Recommendations for an informed and responsible use of Integrated Assessment Models in prospective LCA

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COMMENTARY AND DISCUSSION ARTICLE

Recommendations for an informed and responsible use of Integrated Assessment Models in prospective LCA

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Abstract

Purpose Integrated Assessment Models (IAMs) are increasingly used to generate prospective Life Cycle Inventory (pLCI) databases for prospective Life Cycle Assessment (pLCA). This offers advantages, such as reducing temporal mismatches and representing sector-wide mitigation. However, studies often show limited awareness of associated limitations. We aim to raise awareness of these and provide practice-oriented recommendations for the informed and responsible use of IAM-based pLCI databases in pLCA.

Methods Drawing on literature from both the IAM and LCA communities and recent conceptual discussions on the limitations of IAMs in the context of pLCA, we identify key characteristics, and limitations of IAMs relevant for pLCA practice. Based on the authors' experience and literature, we derive practice-oriented recommendations for the informed and responsible use of IAM-based pLCI databases.

Results and discussion We identify nine key IAM characteristics that pLCA users need to be aware of, including sectoral perspective, focus on climate change, weak representation of material cycles, techno-optimism, and narrow economic paradigms. We offer four main recommendations: using IAM-based pLCI databases selectively and purposefully; focussing on a limited set of diverse scenarios; interpreting results critically; and ensuring transparency and reproducibility. We emphasise treating IAM-based pLCI databases as exploratory reasoning tools rather than predictive models by acknowledging the limitations, using systematic approaches to scrutinise results, and exercising caution when interpreting.

Conclusions and Recommendations IAM-based pLCI databases are valuable for exploring future environmental impacts but require careful, informed application. Their limitations must be explicitly acknowledged, and results interpreted as conditional insights rather than predictions. When used responsibly and transparently, these tools support sustainable decision-making. Future research should evaluate which IAMs provide sufficient technical detail for pLCI integration and expand the diversity of economic paradigms represented. Furthermore, efforts should focus on developing formal decision rules linking IAM characteristics to concrete modelling choices, ensuring a more systematic application of IAM data in pLCA.

Keywords Prospective Life Cycle Assessment (pLCA) · Premise · Integrated Assessment Models (IAMs) · Prospective Life Cycle Inventory (pLCI) databases · Interpretation · Scenario analysis · Prospective background systems

1 Introduction

Prospective life cycle inventory (pLCI) databases generated with the Python library *premise* (Sacchi et al. 2022) are widely used in prospective Life Cycle Assessment (pLCA). *premise* generates prospective versions of the *ecoinvent* database (Wernet et al. 2016), drawing on scenarios from process-based Integrated Assessment Models (IAMs) and additional inventories for emerging technologies (Sacchi et al. 2025). Thanks to this approach, we are now able to use transparent and reproducible pLCI databases for

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systematically considering the temporal evolution[1] of background systems.

Process-based IAMs integrate Earth system, economic and societal modelling, with explicit representations of physical processes, to identify long-term scenarios of technology and resource use consistent with specific climate targets[2] (Sacchi et al. 2025) and embedded in the broader socio-economic narratives of the Shared Socioeconomic Pathways (SSPs) (O'Neill et al. 2014; Braunreiter et al. 2021; Sacchi et al. 2022). In this context, scenarios are understood as "plausible alternative descriptions of how the future may develop based on a coherent set of assumptions" (van Vuuren et al. 2025). Due to their "unique ability to link mitigation strategies and technology portfolios to cumulative emission budgets and, consequently, warming outcomes" (Mundaca et al. 2019), process-based IAMs form the backbone of the scenario analyses of Working Group III of the Intergovernmental Panel on Climate Change (van Beek et al. 2020). When we refer to IAMs in this article, we always mean process-based IAMs.

As Steubing et al. (2023) emphasised, a broader discussion of the models and data sources underpinning pLCI databases is necessary. In IAM research, model structures, assumptions, and limitations are debated extensively (e.g., Keppo et al. 2021; Pauliuk et al. 2017; Krey et al. 2019), but these discussions have only started to reach the pLCA community. Consequently, many studies using *premise* show little awareness of the limitations associated with the use of IAM data and of the resulting implications for their models, results, and interpretation (de Bortoli et al. 2025).

In a recent contribution, de Bortoli et al. (2025) review shortcomings of IAMs and provide a valuable conceptual foundation for discussing the role of IAMs as data sources in pLCA. They address a broad range of important considerations, including modelling assumptions, economic paradigms, the social embeddedness of models, the realism of IAM scenarios, and ethical issues. Their discussion of IAM limitations is also reflected in a disclaimer in the *premise* repository. While their contribution offers extensive conceptual insights and outlines several avenues for improvement, many of these concern medium- to long-term developments, such as integrating alternative economic paradigms into IAMs. The recommendations that can be directly applied in current pLCA practice primarily relate to scenario selection and transparent disclosure of limitations.

In this article, we aim to provide practice-oriented recommendations for an informed and responsible use of IAM-based pLCI databases in general. We partly build upon and extend the work by de Bortoli et al. (2025) to raise awareness of the limitations associated with IAM-based data. As *premise* is, to the best of our knowledge, currently the only tool available to systematically derive pLCI databases from IAMs, our discussion centres on it, although most of our arguments apply more broadly. We primarily examine the IAM component and less the assumptions, limitations, and uncertainties associated with other constituents of *premise* databases, such as the *ecoinvent* database and the additional inventories. Similarly, we do not focus on the assumptions and limitations involved in translating IAM data into *premise* databases, as these are already well documented (Sacchi et al. 2022, 2025) and can be inspected in the open-source code[3]. We do not aim to provide guidance on selecting specific scenarios or models.

For readers interested in further exploring IAMs and their role in pLCA, we provide a curated and annotated list of references in the Appendix.

2 Advantages of using IAM data for pLCA - the promise of *premise*

In *premise*, prospective versions of the *ecoinvent* database are generated by adjusting market shares, efficiencies, and emission factors of technologies according to the scenario results of specific IAM-SSP-climate target combinations (Sacchi et al. 2022; Šimaitis et al. 2025). Currently, five IAMs are supported: *REMIND* (Baumstark et al. 2021), *IMAGE* (Stehfest et al. 2014), *TIAM-UCL* (Pye et al. 2020), *GCAM* (Calvin et al. 2019), and *MESSAGEix* (Huppmann et al. 2019)[4]. The extent to which the *ecoinvent* database is modified depends on the variables[5] provided by the respective IAM; only flows for which corresponding IAM variables are available are modified in the Life Cycle Inventory (LCI) data (Sacchi et al. 2025). *MESSAGEix*, for example, does not provide any transport-related variables (Sacchi et al. 2025); as a result, the temporal evolution of transport systems is not represented in the pLCI database when *MESSAGEix* is selected. As noted earlier, *premise* also incorporates inventories for emerging technologies not yet represented in the *ecoinvent* database, drawing on recent pLCA literature (Sacchi et al. 2025). *premise* also offers the option to add global warming

[1] *Temporal evolution* refers to how future systems could look like at a future point in time, in contrast to *temporal distribution*, which describes how processes and environmental flows are distributed over time for a given demand (Müller et al. 2025).

[2] The IAMs differ in how climate targets are specified; see the *premise* documentation (Sacchi et al. 2025) for details. Throughout our article, we use "climate target" as a shorthand for climate change mitigation target.

[3] https://github.com/polca/premise.

[4] We take all information on *premise* from the version 2.3.7 documentation (Sacchi et al. 2025), last accessed 22 April 2026.

[5] In IAMs, "variables" are not statistical variables, but quantities that can change over time or across scenarios. These may include scenario inputs, intermediate model states, or model outputs.

Table 1 Summary of the key properties of the five IAMs currently supported in *premise* (Keppo et al. 2021; Sacchi et al. 2025). The number of variables used does not necessarily reflect the overall usefulness or relevance of the IAM for *premise*. For further detail, we refer readers to the *premise* documentation (Sacchi et al. 2025)

	REMIND	IMAGE	TIAM-UCL	GCAM	MESSAGEix
Modelling approach	Optimisation	Simulation	Optimisation	Simulation	Optimisation
Economic equilibrium assumption	General	Partial	Partial	Partial	Partial
Foresight	Perfect	Myopic	Perfect	Myopic	Perfect
Geographical scope	Global, 13 regions	Global, 26 regions	Global, 17 regions	Global, 29 regions	Global, 12 regions
Variables used by *premise*					
– electricity	34	51	61	41	43
– fuels	49	56	55	48	24
– heat	24	38	2	13	30
– transport	142	84	174	97	0
– steel	42	117	119	23	14
– cement	4	45	7	12	26
– carbon dioxide removal	11	5	3	4	7
– biomass & crops	2	14	3	12	3
– other	4	4	4	4	4
– total	312	414	428	254	151

characterisation factors for biogenic carbon and hydrogen emissions, which are often not characterised in standard Life Cycle Impact Assessment methods but increasingly relevant in IAM scenarios (Sacchi et al. 2025a).

Through modelling the temporal evolution of the background system, *premise* helps address a central challenge in pLCA: temporal mismatches between foreground and background systems (Arvidsson et al. 2018; Mendoza Beltran et al. 2018; Sacchi et al. 2022). For example, when assessing future electric vehicles, projected powertrain efficiencies (foreground) are sometimes combined with today's electricity mix (background), creating inconsistencies that may distort estimated environmental impacts. *premise* also enables the representation of sector-wide climate change mitigation efforts (Bruhn et al. 2023). Beyond this, *premise* helps align LCA with the narratives used in IPCC assessments and policymaking (i.e. the SSPs and climate targets) and enhances comparability across pLCA studies by providing consistent and reproducible pLCI databases (Sacchi et al. 2022). It is also less prone to human error than manual background-wide inventory modifications (Bruhn et al. 2023).

3 Key characteristics of premise-integrated IAMs and potential limitations for pLCA

While all IAMs can model futures in which specific climate targets are met under specific socio-economic conditions (i.e., SSPs), the pathways to achieving these targets differ among the IAMs. Their heterogeneity makes generalisations somewhat difficult (Pauliuk et al. 2017; de Bortoli et al. 2025). Key differences between IAMs include economic equilibrium assumptions (partial, general, or non-equilibrium); modelling approach (simulation or optimisation of welfare or costs); treatment of foresight (myopic or perfect); representation of technological change (exogenous or endogenous); geographical, sectoral, technological, and temporal resolution; technology coverage; and specific parameter assumptions (Krey et al. 2019; Keppo et al. 2021; Guivarch et al. 2023; Riahi et al. 2023). Table 1 summarises major properties of the IAMs currently supported in *premise*; a detailed discussion of which is beyond the scope of this article.

Building on de Bortoli et al. (2025) and the critiques produced by the long-standing debates around IAMs (see the list of references we provide in the Appendix)[6], we identify nine characteristics of IAMs that are important to understand as they are associated with potential limitations in the context of IAM-based pLCI databases:

1. **Sectoral perspective**: IAMs adopt a sectoral rather than a life cycle perspective (Pauliuk et al. 2017). Sector outputs are typically driven by exogenous assumptions or aggregated economic demand, instead of causality feedback within life cycles (Pauliuk et al. 2017). Coverage varies substantially (Pauliuk et al. 2017), but IAMs are generally focussed on sectors with high climate change impact (Steubing et al. 2023). Many industries, such as the production of chemicals, are aggregated under coarse categories like industry (Pauliuk et al. 2017) and technological resolution within sectors is low compared to LCA needs. Consequently, IAM-based pLCI databases have gaps, as not all sectoral mitigation efforts are represented, and translating IAM outputs to LCI data requires additional assumptions, introducing uncertainty (Sacchi et al. 2022).

[6] Please note that many critiques conflate the *process-based* IAMs, on which *premise* relies, with the conceptually distinct *cost–benefit* IAMs (Braunreiter et al. 2021).

2. **Focus on climate change**: IAMs focus on the sectors most relevant to climate change and scenarios mainly feature technologies that reduce greenhouse gas emissions (Sacchi et al. 2022; Bruhn et al. 2023). As a result, "pLCA based on IAM scenarios integration falls short of supporting decisions for environmental indicators other than climate change" (Bruhn et al. 2023).
3. **Weak representation of material cycles**: IAMs largely overlook material efficiency (Pauliuk et al. 2017). Energy balances are enforced, but mass balances for materials are not; material extraction, manufacturing, waste treatment, and recycling are typically aggregated with other industrial activities; capital stocks are not linked to their physical material requirements; and vintage tracking is usually restricted to energy assets (Pauliuk et al. 2017). This means that climate change mitigation strategies based on material efficiency and circular economy approaches are not represented in IAM-based pLCI databases. These limitations also raise questions about the biophysical realism of IAM scenarios, particularly regarding the availability and constraints of critical minerals that are central to many IAM scenarios (de Bortoli et al. 2025).
4. **IAMs are not neutral**: Through their paradigms, structures, and assumptions IAMs shape what is considered possible and necessary in the future (de Bortoli et al. 2025; Braunreiter et al. 2021; Proctor 2023). These paradigms, structures, and assumptions in turn are based on the experiences and backgrounds of the developers (de Bortoli et al. 2025). Using IAM-based pLCI databases partially incorporates these assumptions, constraining results to what the IAMs consider possible and desirable (de Bortoli et al. 2025). While IAM scenarios include substantial technological shifts, fundamental economic and social structures remain largely unchanged (van Beek et al. 2020; Proctor 2023). This means that IAMs, and hence derived pLCI databases, do not explore the full range of possible future scenarios.
5. **Narrow economic paradigms**: Most IAMs rely on neoclassical, green-growth economic paradigms, with limited representation of alternative economic perspectives (Hickel et al. 2021; de Bortoli et al. 2025). All IAMs in *premise* rely on well-functioning markets in equilibrium (Keppo et al. 2021), an assumption that is contested (Hafner et al. 2020), for example because it implicitly relies on full employment of production factors (Guivarch et al. 2023). The narrow economic paradigms constrain scenario space in IAM-based pLCI databases, although future updates to the SSPs may broaden economic perspectives (O'Neill et al. 2020).
6. **Techno-optimism**: Although recent efforts have sought to broaden the scenario space; for example, by including reduced energy and service demand in sectors (Guivarch et al. 2023; Grubler et al. 2018); sufficiency measures and lifestyle changes are still underrepresented in IAMs (Braunreiter et al. 2021; Riahi et al. 2023). As a result, they often rely on ambitious technological improvements and rapid deployment rates (Hickel et al. 2021; de Bortoli et al. 2025). These are facilitated by the fact that constraints, particularly social, political, and institutional factors, are represented only rudimentarily in IAMs (de Bortoli et al. 2025; Riahi et al. 2023). These ambitious technological improvements and rapid deployment rates propagate into pLCI databases.
7. **Structural modelling choices shape technology adoption**: While IAMs are generally techno-optimist, their specific assumptions and model structures produce varying outcomes for different technologies. Patterns often deviate from the characteristic S-curve of technology adoption (Kaya et al. 2017; Way et al. 2022). Generally, IAMs show persistent overreliance on negative emission technologies (NETs)[7] (van Vuuren et al. 2017; Creutzig et al. 2021; Dhakal et al. 2023; Deprez et al. 2024), and underestimation of renewables (Creutzig et al. 2017; Way et al. 2022; Dhakal et al. 2023). Discount rates, on which all currently in *premise* available IAMs rely (Butnar et al. 2020), reinforce these patterns, as higher rates favour delayed mitigation and increase reliance on NETs (Guivarch et al. 2023). This leads to pLCI databases that show the same overreliance on NETs. Although these limitations are well-known, scenarios without NETs remain rare (Grubler et al. 2018). Generally, staying within climate targets without employing NETs requires a faster transition away from fossil fuels and substantial reductions in energy demand (van Vuuren et al. 2017; Deprez et al. 2024). Therefore, pathways without NETs also rely on strong structural assumptions, for example, a rapid decline in energy intensity of the Gross Domestic Product (Hickel et al. 2021).
8. **Limited transparency and specialised expertise required**: The documentation of IAMs is often scattered and incomplete, making them challenging to understand (Pauliuk et al. 2017; Butnar et al. 2020). Transparency has improved, *REMIND*'s and *MESSAGEix*'s code being

[7] The term NET is used inconsistently in the literature (Tanzer and Ramírez 2019), and none of the papers we cite on the topic provide explicit definitions. While we retain the term NET for consistency with the cited literature, we understand it to mean the same as the IPCC AR6 WGIII definition of carbon dioxide removal: "Anthropogenic activities removing carbon dioxide (CO_2) from the atmosphere and durably storing it in geological, terrestrial, or ocean reservoirs, or in products" (van Diemen et al. 2023). This does not imply that these technologies necessarily deliver net negative greenhouse gas emissions across their full life cycle (Tanzer and Ramírez 2019).

open source[8] are notable examples, but "having, and transmitting, a full understanding of the various choices made in the modelling process is likely to remain a challenge" (Keppo et al. 2021). Even with better documentation, fully comprehending an IAM requires expertise rarely possessed by LCA practitioners (Keppo et al. 2021; de Bortoli et al. 2025). This is not a reason to strictly avoid IAM-based pLCI databases; complex assessments like LCA always rely on expertise from multiple disciplines. For example, LCA practitioners typically do not understand the impact assessment methods they use in detail. Nevertheless, the use of IAM-based pLCI databases further increases underlying model complexity and thus makes interpreting the results of pLCI studies potentially more challenging.

9. **Additional assumptions in translating IAM scenarios into pLCI databases**: On top of the limitations of IAMs discussed above, there is also the matter of translating this data into a pLCI database. Generic data with coarse technological and geographical resolution, such as grid-mixes for electricity production within an IAM world region, need to be translated to specific inventory data, introducing uncertainty. For example, an IAM may prescribe 'x% market share for electricity from solar' but a mix of different solar technologies could fulfil this requirement in an LCI database. These choices must be made using external data or assumptions in *premise*. While *premise* reduces human error (Bruhn et al. 2023), frequent updates lead to version-dependent results, even for identical IAM–SSP–climate target–year combinations, and the underlying changes can be difficult for non-technical users to trace.

Generally, users of IAM-based pLCI databases need to be aware that building on another modelling family inherently carries forward its characteristics and limitations (de Bortoli et al. 2025). IAM-based pLCI databases should therefore be used thoughtfully, interpreted critically, and selected in alignment with the research question, as we outline in the recommendations below.

4 Recommendations for an informed and responsible use of IAM-based pLCI databases

Based on the aspects discussed above and our own experience, we offer four recommendations for users of IAM-based pLCI databases. We structured this section loosely around the typical sequence of conducting a pLCA, focusing only on the steps where our recommendations are applicable: first, deciding whether to use IAM-based pLCI databases; next, developing scenarios if they are used; then, interpreting the results; and finally, ensuring transparency and reproducibility.

4.1 Use with purpose

Generally, pLCA practitioners are free to choose their scenario-building approach, IAMs being only one of them. We recommend that LCA practitioners carefully consider whether the use of IAM-based pLCI databases is necessary, given the goal and scope of their study. IAM-based pLCI databases should be applied only when they clearly serve the goal and scope of the specific LCA study, not by default.

Critical in this decision is an understanding of the characteristics and potential limitations of IAMs for pLCI databases, as outlined in sect. 3, including their strong focus on climate change and limited sectoral coverage. Apart from these, we identify four key aspects to consider when deciding if and how to use IAM-based pLCI databases for the background system:

1. **Temporal scope**: Although one could argue that every pLCA requires a pLCI database to prevent temporal mismatches between foreground and background systems, one may weigh the advantages and disadvantages of using pLCI databases for studies focussed on the near future (e.g., 1–5 years ahead). In that case, a pLCI database may not be strictly necessary as supply chains may not differ substantially from current ones. Nevertheless, as databases such as *ecoinvent* do not always reflect the most recent technological developments, it can still be valuable to include additional inventories available in *premise*, even for short-term assessments. This choice should be made on a case-by-case basis by considering which inventories are most up to date and best suited. For studies that look further into the future, avoiding a strong temporal mismatch calls for the use of pLCI background data. We also note that IAM scenarios are created for a specific target year (e.g., 2030) based on assumptions and knowledge at the time of scenario development. When these scenarios are applied in a later calendar year, some assumptions may no longer hold, and this temporal misalignment can complicate the interpretation of pLCA results.
2. **Where are impacts expected to occur**: We recommend assessing where impacts are likely to occur, i.e. rather in the foreground system modelled by the LCA practitioner or deeper in the background supply chains (represented by the pLCI database). If a large part of the impacts is likely to occur in the foreground system,

[8] https://github.com/iiasa/message_ix & https://github.com/remindmodel/remind.

a potential temporal mismatch will have smaller consequences and one might argue that using a conventional LCI database is more acceptable, as the foreground system captures most of the future-related changes. On the other hand, if important contributions are expected throughout supply chains, the benefits of using pLCI databases are evident.

3. **Concentration of impacts in the background system**: However, even if the temporal scope and impacts in background supply chains call the use of a pLCI database, the results should not be blindly trusted. Instead, the model should be scrutinised and amended with own modelling where necessary. This is especially the case when the background system's impacts are dominated by a few key processes (e.g., heat supply). In this case targeted projections for these may be preferable, depending also on their quality in *premise.*
4. **Alternatives to IAM-based pLCI databases**: Consider available alternatives, for example developing custom scenarios through expert elicitation or sector-specific modelling. *premise*'s user-defined scenario function can support this approach (Sacchi et al. 2025). Advantages include greater control for practitioners and the ability to explore extreme or unconventional scenarios; for instance, the potential impacts of breakthroughs such as nuclear fusion on electricity supply.

4.2 Focus on a limited set of distinct and diverse future scenarios

Exploring potential futures comprehensively is important, but too many scenarios can overwhelm interpretation and risk decision paralysis. We recommend selecting a set of cornerstone scenarios that capture a broad range of uncertainties in both foreground and background systems (Langkau et al. 2023; Steubing et al. 2023). One practical method for this is the SIMPL approach (Langkau et al. 2023), as demonstrated by Alaux et al. (2025). We note, however, that larger scenario sets can remain interpretable if results are properly clustered or visualised, and these techniques deserve more attention in pLCA.

For the set of scenarios, diverse IAM–SSP–climate target combinations should be selected (Bruhn et al. 2023; Sacchi et al. 2025). The *premise* documentation provides a good and concise overview of available combinations (Sacchi et al. 2025). Expanding the diversity of IAMs represented in *premise*, as suggested by de Bortoli et al. (2025), is important, but constrained by the need for detailed technological data, which not all IAMs provide (Sacchi et al. 2025). A systematic assessment of which IAMs, beyond those currently integrated in *premise*, provide sufficient technological detail for pLCI databases and expand the diversity of economic paradigms is beyond the scope of this work, but represents an important avenue for future research.

De Bortoli et al. (2025) further recommend either using the full ensemble of IAM scenarios to capture variability or pre-screening scenarios based on "realism criteria", such as historical trends and biophysical flow constraints. They warn that the latter approach can conceal uncertainty. We share this concern and emphasise that excluding future scenarios on the basis of perceived feasibility requires strong justification, ideally grounded in absolute physical limits, such as thermodynamic constraints. Other criteria are less reliable; for instance, historical trends would not have anticipated the rapid development of renewable energy technologies (Way et al. 2022), and resource availability can change substantially over time. Rather than excluding "unfeasible" futures, we suggest focusing on the conditions under which results occur; for example, highlighting outcomes that only emerge in scenarios with strong reliance on NET deployment. Orientation could be drawn from Deprez et al. (2024), who suggest sustainability risk thresholds for land-based carbon dioxide removal. For bioenergy with carbon capture and storage, for example, they define the low sustainability risk zone as up to 0.7–1.2 $GtCO_2$/year, depending on the carbon capture rate.

In the context of scenario design, it is also important to consider that *premise* does not automatically resolve temporal mismatches, but consistent treatment of temporal evolution in the foreground system is also required. Practitioners must also ensure internal consistency between scenarios in the foreground and background systems; for example, avoiding combinations where ambitious climate action narratives in the background system are paired with no climate change mitigation in the foreground system. Consistency checks as included in the SIMPL approach (Langkau et al. 2023) can help here.

4.3 Interpret critically

The interpretation stage of pLCAs is crucial. In the context of IAM-based pLCI-databases, we recommend six aspects to consider:

1. **One can never model *THE* future, but only *A* future**: Despite the IAM community and *premise* developers emphasising the exploratory nature of IAM scenarios, we see users treating results as objective predictions rather than plausible futures. We recommend highlighting which conditions support specific insights and expressing conclusions in the form of 'If…, then…' statements. We furthermore recommend emphasising that scenarios are exploratory, not predictive, and that their likelihoods may differ (Steubing et al. 2023).

2. **Only the IAM scenario can be compatible with a climate target, not the pLCI database**: While it is appropriate to describe an IAM scenario as compatible with the climate target it achieves, this characterisation cannot be directly extended to the corresponding IAM-based pLCI database generated with *premise*. Labelling a pLCI database as "1.5°C target compatible", for instance, should be avoided. This is the case because *premise* does not cover all sectors, the integration of included sectors is incomplete (not all IAM variables are used), and additional assumptions are introduced when translating IAM data into LCI data (Sacchi et al. 2025). As a result, pLCI backgrounds are not fully consistent with the respective IAM scenario and its climate target and may overestimate greenhouse gas emissions (Sacchi et al. 2025). If LCA practitioners choose to use scenario names reflecting those of the IAM, we recommend adding an explanation similar to ours above.
3. **Understand the implications of *premise* background systems for your pLCA**: Interpreting LCA results is often challenging, and more so if it is based on additional complicated models, such as IAM-based pLCI scenarios. We therefore recommend performing systematic contribution analyses (see also van der Meide et al. 2025b) to understand and scrutinise pLCA results. Approaches that could additionally help are: incrementally adding different sectors in *premise* to better understand which sectors drive the results (see e.g. Müller et al. 2024), checking specific flows in the scenario difference file used in the superstructure approach (Steubing and Koning 2021) for data differences between scenarios and the underlying original LCI data (Steubing et al. 2023), and using the *premise* scenario explorer to examine the evolution of variables across IAM scenarios[9]. For an analysis of how environmental impacts of selected products develop across *premise* databases, one may also have a look at Sacchi et al. (2022); Šimaitis et al. (2025); van der Meide et al. (2025a).
4. **Critically assess surprising results**: Some findings may be the result of modelling mistakes (in the *ecoinvent* database, *premise*, IAMs or your own models) and not actual findings. While practitioners should always be critical of LCA results, this should be more so the case for pLCAs. Variations in results between different scenarios are expected; however, large deviations or, conversely, unusually small differences may indicate an underlying error. In such cases, we strongly recommend reporting potential errors to the respective model developers (e.g. the *ecoinvent* database, *premise*, or the IAM).
5. **Interpret impact indicator results beyond climate change cautiously**: Because of the climate change mitigation focus of IAMs, *premise*-based results for impact categories other than climate change should be interpreted with caution (Sacchi et al. 2022; Bruhn et al. 2023; van der Meide et al. 2025a). For example, neither the *ecoinvent* database nor *premise* currently provide inventories for novel refrigerants with lower ozone-depletion impacts, and such substances are also not represented in IAMs. As a result, upcoming bans on ozone-depleting refrigerants are currently not reflected in *premise*, potentially leading to unexpectedly high ozone depletion results (van den Oever et al. 2024). Moreover, pLCA is further complicated by the lack of prospective characterisation factors and by the absence of novel environmental flows from emerging technologies in current Life Cycle Impact Assessment methods (Thonemann et al. 2020; Cucurachi et al., 2023), making impact assessment in pLCA highly uncertain in general.
6. **Treat the model as a reasoning tool, not as a magic box**: Models are simplified representations of reality, useful for understanding systems but not replacing critical reasoning, reflection, and interpretation (Keppo et al. 2021). As Saltelli et al. (2020) put it: "Excessive regard for producing numbers can push a discipline away from being roughly right towards being precisely wrong". Outcomes must always be contextualised and communicated together with their underlying assumptions (Riahi et al. 2023). This also entails acknowledging limitations and uncertainty; not as a formality, but as a discussion of their effects on results through sensitivity and uncertainty analyses.

4.4 Ensure transparency and reproducibility

It is crucial to report the choice of IAM, SSP, and climate target transparently, including their underlying assumptions, scope, and limitations (Bruhn et al. 2023). Beyond this, users should also report the versions of all software used, particularly the exact system model and version of the *ecoinvent* database (Wernet et al. 2016), and for *premise*, the version, covered sectors, and, if applicable, the altered characterisation factors. As noted above, the data can vary substantially between different *premise* versions.

Finally, it is important to clearly document how the *premise* scenarios were derived; for example, through the *Activity Browser* (Steubing et al. 2020) with *ScenarioLink*[10] or via Python. To maximise reproducibility, we recommend using Python and providing the script or notebook, including a list of the software package versions used, alongside the study.

[9] https://premisedash-6f5a0259c487.herokuapp.com/.

[10] https://github.com/polca/ScenarioLink.

5 Conclusions

Generally, we need to remain mindful of what LCA can realistically achieve, which questions it can meaningfully address, and the limitations of the underlying data when interpreting our findings. This calls for humility about what our models can truly tell us, which is an argument increasingly echoed in the literature (e.g., de Bortoli et al. 2025) and a principle that extends beyond pLCA. LCA often relies on incomplete, outdated, and uncertain data even for present-day systems, which limits what can be confidently inferred about current conditions, let alone future ones.

Nevertheless, supporting decisions towards more sustainable societies requires exploring future scenarios, as relying solely on present data can lead to misleading conclusions. In this context, pLCI databases are crucial to avoid biased insights resulting from temporal mismatches. Currently, no alternative to IAMs provides the global scope and technical detail needed for pLCI databases, and a perfect data source will likely never exist (Steubing et al. 2023).

We are convinced that, when used in an informed, selective, responsible, and transparent way, with careful interpretation and alongside a broader reflection on possible, plausible, and desirable futures (Sacchi 2025b) as well as the status of contemporary LCI databases, IAM-based pLCI databases provide valuable information to support decisions that advance more sustainable societies.

Future research should assess which IAMs provide sufficient technical detail for pLCI databases and expand the diversity of economic paradigms. Furthermore, it should explore whether it is possible to develop decision rules linking IAM characteristics to concrete modelling choices in pLCA.

Appendix

For readers wishing to explore further, we suggest beginning with the following (non-exhaustive) set of readings.

Braunreiter et al. (2021) Transformative pathways – Using integrated assessment models more effectively to open up plausible and desirable low-carbon futures. Energy Res Soc Sci 80:102220. https://doi.org/10.1016/j.erss.2021.102220.

The authors summarise critiques of IAMs well, highlighting how they risk to "prematurely closing down possible futures without sufficient societal deliberations". They suggest three directions to mitigate this, which are relevant for any scenario modelling, not only for IAMs.

Bruhn et al. (2023) Ten questions concerning prospective LCA for decision support for the built environment. Build Environ 242:110535. https://doi.org/10.1016/j.buildenv.2023.110535.

Although focussed on pLCAs of the built environment, this review discusses many aspects relevant to any pLCA study.

de Bortoli et al. (2025) More rationality and inclusivity are imperative in reference transition scenarios based on IAMs and shared socioeconomic pathways - recommendations for prospective LCA. Renew Sustain Energ Rev 222:115924. https://doi.org/10.1016/j.rser.2025.115924.

As far as we know, this is the only paper so far that focuses specifically on the limitations of IAMs for pLCI databases. It provides an excellent entry point to the debate.

Evans & Hausfather (2018) Q&A: How 'integrated assessment models' are used to study climate change. https://www.carbonbrief.org/qa-how-integrated-assessment-models-are-used-to-study-climate-change/. Accessed 22 April 2025

A clear and accessible overview of IAMs, their structure, and their role in climate research and policy. We recommend starting with this article.

Guivarch et al. (2023) Annex III: Scenarios and Modelling Methods. In: IPCC (ed) Climate Change 2022: Mitigation of Climate Change: Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK and New York, USA, pp 1841–1908. https://doi.org/10.1017/9781009157926.022.

This Annex to the sixth IPCC assessment report provides a concise overview of key IAM properties, including information on specific models.

Hafner et al. (2020) Emergence of New Economics Energy Transition Models: A Review. Ecol Econ 177:106779. https://doi.org/10.1016/j.ecolecon.2020.106779.

Though not focussed exclusively on IAMs, this review offers a good overview of aspects that are not yet well addressed in mainstream economy-environment models and outlines perspectives that could help overcome these gaps.

Hickel et al. (2021) Urgent need for post-growth climate mitigation scenarios. Nat Energy 6:766–768. https://doi.org/10.1038/s41560-021-00884-9.

A concise comment criticising mainstream climate mitigation models, particularly for their lack of post-growth scenarios, while also discussing other important limitations.

Keppo et al. (2021) Exploring the possibility space: taking stock of the diverse capabilities and gaps in integrated assessment models. Environ Res Lett 16:53006. https://doi.org/10.1088/1748-9326/abe5d8.

The most comprehensive review of limitations of IAMs we have found, including responses by the IAM community. Essential for understanding what IAMs can and cannot do.

Krey et al. (2019) Looking under the hood: A comparison of techno-economic assumptions across national and global integrated assessment models. Energy 172:1254–1267. https://doi.org/10.1016/j.energy.2018.12.131.

Another review of IAMs, but with a stronger emphasis on comparing their assumptions, particularly regarding technologies.

Pauliuk et al. (2017) Industrial ecology in integrated assessment models. Nat Clim Change 7:13–20. https://doi.org/10.1038/nclimate3148.

A review of IAMs from an Industrial Ecology perspective. Essential for understanding the key differences between the two fields.

Proctor (2023) Expanding the possible: exploring the role for heterodox economics in integrated climate-economy modeling. Rev Evol Polit Econ 4:537–557. https://doi.org/10.1007/s43253-023-00098-7.

A good overview of different schools of economic thought and how mainstream models could benefit from integrating alternative perspectives.

Sacchi et al. (2022) PRospective EnvironMental Impact asSEment (premise): A streamlined approach to producing databases for prospective life cycle assessment using integrated assessment models. Renew Sustain Energ Rev 160:112311. https://doi.org/10.1016/j.rser.2022.112311.

This paper describes the *premise* approach and is foundational to the entire field of pLCI databases.

Sacchi et al. (2025) premise: Release 2.3.7. https://premise.readthedocs.io/en/latest/index.html.

The *premise* documentation is essential reading for any user and provides valuable input for discussing the role of IAMs in prospective LCA.

Šimaitis et al. (2025) Expanding scenario diversity in prospective LCA: Coupling the TIAM-UCL integrated assessment model with Premise and ecoinvent. Renew Sustain Energ Rev 211:115298. https://doi.org/10.1016/j.rser.2024.115298.

This paper introduces a new IAM within *premise* and provides valuable insight into what this integration entails and how the choice of IAM influences pLCA results.

Steubing et al. (2023) Conditions for the broad application of prospective life cycle inventory databases. Int J Life Cycle Assess 28:1092–1103. https://doi.org/10.1007/s11367-023-02192-8.

This paper, authored by one of the co-authors of the present article, provides a comprehensive overview of the requirements for pLCI databases.

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Declarations

Competing interests NT serves as Guest Editor for the Special Issue to which this paper was submitted but was not involved in the editorial handling of this manuscript. JG is a member of the Editorial Board of the journal.

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