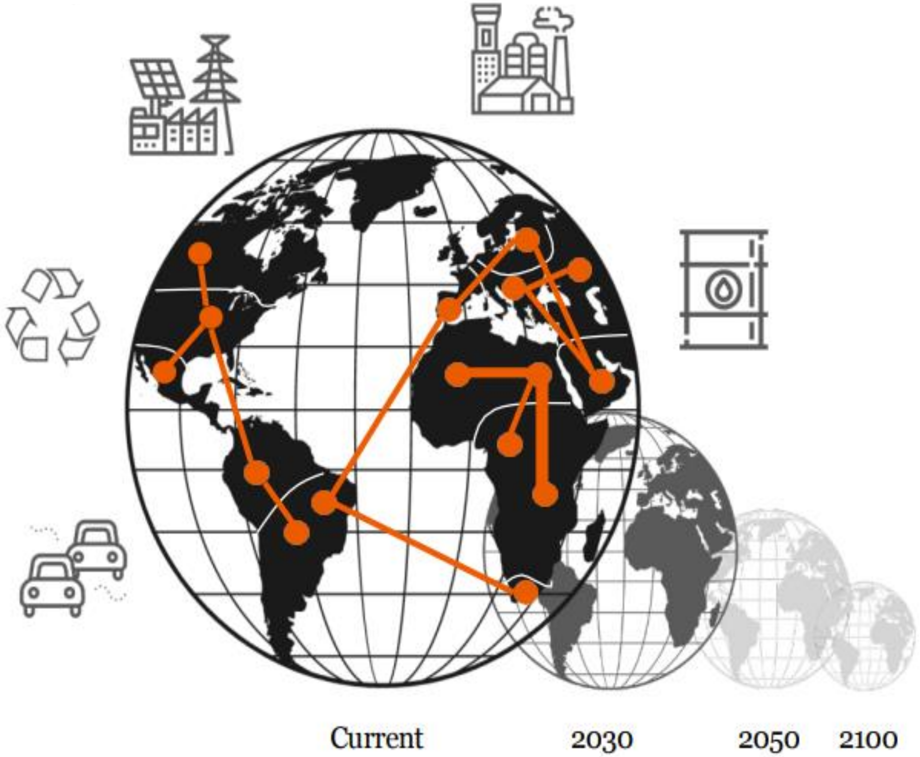
AGENDA

- Introduction
- Background
- Methodology
- Conclusion

Introduction

- **Energy** is generated or utilized from the power sector, industry, transport, and households
- Going forward, all these sectors, including their technologies → **massive transformations** to achieve sustainable pathways
- **Prospective life cycle assessment (pLCA)** → future environmental impacts of these technologies can be evaluated over their life

Transformation of energy pathways*



*Source:*Romain 2021*

Background

- pLCA studies in the literature → Focus on the implementation of future scenarios **either in the foreground or background systems**
- Life cycle inventory (LCI) data in the foreground **does not change** in line with the background system or vice versa
- Also, PREMISE* **does not offer** background system data at a country level for pLCA, offering support only at regional level

**Premise is an open source software developed by PSI → facilitates the creation of prospective inventory databases*

Research Question

- How to carry out pLCA for a specific technology at country level, considering the approach of harmonizing the foreground with background systems?

Methodology

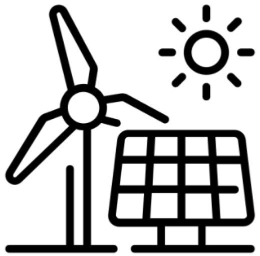
- Harmonization could be achieved in three steps:
  - Step 1 → Identification of key measures in a background scenario
  - Step 2 → Design of the foreground system
  - Step 3 → Integration of background system data into PREMISE*

**Premise is an open source software developed by PSI → facilitates the creation of prospective inventory databases*

Step 1: Identification of key measures in a background scenario (1/4)

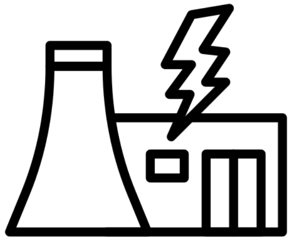
Some of the key measures identified in an exemplary scenario of IMAGE RCP 1.9*

Technological review at sectorial level

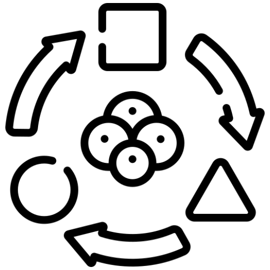


Direct use of renewables – Heat

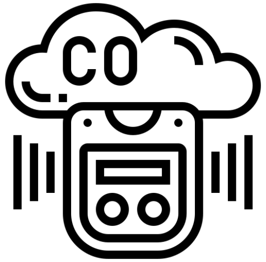
Energy conservation and efficiency



Electrification



Material Circularity



Carbon removal measures

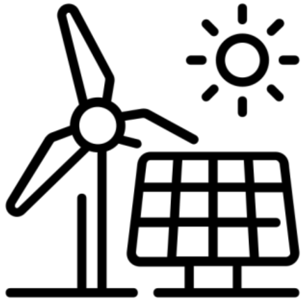
*IIASA (2024) RCP Database. https://tntcat.iiasa.ac.at/RcpDb/dsd?Action=htmlpage&page=about

Step 1: Identification of key measures in a background scenario (2/4)

Technological review at sectoral level

- Sectors like electricity, transport, steel, cement, others
- Identify the technologies at sectoral level responsible for energy transition
- Power sector by 2050 → Renewables (75%), fossil with CCS (25%)

Direct use of renewables – Heat



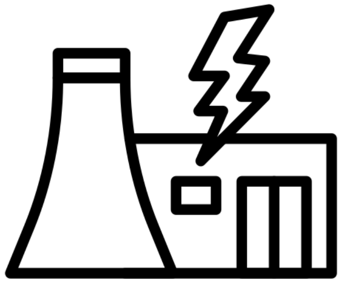
- Heat produced renewable sources like solar, wind, biomass, geothermal
- Identify the fuels (possibly greener) that could be used for heating applications
- Natural gas is replaced by green hydrogen after 2030

Step 1: Identification of key measures in a background scenario (3/4)

Energy conservation and efficiency

- Point out the energy efficiency measures at sectoral level to the reduce energy demand
- Most of the technologies across the sectors assumed to reach optimal efficiency by 2050

Electrification

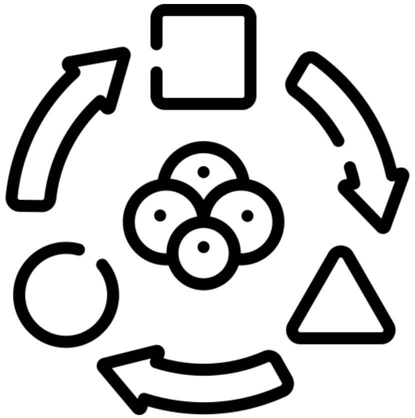


- Identify the sectors that use direct electricity for end-use applications
- Road Transport – EV’s, Steel – EAF

**EAF – Electric Arc Furnaces*

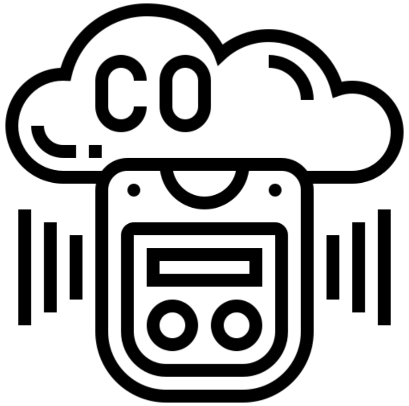
Step 1: Identification of key measures in a background scenario (4/4)

Material circularity



- Focus on the raw materials as a part of circular economy practices
- Production of steel through scrap → dominates by 2050

Carbon removal measures



- Identify the sectors that deploy CCS systems
- Sectors deployed CCS include power generation, fuel production, steel, cement → 2030

**EAF – Electric Arc Furnaces*

Step 2: Design of the foreground system (LCI)

- Aim is to use the **synergies** from the measures of a background scenario
- Focus on selection of **technology, components, and materials/energy carrier**
- Two exemplary use-cases to demonstrate the foreground system design considering key measures includes:

− **Production of liquid hydrogen**

− **Production of a fuel cell**

Step 2: Design of the foreground system (LCI)

Assessment Level	Status Quo	2030	2040	2050
Technology considered → Align with background scenario				
Components considered → Subsystems of a technology				
Materials/Energy carriers considered → Substances from which components are made/ to operate				

Step 2: Design of the foreground system (LCI)

Assessment Level	Status Quo	2030	2040	2050
Technology considered				
*Production of liquid hydrogen	Natural gas (SMR)	Natural gas (SMR)	Green hydrogen (Electrolysis)	Green hydrogen (Electrolysis)
Components considered				
Materials/Energy carriers considered				

Use-case: **Production of liquid hydrogen, **Production of a fuel cell*

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Components considered				
*Carbon capture technology incorporated in power to liquid	-	CCS	CCS	CCS
Materials/Energy carriers considered				

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Materials/Energy carriers considered				
**Fuel cell stack → Bipolar plates	Graphite	Stainless Steel	Stainless steel	Stainless steel

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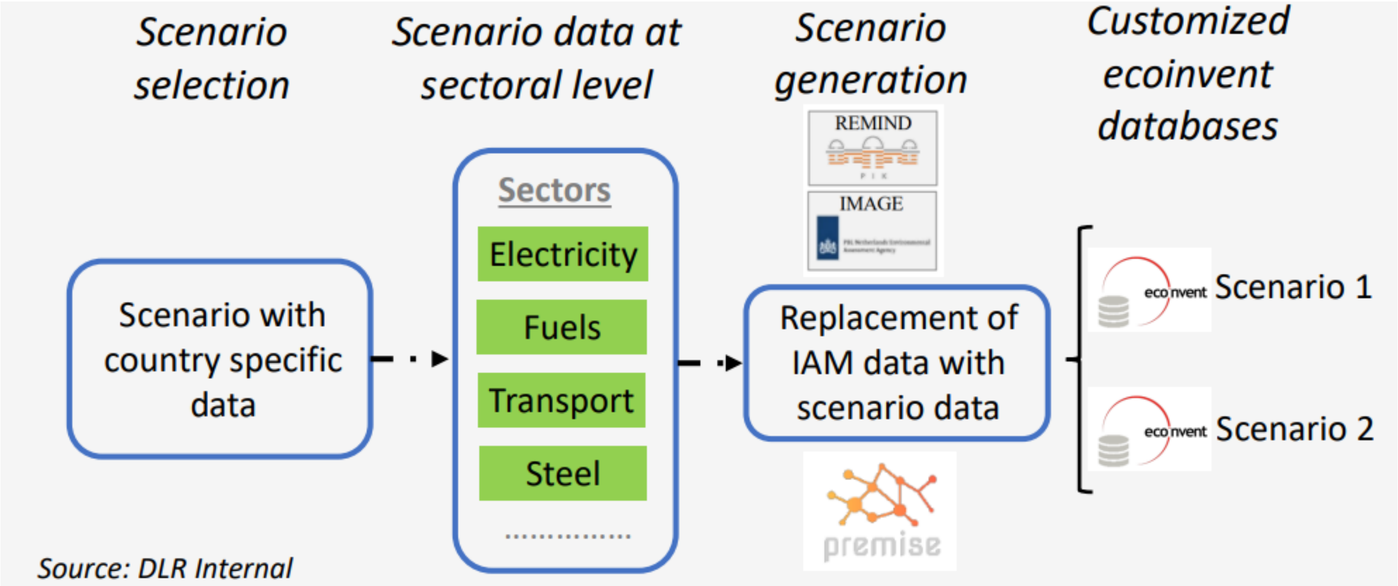
Materials/Energy carriers considered				
**Fuel cell stack → Bipolar plates	Graphite	Stainless Steel	Stainless steel	Stainless steel
**Carbon fiber production → Source of heat	Natural gas	Natural gas	Green hydrogen	Green hydrogen

Use-case: **Production of liquid hydrogen, **Production of a fuel cell*

Step 3: Integration of background system data into Premise



- As PREMISE offers scenario data at only the regional level → need for country-specific scenario
- Scenario data (country-specific) with sectorial level is integrated into PREMISE by using its External Scenario Framework
- These databases are imported into Brightway or Activity Browser to perform pLCA

Conclusion

- Harmonization approach stresses the importance and **inclusion of background systems** in the design of foreground system
- Decision-makers find it easier **to select the prospective technologies,** when both systems are consistent
- It also increases the **accuracy** of environmental impacts evaluation
- Future work will focus on testing the methodology on a use case

THANK YOU

Premise Framework – External Scenario

datapackage.json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{
    "profile": "data-package",
    "name": "ammonia-prospective-scenarios",
    "title": "Ammonia decarbonisation pathways…",
    "description": "Implementation of…",
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    "version": "0.0.1",
    "contributors":[
        {
        "title": "Johanna C. Boyce",
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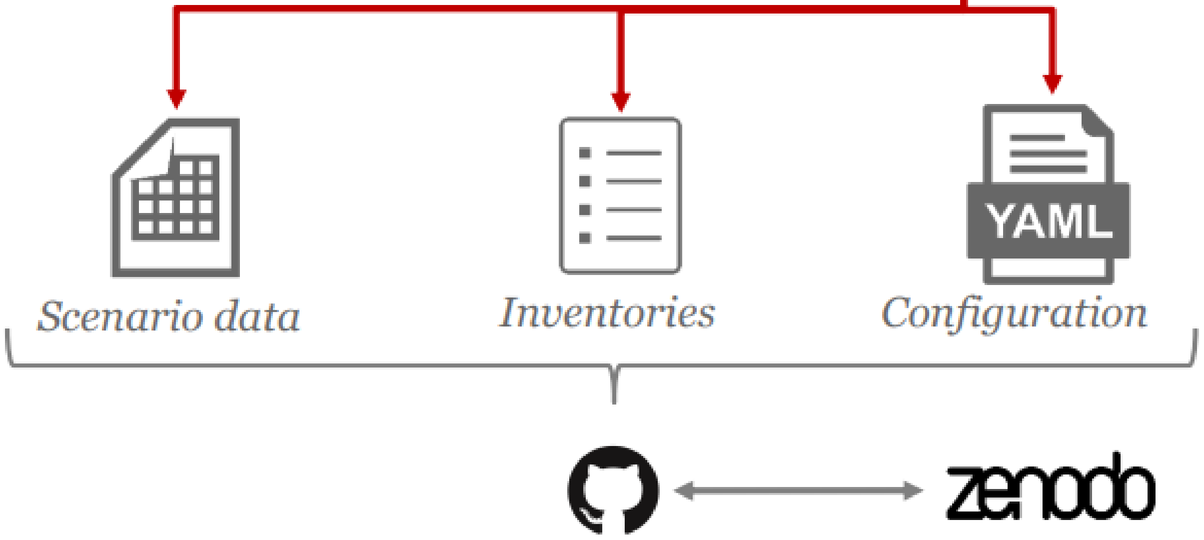
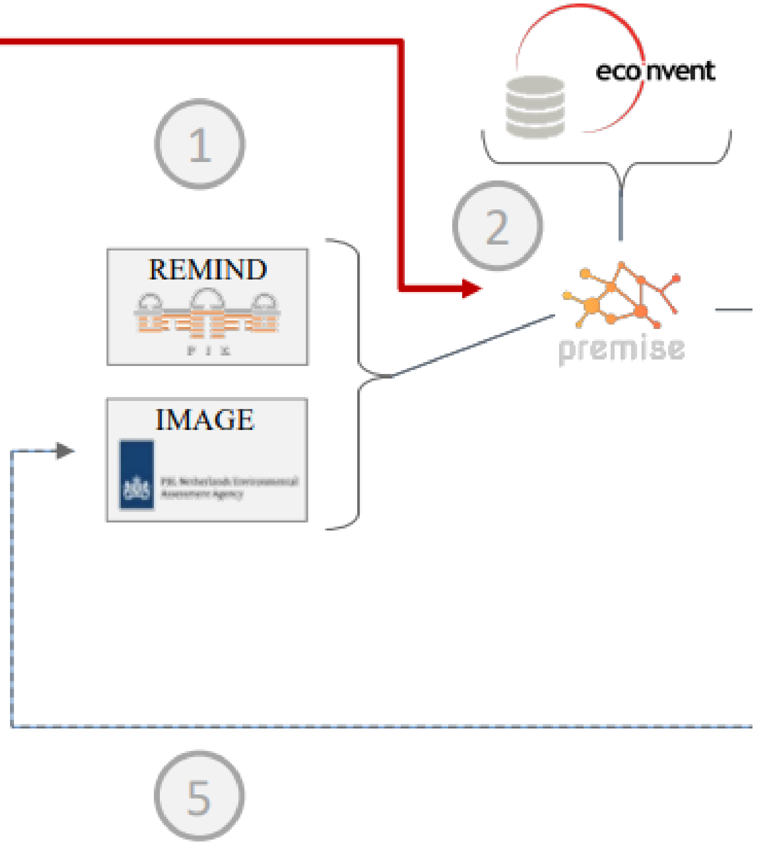
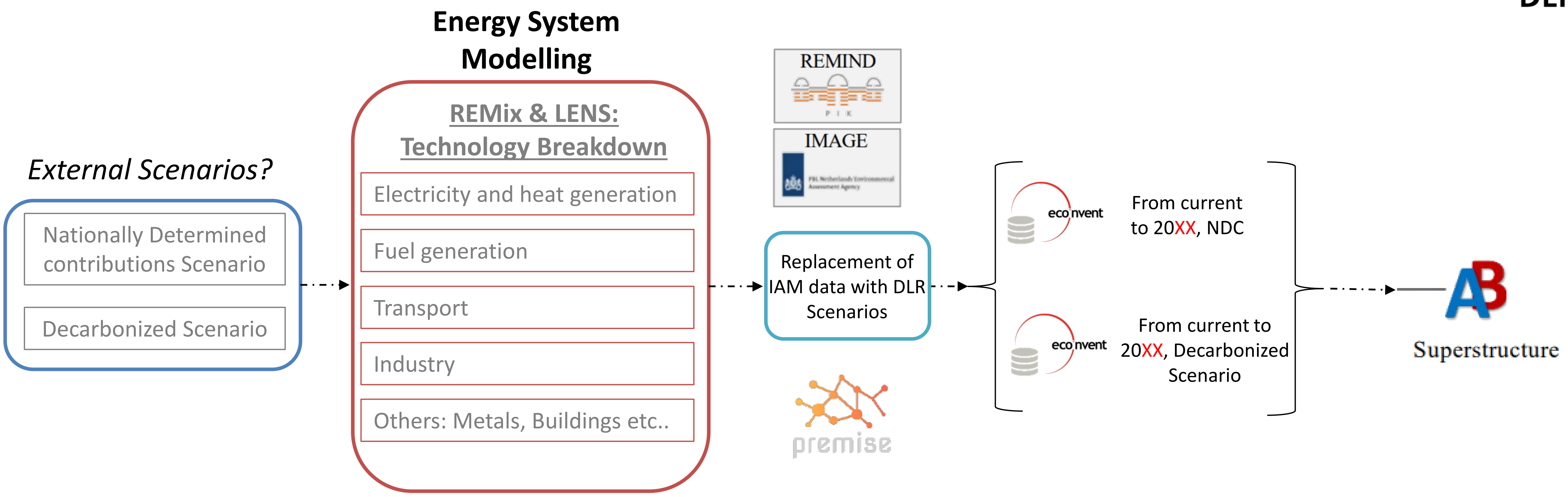




Premise – DLR Scenarios



- Superstructure databases → Imported to activity browser of users to do prospective LCA
- Users could always update scenario data and create a new ecoinvent databases → One individual could control the versions
- Provides flexibility to all team members to carry-out prospective LCA (using AB) without deep knowledge on Premise