Prospective LCA

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Contents

- Research question
- Definition and aims of prospective LCA
- Prospective LCA in the SSbD context
- Challenges of prospective LCA
- Methodologies for prospective LCA
- Scenario construction

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Research question

How can we ensure that emerging technologies are safe and sustainable from the outset—while delivering lower environmental impacts than the mature technologies they aim to replace?

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Prospective LCA – Definition

When the (emerging) technology studied is in an early stage of development (e.g., small-scale production), but the technology is modelled at a future, more-developed stage (e.g., large-scale production).

(Arvidsson et al., 2017)

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Aims

Prospective LCA can be used to assess the environmental performance of an emerging technology to:

Inform technology developers of beneficial changes at an early stage of development

Support decisions of policy makers looking to fund projects

Push manufacturers toward the most sustainable application of a technology

(Caldeira et al. 2017)

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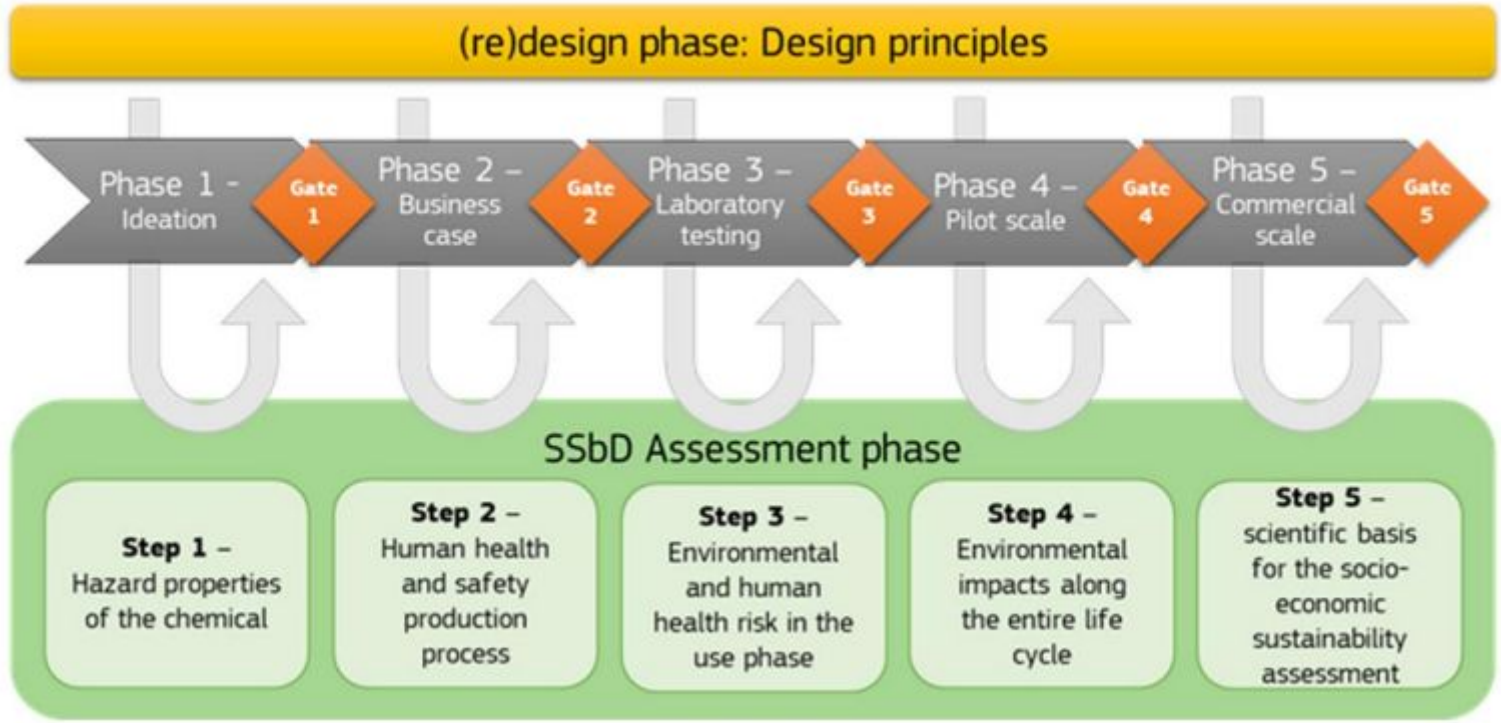
Prospective LCA in the SSbD context



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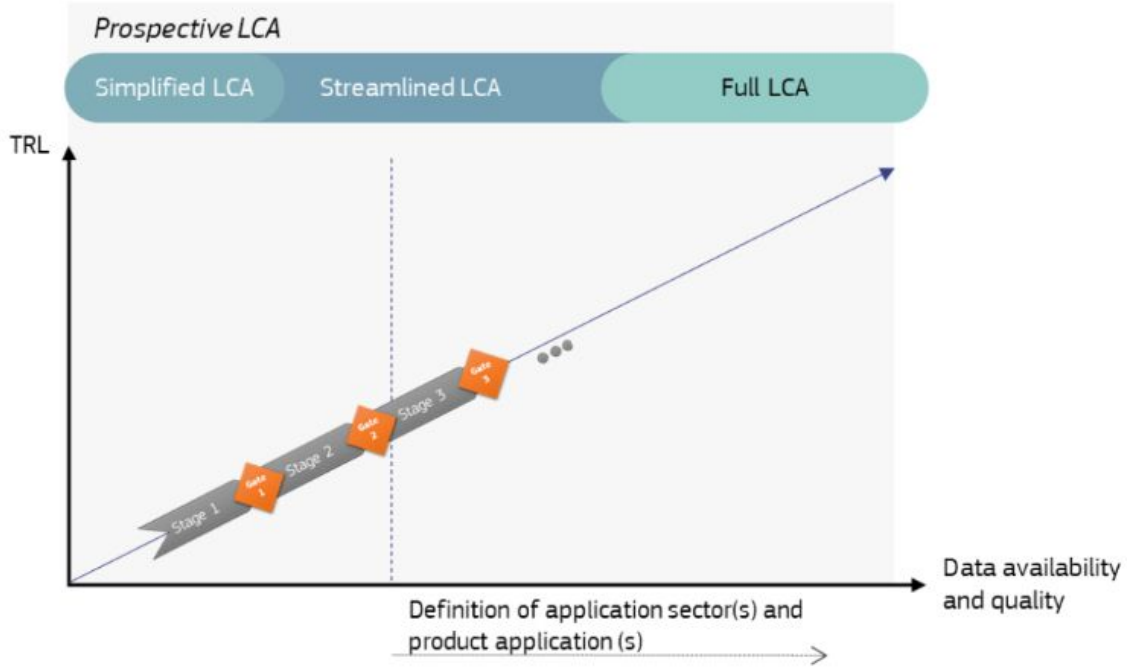
Prospective LCA in the SSbD context

During the innovation process, the following constraints and aspects should be considered, to frame the LCA alongside the innovation stages of a chemical/material:



Tiered approach of the increasing completeness of the (prospective) LCA (JRC, SSbD Methodological guidance 2024)

- The knowledge of the innovation technology, this will increase as the innovation proceeds.
- The temporal scale (timeline) between the start of the innovation and the placing of the end-product of the innovation process on the market.

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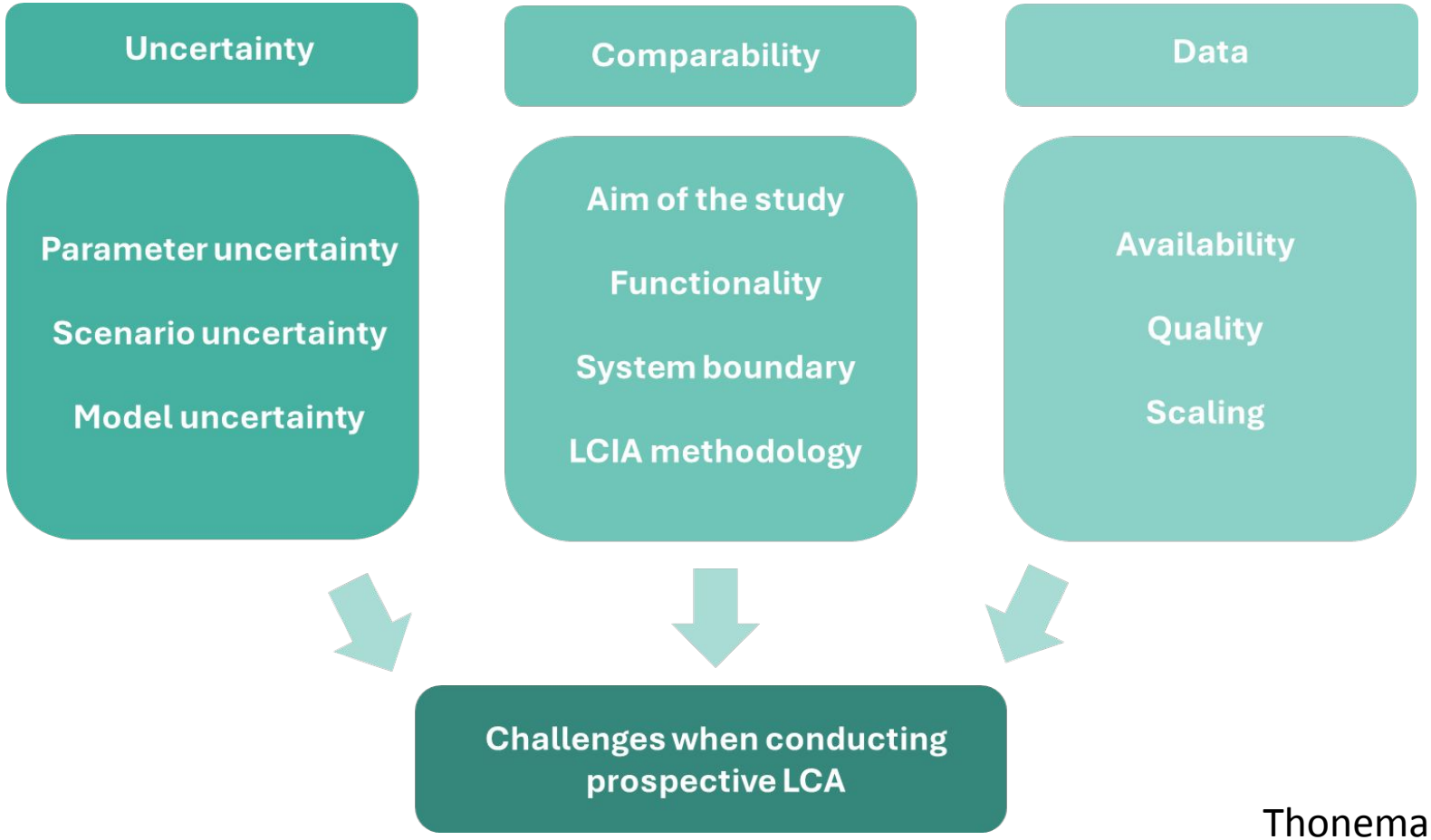
Challenges



Thonemann et al. 2020

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Methodological approaches

How to set up a robust comparison between an emerging and a mature technology

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Comparative analysis

A consistent comparison requires aligning the TRLs of the technologies being assessed.

Functional unit: For emerging systems, functionality may not be fully defined—especially in material production, where quality and technical specifications are critical.

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System boundaries: Are you assessing an intermediate chemical or a final product?

- Avoid limiting the scope to cradle-to-gate, particularly for final products For emerging technologies, downstream processes, use phase, and end-of-life are often unknown.
- It is essential to determine whether these factors could be influenced by product quality.

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→ use scenarios!

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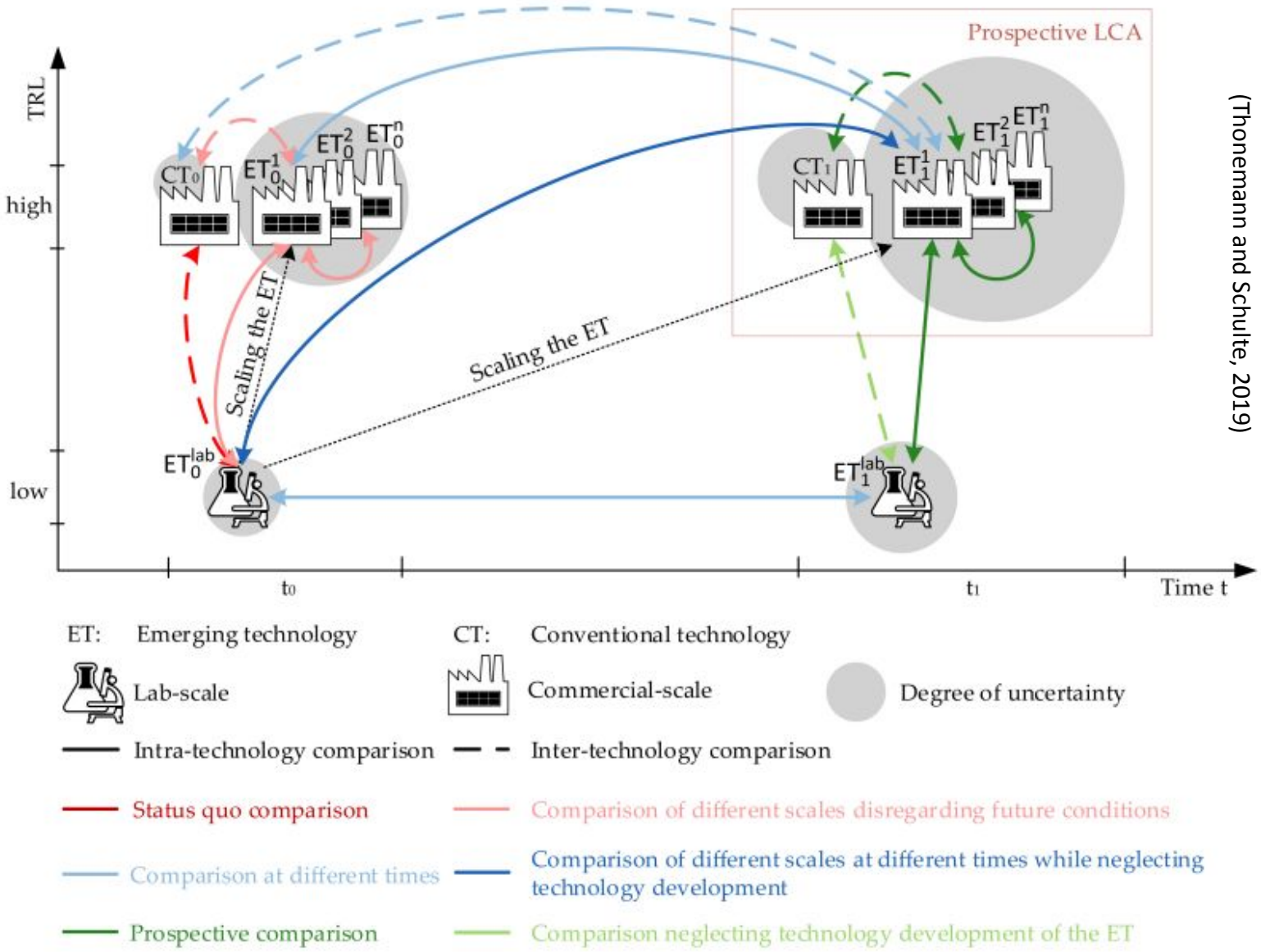
Scale analysis

1. Time scale (years)
2. Technology scale (TRL)



(Thonemann and Schulte, 2019)

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Scale analysis

1. Time scale (years)
2. Technology scale (TRL)
3. Geographic scale
   - **Small/micro scale:** early quantification of LCA impacts for emerging products/technologies.
   - **Medium scale:** support for scale-up and integration of new products/technologies into current and future systems.
   - **Large/macro scale:** regional/national policy evaluation.

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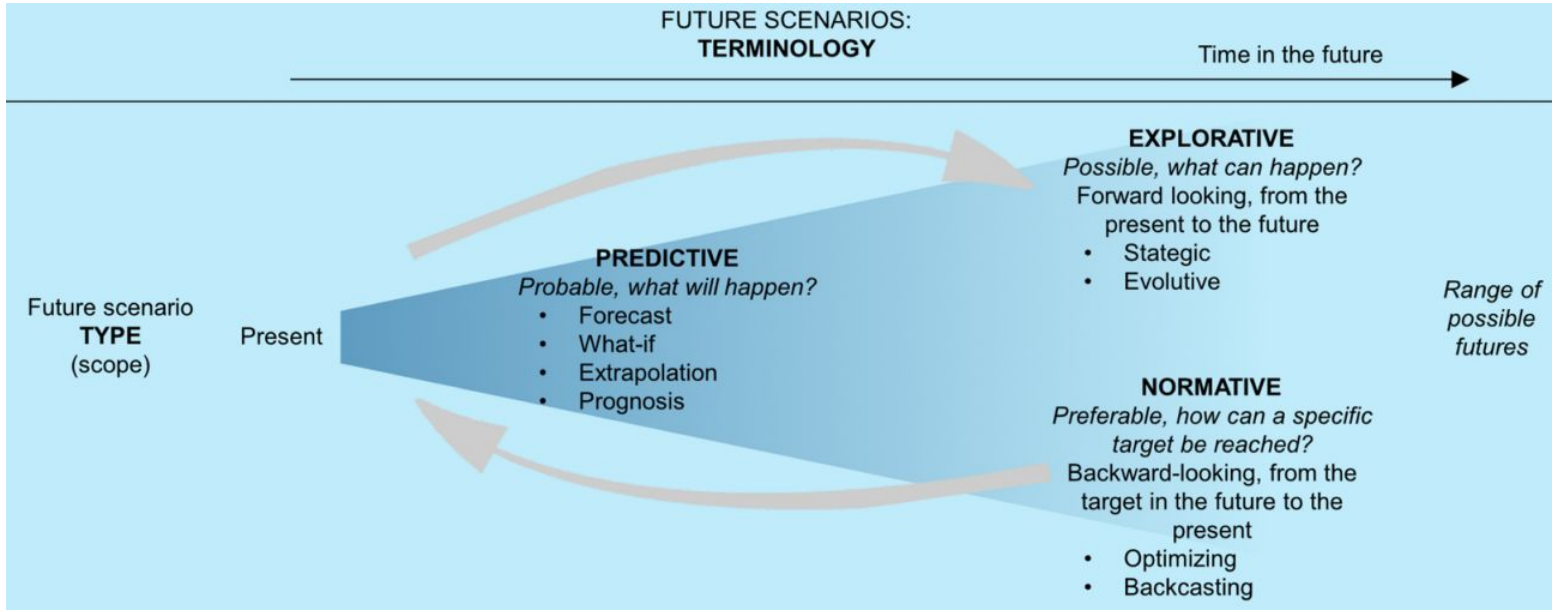
Scenario types

Scenarios are commonly classified into three types:

1. **Predictive** – exploring what might happen.
2. **Explorative** – investigating what could happen under different assumptions.
3. **Normative** – envisioning what should happen to achieve specific goals.



Concept from Börjeson et al., 2006, Image from Bisinella et al. 2020

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Identification of sub-scenarios

Example of an early-stage technology:

Bio-based ethanol production

Two alternative designs:

"Fermentation X" and "Fermentation Y"

each with a different process setup and, consequently, a different flowchart.

Up-scaling

Identification of influencing parameters

Innovative vs Benchmark	Alternatives at present	Alternatives in the future	Main scenarios	Sub-scenarios for different parameters
Innovative	Bio-based ethanol (novel)	Bio-based ethanol (novel) Design x	Scenario 1	
		Bio-based ethanol (novel) Design y	Scenario 2	
Benchmark	Fossil based traditional product	Fossil based ethanol	Scenario 3	

JRC Report on Prospective LCA for Bio-based products(Cucurachi et al. 2022)

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Normative scenarios

SSPX-RCPY scenarios based on the Shared Socio-economic Pathways (SSPs) and the Representative Concentration Pathways (RCPs) scenarios can be used

Shared Socio-Economic Pathway (SSP) scenarios

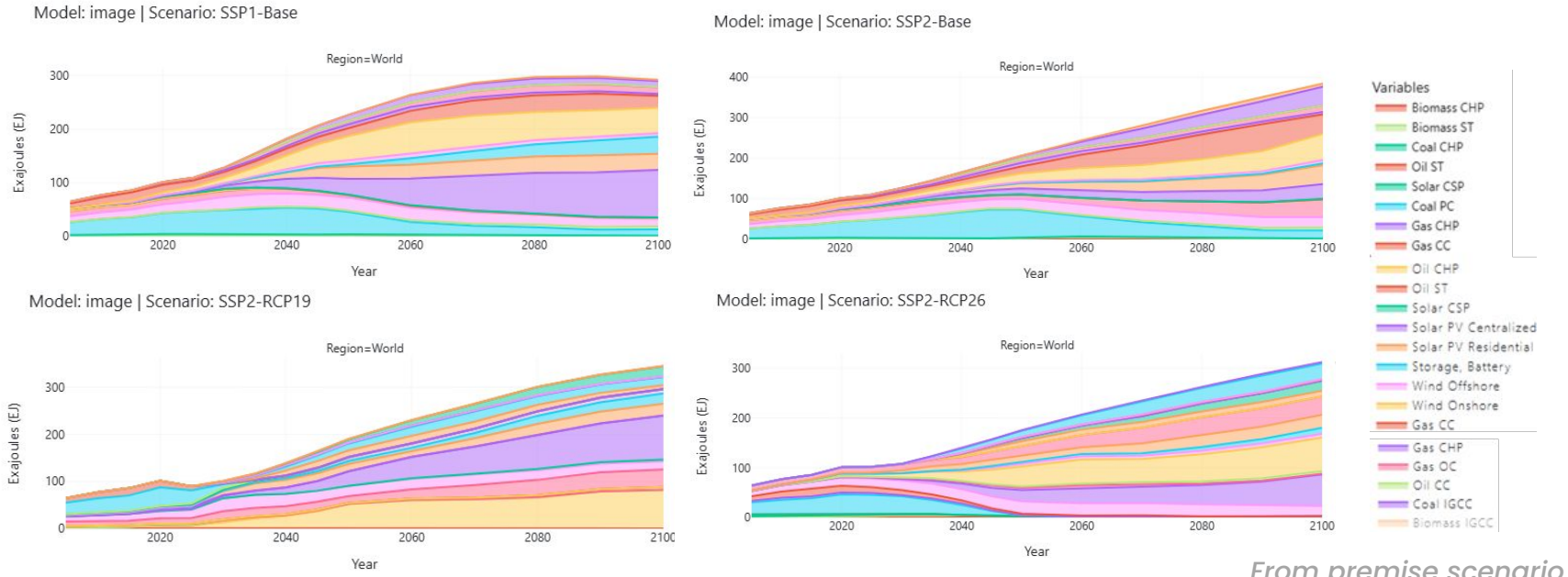
(Brian C. O'Neill et al., 2017)

premise

premise (PRospective EnvironMental Impact asSEment) is a useful tool to integrate projected climate change scenarios from **Integrated Assessment Models** (IAMs)

Example of parameter covered through the use of future background scenarios

Generated volumes of electricity, per technology. Used to calculate the electricty supply mix.



From premise scenario explorer

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Thanks for your attention

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