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RESEARCH ARTICLE

REVISED Open Science Practices in Integrated Assessment Models

[version 2; peer review: 3 approved]

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Abstract

Background

Open science emphasizes the free and accessible dissemination of scholarly outputs to a wide audience, including scientists, stakeholders, and the general public. Its core principle is the open sharing of knowledge to enable reuse, replication, and uphold research integrity.

Methods

Using insights from a survey designed to explore the open science practices within integrated assessment modeling (IAM) teams, as well as the challenges and barriers they face, we propose an open science protocol tailored specifically to the needs of IAMs.

Results

The proposed protocol improves the transparency, accessibility, reliability, reusability, and interoperability of IAM models and results. Grounded in the findability, accessibility, interoperability, and reusability (FAIR) and transparency, responsibility, user focus, sustainability, and technology (TRUST) principles, it supports the transformation of models' outputs into real-world applications.

Conclusions

Open Peer Review

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Any reports and responses or comments on the article can be found at the end of the article.

By fostering enhanced trust and engagement from policymakers, this protocol supports the broader adoption of open science in IAMs. It is complemented by a checklist and includes recommendations for open-source platforms and tools, simplifying workflows and minimizing the need for specialized expertise.

Plain language summary

Open science encourages the free sharing of research and data with scientists, policymakers, and the general public, aiming to make knowledge accessible for reuse and further development. To improve the reliability and widespread adoption of these practices, many scientific communities have developed tailored protocols and standardized methods. Integrated assessment models (IAMs), which provide quantitative insights for global environmental change and sustainable development, and feed into major scientific assessments, must be transparent and open to support informed decision-making. Based on a survey of open science practices carried out by different IAM teams, we developed a protocol to address key challenges and overcome existing barriers in the use of open science practices in integrated assessment modelling. This protocol enhances the transparency, accessibility, and reliability of IAMs and their results, fostering greater trust among policymakers and helping to transform model results into real-world applications.

Keywords

open science, integrated assessment models, protocol, transparency, FAIR, TRUST, open-source, open data



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REVISED **Amendments from Version 1**

This updated version includes several key refinements based on the valuable feedback provided by the reviewers. The following summarizes the specific changes made to enhance clarity, empirical rigor, and technical depth:

1. Expanded Survey Sample: The sample size has been increased to improve the representativeness and robustness of the survey findings.

2. Enhanced Background on Open Science: Additional context has been provided regarding Open Science principles, both generally, in other modeling communities, and in the specific context of Integrated Assessment Models (IAMs).

3. New Methods Section: A dedicated Methods section has been added to detail the survey design, data collection procedures, and analytical approach.

4. Illustrative Table of Examples: A new table compiles illustrative studies aligned with each protocol step, alongside recommended tools to support their implementation.

5. Improved README and Data Format: Revisions to the README file and data formatting enhance reproducibility and transparency of the materials.

6. Refined Figures: All figures have been updated for improved clarity, visual design, and interpretability.

Any further responses from the reviewers can be found at the end of the article

State of the art in open science practices

Open science is a concept that aims to make scientific research and data available to scientists, stakeholders, and the general public. The main principle of open science is based on the idea that scientific knowledge should be freely available to everyone and should be easily accessible for reuse, replication, and further development[1]. It rests on a set of core values[2,3], including transparency, reproducibility, accessibility, and interdisciplinarity, to ensure that scientific research is conducted in an open and transparent manner, and that the resulting data, methodologies, and findings are made available to the broader scientific community and non-expert audiences[4]. By making scientific research and data available to everyone, open science can help to promote scientific progress and drive innovation[5].

The concept of open science has gained momentum in recent years, with a significant number of researchers, policymakers, and funding agencies recognizing the importance of openness in scientific research[6–8]. Researchers from a diverse range of fields strive to remove barriers to information exchange and encourage the academic community to embrace open science procedures[5]. Numerous initiatives and policies also drive the adoption of open science, such as the European Union's Horizon 2020 program, which have implemented open-access mandates[9]. Meanwhile, the European Commission created the EU's Open Science Policy Platform to provide high-level guidance on the development of its Open Science Policy[10]. Similarly, in the United States, a Memorandum[11] was issued to the Heads of Departments and Agencies, promoting the adoption of open science and public access policies across a broad range of institutions, such as the National Institutes of Health[12].

There is an increasing number of resources and platforms available to support open science, including open-access journals, indexed and browsable in the Directory of Open Access Journals[1]; open data repositories, such as the World Bank open data[2] or the World Health Organisation data[3]; open access repositories, such as Zenodo[4] and PubMed Central[5]; software for open-source computing and development, for instance, Unix[6] and Git[7]; collaborative data and computational platforms, such as MSD-Live[8]; and projects to promote open data-driven science, such as the European Open Science Cloud[9] and the Open Energy Modelling Initiative[10]; all of which can help to ensure that clear and accessible research methods are used.

As open data gains prominence, the FAIR principles have emerged as a measurable guideline for assessing the Findability, Accessibility, Interoperability, and Reusability of scientific data[2]. These principles, adopted by institutions like the European Commission, promote data exchange and usage, enabling researchers to build upon existing knowledge. However, the FAIR principles face limitations, including a focus on individual practices and short-term data management[13,14]. To address these potential barriers, the TRUST principles, based on the pillars of Transparency, Responsibility, User focus, Sustainability, and Technology, were introduced in 2020, ensuring digital repository trustworthiness and long-term data preservation[3].

The benefits of open science are wide-ranging. First, it improves research efficiency and reduces total costs through multiple factors such as labor cost savings, productivity improvements, access cost savings, or duplication avoidance[15]. Importantly, it facilitates interdisciplinarity by using new products, services, companies, and collaborations, which would have been less likely to occur in closed environments[15,16]. Likewise, open science practices increase public engagement by making research more accessible and understandable to non-experts, which expands reliability and funding opportunities[15,17,18]. A representative example of the benefits of open science practices is the scientific research during the COVID-19 pandemic. In order to boost scientific collaboration to fight the pandemic, several publishers and researchers sped up their adoption of open science practices[19,20]. Reviewing processes were accelerated and preprints were shorter and more quickly available[21]. In the same way, data —especially COVID-19 related— were shared among different institutions and countries, which enhanced the transparency and cooperation between scientists. While this new research paradigm and the

[1] https://doaj.org/

[2] https://data.worldbank.org/

[3] https://www.who.int/data/gho/

[4] https://doi.org/10.5281/zenodo.13970492

[5] https://pmc.ncbi.nlm.nih.gov/

[6] https://unix.org/

[7] https://git-scm.com/

[8] https://msdlive.org/

[9] https://research-and-innovation.ec.europa.eu/strategy/strategy-2020-2024/our-digital-future/open-science/european-open-science-cloud-eosc_en

[10] https://openmod-initiative.org/

new sharing and publication rhythm raised concerns about the potential impact on the quality of research output[19], it also encouraged the development of additional guidelines and specific protocols to guarantee the successful deployment of open science practices, which have been maintained in the post-pandemic era in a wide range of scientific disciplines (e.g., sustainable transport[22], criminology[23], and artificial intelligence[24]).

Open science practices in IAMs

Open science is rapidly transforming research practices across disciplines[22–25], including the energy and climate modeling communities. In recent years, Energy System Optimization Models (ESOMs) like OSeMOSYS[11] and Power System Models (PSMs) like PyPSA[26] have embraced transparency by releasing their model code under open-source licenses. Some PSMs go a step further by providing fully reproducible workflows and interactive examples through Jupyter notebooks, making them not only more accessible but also valuable tools for education and capacity building. At the same time, the integrated assessment modeling (IAM) community is increasingly adopting open science principles to improve the transparency, accessibility, and understanding of the scenarios they generate[27,28]. IAMs are essential tools for global scenario analysis and for exploring the systemwide impacts of climate policies[29]. These models represent the world energy, land, water, climate, and socio-economic systems and estimate plausible scenarios[30]. For instance, their outcomes and results have been used in the latest Intergovernmental Panel on Climate Change (IPCC) report (AR6;[31]), which required all contributors to homogenize their data to enable comparisons and ensure full transparency[32].

Several well-established IAMs are freely available as open-source projects in their respective repositories, such as GCAM[12], MESSAGEix[13], MUSE[14], REMIND[15], and WITCH[16]. Moreover, efforts are underway to transition models to open access formats, such as OMNIA and OPEN-PROM, which were previously not fully open-source[33]. Notably, emerging IAMs such as FRIDA[17], GCAM-Europe[18], NEMESIS-World, and WILIAM[19] have been, or are expected to be, released under open-source licenses.

Apart from the open-source licensing of IAMs and related models, modeling teams have recently started to produce standardized reporting procedures to harmonize model outputs, a critical step for facilitating effective result comparisons and enabling robust multi-model studies[34–36]. In parallel, to communicate effectively the model results, several user-friendly visualization platforms have emerged, standing out to stakeholders and policymakers. Key tools in this domain include the 1.5° C Scenario Explorer[37], the Global Hotspots Explorer[20], and the Sixth Assessment Report (AR6) Scenario Explorer[38]. Moreover, various platforms, packages, and libraries have been developed to streamline the analysis, visualization, validation, and comparison of model outputs. Tools like `pyam`[39] assist in data analysis and figure creation, while others, such as `nomenclature`[34] and `common-definitions`[40] hold definitions and mappings to facilitate validation and processing of scenario data. Platforms like I²AMPARIS Validation Tool[21] vet the models' outputs, while R packages like `iamc`[41] and `gcamreport`[35] standardize model outputs, enabling seamless multi-model comparisons. For visualizing model results, tools like `witch-plot`[42] offer specialized features tailored for modelers. Finally, artificial intelligence (AI) is increasingly integrated with IAMs, exemplified by the GCIMS Model Integration System. This powerful agentic AI tool features a cloud-optimized platform equipped with advanced visual analytics and an AI assistant, capable of launching and coordinating multi-stage sequential GCAM runs and their coupled tools, greatly enhancing automation and efficiency.

The development of all these tools facilitates reproducibility, translating results to broad audience, and multi-model comparison studies, which are crucial for improving the consistency and robustness of policy recommendations[28,43]. Open science strengthens the understanding and integration of models, while also streamlining data analysis by providing comprehensive documentation of model linkages[27]. Recently, several reports examining methodologies used in large-scale initiatives, such as the IPCC AR6, have highlighted valuable lessons and opportunities for future research[44–46]. In parallel, several research teams are making substantial efforts to openly share their workflows, methodologies, data, and code[47–49], crucial steps to prevent models from being perceived as "black boxes". However, the implementation of open science practices varies widely across modeling teams and is often hindered by various factors, which can slow scientific progress, limit the reporting and reuse of research findings, and hamper the reliability of the representation of real-world complex systems[8,44,50–53]. To fill this gap, this study proposes a protocol for the IAM community, grounded in the current state of open science efforts and obstacles encountered by modeling teams.

Methods

To identify the open science practices employed by various modeling teams, as well as the main challenges and barriers they face, we designed a survey[54]. The survey was structured into three sections aligned with the traditional IAM modeling steps: (1) model(s) development, calibration, and interconnection; (2) model(s) output analysis and dissemination; and (3) tools used throughout the process. Specifically, the first section

[11] http://www.osemosys.org/get-started.html

[12] https://github.com/JGCRI/gcam-core

[13] https://github.com/iiasa/message_ix

[14] https://github.com/EnergySystemsModellingLab/MUSE_OS

[15] https://github.com/remindmodel/remind

[16] https://github.com/witch-team/witchmodel

[17] https://github.com/metno/WorldTransFRIDA

[18] https://github.com/bc3LC-GCAMEurope/gcam-core

[19] https://github.com/LOCOMOTION-h2020

[20] https://www.hotspots-explorer.org/

[21] https://validation.i2am-paris.eu/

focused on the documentation process, including model documentation, input harmonization, and potential multi-model connectivities. The second section examined the management of project outcomes, addressing output standardization, the vetting process, output storage, and results presentation. Finally, the third section investigated the tools used or developed to support open science principles.

This survey was sent to all modeling teams from the IAM COMPACT[55] and DIAMOND[56] consortia, gathering a total of 13 responses. IAM COMPACT, a Horizon Europe research project, aims to support the assessment of global climate goals and the design of the next round of Nationally Determined Contributions and policy planning beyond 2030. At its core are diverse multi-model analyses that emphasize the adoption and standardization of open science practices to ensure that model outputs are comparable, reliable, accessible, transparent, and reusable. On the other hand, the Horizon Europe DIAMOND project focuses on developing open-source IAMs, which stand to benefit significantly from open science principles by enhancing usability and broadening access across modeling teams. With this broad representation of models, institutions, and project scopes, our survey captures a robust and representative sample of the IAM community.

The quantitative and qualitative survey results were analyzed both individually and collectively to identify patterns within specific modeling teams and to highlight common practices shared across the broader community. This dual approach allowed us to capture both the diversity of experiences and the overarching trends in how open science principles are being implemented.

Survey results

As Figure 1 depicts, the consulted modeling teams document their models not only to ensure transparency and facilitate external use but also as a reliable internal reference when uncertainties arise. When models are interconnected, either through soft- or hard-linking, teams typically document the process, along with harmonization procedures, in the Methodology or Supplementary Information section of their papers. However, time constraints often prevent consistent documentation across teams (Figure 1).

In terms of model output, not all teams adhere to the standardized reporting formats. IAM models generally recognize the advantages of using the IAMC time-series reporting template[57], which standardizes model outputs, facilitating comparisons across different models. However, sector-specific (e.g., energy) models, often linked to IAMs, tend to follow other reporting methods due to their more specialized and disaggregated results. Furthermore, not all modeling teams employ vetting procedures to validate their output. These procedures, designed to assess the accuracy of results, typically compare the first model period to observed data or check that key outputs, such as demand and supply, align correctly. However, these methods are unfamiliar to some teams and can be time-consuming, particularly when done manually rather than using automated tools (Figure 1).

Lastly, modeling teams increasingly publish models' raw output or relevant datasets on platforms like Zenodo[22], and more papers are now accompanied by the analysis code used in the study. However, due to heavy data weight, limited knowledge, or time constraints, this information is not always uploaded to a secure long-term location. To improve the communication of the results, many models are incorporating user-friendly interfaces, which, albeit requiring time to build and set up, make them more accessible and understandable for non-expert audiences (Figure 1).

Open Science Protocol

Based on the collected results, we propose an Open Science Protocol for the IAM community to encourage and support the adoption of open science practices (Figure 2). The protocol structure aligns with the survey sections, with each stage designed to adhere to the FAIR and TRUST principles. It focuses on the key steps of IAM studies, offering detailed guidance and practical strategies to address the challenges identified through the survey. This protocol aims to ensure full transparency and thorough documentation of models, while making outcomes accessible, interoperable, reusable, reproducible, and reliable for a wide range of audiences, including both scientific and non-expert communities, serving as a dependable resource for informed decision-making.

The first stage of the protocol emphasizes the documentation and harmonization of models and data. It is crucial to ensure transparency in model assumptions, inputs, and outputs so that models developed by different teams can be interoperable and their results comparable. To achieve this, we recommend creating a dedicated platform for thorough documentation of each model with specific details about its versions (see Table 1). It is advisable to assign a Digital Object Identifier (DOI) to each model version release and register the identifier in an indexed searchable resource, ensuring that it is findable, accessible, reusable, and citable for everyone. In the same line, the data should be open and linked to a globally unique and persistent identifier. Well-detailed metadata should be uploaded, even when then data is no longer available.

It is difficult to have a rule to report model interconnections since each case is unique. Thus, these details can be clearly outlined in the corresponding paper or case study, detailing how models interact, as well as the assumptions, inputs, outputs, and model versions used in the integration. If applicable, models' inputs must be homogenized to have comparable results, a task that should be documented thoroughly in the corresponding paper (see Table 1). Additionally, publications should reference and cite the specific model versions used, including any modification details (if applicable), with links to the version repository if models are open-source. Modeling teams can leverage open-source platforms such as GitHub[23] for code hosting and version control, and Zenodo[24] for

[22] https://zenodo.org/

[23] https://github.com/

[24] https://zenodo.org/

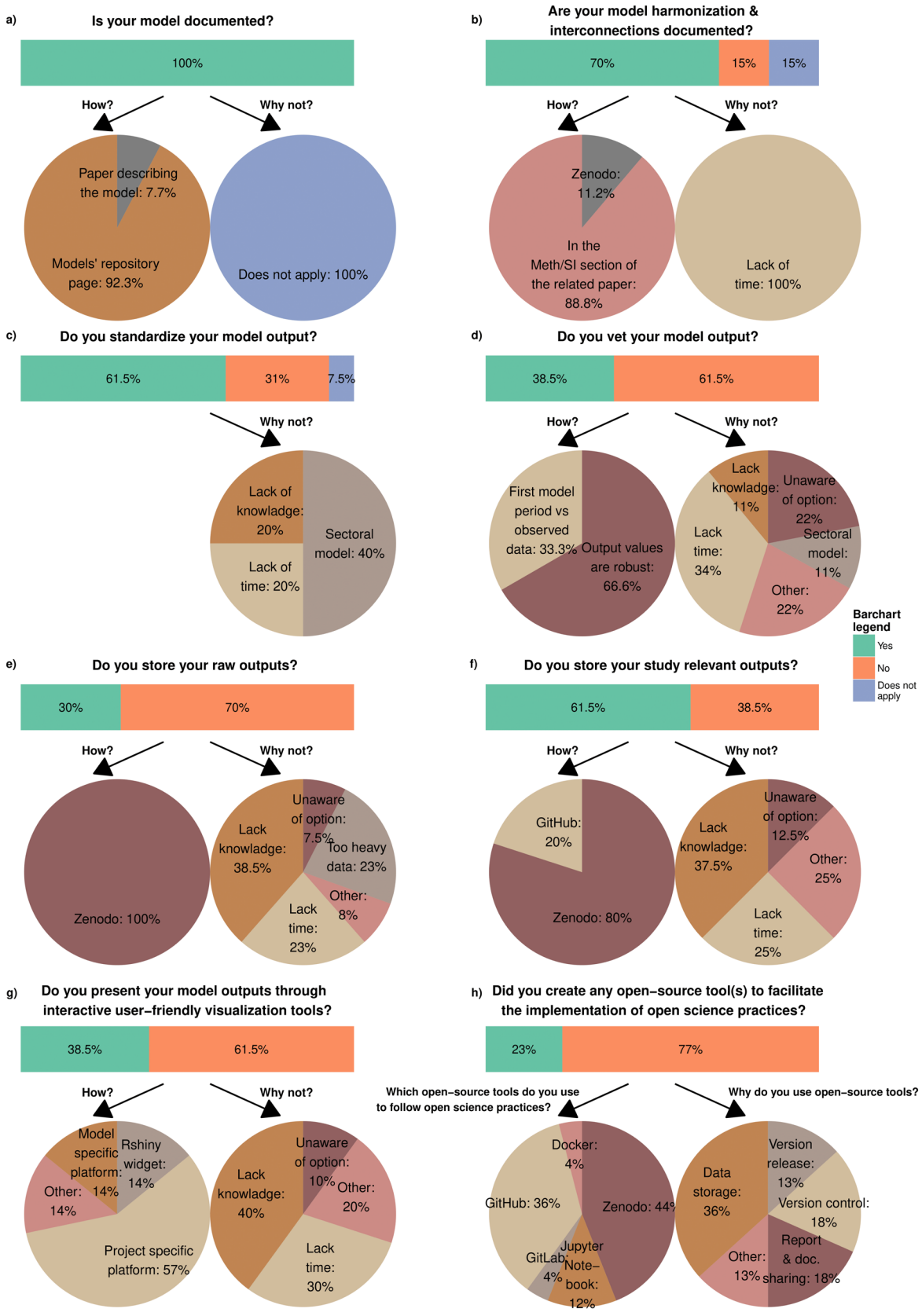

Figure 1. Summary statistics of responses to the primary survey questions.

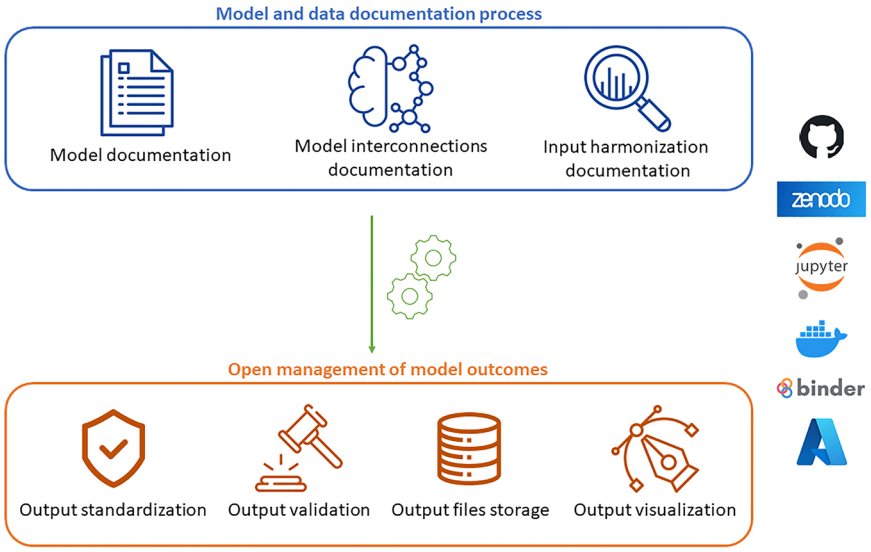

Figure 2. Scheme of the Open Science Protocol for the IAM community.

Table 1. Examples of studies aligned with each protocol step and recommended tools to support their implementation.

Protocol section	Protocol step	Example/s	Suggested tool/s
1. Model and data documentation process	Model documentation	GCAM[25], MEDEAS[26] documentations	Tailor made documentation page
1. Model and data documentation process	Model interconnections documentation	Moreno *et al.* 2024[58], Nikas *et al.* 2024[59]	Supplementary Information of the related paper
1. Model and data documentation process	Input harmonization documentation	Moreno *et al.* 2024[58]	Supplementary Information of the related paper
2. Open management of project outcomes	Output standardization	Fragkos *et al.* 2024[60]	Tailor made tools, e.g., gcamreport[35]
2. Open management of project outcomes	Output validation	Van Vuuren *et al.* 2025[61]	gcamreport[35], piamValidation[62], I²AMPARIS Validation tool[63],
2. Open management of project outcomes	Output files storage	Reisinger *et al.* 2024[64], Rinaldi & Ghezzi, 2024[48], Sampdero *et al.* 2024[49],	Zenodo[4]
2. Open management of project outcomes	Visualization tools	Khan *et al.* 2022[27]	Tailor made user friendly interfaces (e.g., WILIAM web base[28], witch-plot[42]), external platforms (e.g., I²AMPARIS platform[28]), libraries (e.g., pyam[39])

distributing model releases and, when needed, associated data.

The second stage of the protocol focuses on ensuring the quality and transparency of the outcomes. The first step is to standardize the outputs using the IAMC time-series data template[57], which facilitates cross-comparison of results between modeling teams and enables automated validation. While this procedure is specific to each model, it must be traceable, transparent, and reproducible. Automating this process is recommended, as it allows for the detection of errors or bugs over time[35] (see Table 1).

[25] https://jgcri.github.io/gcam-doc/

[26] https://medeas.eu/model/medeas-model

[27] https://immm-sfa.github.io/khan-etal_2023_im3gcamusa/index.html

[28] https://www.i2am-paris.eu/

To ensure consistency in the outputs, we suggest implementing a vetting procedure, ideally automated, using model-independent platforms like the I²AMPARIS Validation tool[63] or model-specific tools such as `gcamreport`[35] (see Table 1). Through this process, the accuracy of the outcomes is assessed by verifying that paired outputs, such as supply and demand, are properly aligned, and by comparing the initial model period with observed data. With the automation of these processes, modeling teams can save time and effort, as well as ensure the clarity and replicability of the workflows.

To guarantee full transparency, accessibility, and reusability of results, it is advisable to upload the outputs to a platform under a DOI, such as Zenodo. However, as the survey indicates, it may not always be feasible to upload raw outputs due to their size. In such cases, the relevant study results and/or lighter standardized datasets should be made available. The shared outputs must be accompanied by detailed metadata documenting the data origin and the specific step-by-step data handling processes used to develop and reuse it (see Table 1). Assigning a DOI and detailing tailor-made metadata helps to ensure that data is easily located and preserved over time, and facilitates its use in future research projects.

In order to efficiently share the findings with both the scientific community and the general public, the protocol suggests the dissemination of results through visualization tools that transform complex data outputs into comprehensible formats. Although creating these tools can be time-consuming, user-friendly visualizations enable clear exploration of the results and significantly enhance transparency, engaging policymakers and other stakeholders. Programming tools and platforms, such as dedicated websites, R Shiny apps[29], and visualization packages like `pyam`[65], can leverage the development of these interactive interfaces (see Table 1).

Finally, AI can be integrated at any stage of the protocol to support tasks such as output visualization, workflow design, model interpretation, and execution of simulation runs. Capsule modules, like those offered by MSD-Live[38], enable seamless integration of code and data, facilitating interaction with non-expert users and allowing the automated launch of complex workflows.

To facilitate the protocol application and boost the implementation of open science principles, we provide a checklist to modeling teams[54], available at Zenodo[4]. This comprehensive list, structured in the same blocks as the protocol, serves as a useful tool to ensure that no steps are overlooked and acts as a reminder of best practices in open science. In the same line, to ensure that uploaded data and metadata follow the FAIR principles, we recommend ensuring that data is retrievable through an open protocol, and that metadata and data use a broadly applicable language and have assigned a unique persistent identifier[30].

[29] https://shiny.posit.co/

[30] https://www.go-fair.org/fair-principles/

Discussion

Open science has developed into a major area of policy interest for academic institutions and a common approach for many researchers. The IAM community is rapidly adhering to these principles since IAM results hold particular significance for a wide range of stakeholders and policymakers. IAM models have traditionally faced criticism for their lack of transparency and the difficulty in fully testing their assumptions due to the complexity of the underlying code[66]. This has led to perceptions of IAMs as "black box" models, diminishing their reliability in the eyes of some decision-makers[50]. Embracing open science practices would greatly benefit the IAM community by demystifying these models and making their methods and procedures far more transparent and accessible. This is a crucial step in translating model insights into real-world policy actions.

As in other scientific communities, the adoption of open science principles faces several challenges, such as limited awareness, knowledge gaps, time constraints, limited financial resources, intellectual property concerns, and various cultural and social factors[67–69]. However, several scientific disciplines have established protocols, data repositories, and best practices (e.g., Nature Protocols[31], BioModels Database[32], and the Environmental Data Initiative[33]), which help promote open science and ensure transparency. Similarly, projects like the Reproducibility Project Cancer Biology[34] and the Reproducibility Project Psychology[70] work to verify research reproducibility, thereby enhancing the credibility and reliability of scientific findings. While the IAM community has developed output standardization guidelines[34] and user-friendly visualization interfaces[37,38], it still lacks a comprehensive protocol to guide the development of modeling studies.

To address this gap, this paper introduces a protocol for the entire IAM community that offers a structured framework for modeling teams and related projects. While it is built on the challenges faced by specific modeling teams and may not capture all perspectives, the protocol aims to serve as a valuable resource for the broader community. It outlines best practices and recommended platforms and tools to streamline labor intensive tasks. By adopting this protocol, modeling teams can optimize time and resources while improving the transparency, accessibility, reliability, interpretability, and reusability of their results. With collective effort, the protocol can be continually updated and refined to better meet the evolving needs of modelers, ultimately advancing climate science and supporting the development of evidence-based policies.

Ethics and consent

All survey respondents were members of the IAM COMPACT or DIAMOND consortium and provided informed consent

[31] https://www.nature.com/nprot/

[32] https://www.ebi.ac.uk/biomodels/

[33] https://portal.edirepository.org/nis/home.jsp

[34] https://www.cos.io/rpcb

[35] https://www.locomotion-h2020.eu/locomotion-models/model-explorer/

for the use of the information shared in this study. They were informed that their responses would be utilized for research purposes and included in this paper. The data were collected under the assurance of anonymity and were used exclusively to support the development of open science practices and protocols for integrated assessment models. This process was conducted in compliance with ethical approval from the Basque Centre for Climate Change (BC3) Management Committee. Respondents also retained the right to withdraw their participation at any point.

Data availability

The checklist and survey results are available in Zenodo (https://zenodo.org/records/13970492) DOI: 10.5281/zenodo.13970492[54]

Data available under the terms of the Creative Commons Attribution 4.0 International license (CC-BY 4.0) (https://creativecommons.org/licenses/by/4.0/).

Software availability

Source code available from GitHub (https://github.com/klau506/open_science_iams).

Archived software available from (https://zenodo.org/records/13970492).

Data and archived software available under the terms of the Creative Commons Attribution 4.0 International license (CC-BY 4.0) (https://creativecommons.org/licenses/by/4.0/).

Source code available under the terms of the Apache 2.0 license (https://www.apache.org/licenses/).

Authors contributions

C.R. participated in the Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Software, Validation, Visualization, Writing - Original Draft Preparation, and Writing – Review & Editing; J.S. participated in the Conceptualization, Funding Acquisition, Methodology, Resources, Supervision, Validation, and Writing – Review & Editing; N.F. participated in the Conceptualization, Funding Acquisition, Project Administration, Resources, Validation, and Writing – Review & Editing; F.B. participated in the Validation and Writing – Review & Editing; and C.L.G. participated in the Validation and Writing – Review & Editing.

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References

1. European Commission: **The European Union's Research and Innovation Performance - Facts and Figures 2019.** 2019.
2. Wilkinson MD, Dumontier M, Aalbersberg IJJ, *et al.*: **The FAIR guiding principles for scientific data management and stewardship.** *Sci Data.* Publisher: Nature Publishing Group, 2016; **3**(1): 160018. **PubMed Abstract** | **Publisher Full Text** | **Free Full Text**
3. Lin D, Crabtree J, Dillo I, *et al.*: **The TRUST principles for digital repositories.** *Sci Data.* Publisher: Nature Publishing Group UK London, 2020; **7**(1): 144. **PubMed Abstract** | **Publisher Full Text** | **Free Full Text**
4. Munafò MR, Nosek BA, Bishop DVM, *et al.*: **A manifesto for reproducible science.** *Nat Hum Behav.* 2017; **1**(1): 0021. **PubMed Abstract** | **Publisher Full Text** | **Free Full Text**
5. Fecher B, Friesike S, Hebing M: **What drives academic data sharing?** *PLoS One.* 2015; **10**(2): e0118053. **PubMed Abstract** | **Publisher Full Text** | **Free Full Text**
6. Burgelman JC, Pascu C, Szkuta K, *et al.*: **Open science, open data, and open scholarship: European policies to make science fit for the twenty-first century.** *Front Big Data.* 2019; **2**: 43. **PubMed Abstract** | **Publisher Full Text** | **Free Full Text**
7. Piwowar HA, Vision TJ: **Data reuse and the open data citation advantage.** *PeerJ.* Publisher: PeerJ Inc, 2013; **1**: e175. **PubMed Abstract** | **Publisher Full Text** | **Free Full Text**
8. Tenopir C, Dalton ED, Allard S, *et al.*: **Changes in data sharing and data reuse practices and perceptions among scientists worldwide.** *PLoS One.* Publisher: Public Library of Science San Francisco, CA USA, 2015; **10**(8): e0134826. **PubMed Abstract** | **Publisher Full Text** | **Free Full Text**
9. European Commission: **H2020 guidelines on open access to scientific publications and research data in Horizon 2020.** 2017.
10. Mendez E, Lawrence R, MacCallum CJ, *et al.*: **Progress on open science: towards a shared research knowledge system.** Final report of the Open Science Policy Platform. Publisher: European commission, 2020. **Reference Source**
11. White House Office of Science and Technology Policy (OSTP): **Desirable characteristics of data repositories for federally funded research**. Executive Office of the President of the United States, May, 2022; [cited 2025 May 15]. **Publisher Full Text**
12. NIH: **NIH plan to increase findability and transparency of research results**. 2024.
13. Boeckhout M, Zielhuis GA, Bredenoord AL: **The FAIR guiding principles for data stewardship: fair enough?** *Eur J Hum Genet.* 2018; **26**(7): 931–936. **PubMed Abstract** | **Publisher Full Text** | **Free Full Text**
14. Peng G, Gross WS, Edmunds R: **Crosswalks among stewardship maturity assessment approaches promoting trustworthy FAIR data and repositories.** *Sci Data.* 2022; **9**(1): 576. **PubMed Abstract** | **Publisher Full Text** | **Free Full Text**
15. Fell MJ: **The economic impacts of open science: a rapid evidence assessment.** *Publications.* Publisher: MDPI, 2019; **7**(3): 46. **Publisher Full Text**
16. Mons B, Neylon C, Velterop J, *et al.*: **Cloudy, increasingly FAIR; revisiting the FAIR Data guiding principles for the european open science cloud.** *Information Services & Use.* 2017; **37**(1): 49–56. **Publisher Full Text**
17. Wehn U, Ajates R, Mandeville C, *et al.*: **Opening science to society: how to progress societal engagement into (open) science policies.** *R Soc Open Sci.* 2024; **11**(5): 231309. **PubMed Abstract** | **Publisher Full Text** | **Free Full Text**
18. Grand A, Wilkinson C, Bultitude K, *et al.*: **On open science and public engagement with engineering.** 2010; **09**. **Reference Source**
19. Besançon L, Peiffer-Smadja N, Segalas C, *et al.*: **Open science saves lives: lessons from the COVID-19 pandemic.** *BMC Med Res Methodol.* 2021; **21**(1): 117. **PubMed Abstract** | **Publisher Full Text** | **Free Full Text**
20. Hayashi K: **How could COVID-19 change scholarly communication to a new normal in the open science paradigm?** *Patterns (N Y).* 2021; **2**(1): 100191. **PubMed Abstract** | **Publisher Full Text** | **Free Full Text**
21. Fraser N, Brierley L, Dey G, *et al.*: **Preprinting a pandemic: the role of preprints in the COVID-19 pandemic.** 2020. **Publisher Full Text**
22. Nielsen AF, Michelmann J, Akac A, *et al.*: **Using the future wheel methodology to assess the impact of open science in the transport sector.** *Sci Rep.* 2023; **13**(1): 6000. **PubMed Abstract** | **Publisher Full Text** | **Free Full Text**

23. Branney P, Brooks J, Kilby L, *et al.*: **Three steps to open science for qualitative research in psychology.** 2023; **17**(4): e12728.
Publisher Full Text

24. Brinkhaus HO, Rajan K, Schaub J, *et al.*: **Open data and algorithms for open science in AI-driven molecular informatics.** *Curr Opin Struct Biol.* 2023; **79**: 102542.
PubMed Abstract | **Publisher Full Text**

25. Chin JM, Pickett JT, Vazire S, *et al.*: **Questionable research practices and open science in quantitative criminology.** *J Quant Criminol.* Publisher: Springer, 2023; **39**: 21–51.
Publisher Full Text

26. Brown T, Hörsch J, Schlachtberger D: **PyPSA: Python for Power System Analysis**. arXiv preprint arXiv: 1707.09913. 2017.
Reference Source

27. IAMC: **IAMC Documentation Wiki.** 2022.

28. Nikas A, Gambhir A, Trutnevyte E, *et al.*: **Perspective of comprehensive and comprehensible multi-model energy and climate science in Europe.** *Energy.* Publisher: Elsevier, 2021; **215**: 119153.
Publisher Full Text

29. Van Beek L, Hajer M, Pelzer P, *et al.*: **Anticipating futures through models: the rise of integrated assessment modelling in the climate science-policy interface since 1970.** *Global Environ Chang.* 2020; **65**: 102191.
Publisher Full Text

30. Weyant J: **Some contributions of integrated assessment models of global climate change.** *Rev Environ Econ Policy.* 2017; **11**(1): 115–137.
Publisher Full Text

31. Shukla PR, Skea J, Slade R, *et al.*: **Climate change 2022 mitigation of climate change**. Cambridge University Press, Cambridge, UK and New York, NY, USA, 2022.
Reference Source

32. Krey V, Masera O, Blanford G, *et al.*: **Annex ii: metrics & methodology.** In: O. Edenhofer, R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel, and J. C. Minx, editors, *Climate change 2014: mitigation of climate change. Contribution of working group iii to the fifth assessment report of the intergovernmental panel on climate change.* Cambridge University Press, 2014.
Reference Source

33. Climate-Diamond: **Upgrading models**. 2023; Accessed: 2024-09-13.
Reference Source

34. Huppmann D, Wienpahl L, Hackstock P, *et al.*: **nomenclature**. 2024.
Publisher Full Text

35. Rodés-Bachs C, Sampedro J, Horowitz R, *et al.*: **gcamreport: an R tool to process and standardize GCAM outputs.** *J Open Source Softw.* Publisher: The Open Journal, 2024; **9**(96): 5975.
Publisher Full Text

36. Usher W, Pietzcker R, Dekker M: **Ecemf: model comparison protocol**. 2022.
Publisher Full Text

37. Huppmann D, Rogelj J, Kriegler E, *et al.*: **A new scenario resource for integrated 1.5 °C research.** *Nat Clim Change.* 2018; **8**(12): 1027–1030.
Publisher Full Text

38. Byers E, Krey V, Kriegler E, *et al.*: **Ar6 scenarios database**. 05, 2022.
Publisher Full Text

39. Gidden MJ, Fujimori S, Van Den Berg M, *et al.*: **A methodology and implementation of automated emissions harmonization for use in Integrated Assessment Models.** *Environ Modell Softw.* 2018; **105**: 187–200.
Publisher Full Text

40. IAM Consortium: **Common definitions**. 2024; Accessed: 2024-09-18.
Reference Source

41. Dietrich JP, Auer C, Giannousakis A, *et al.*: **iamc: IAMC tools**. R package version 0.29.8, 2023.
Reference Source

42. WITCH Team: **Witch plot: visualization tool for witch model outputs**. 2024; Accessed: 2024-09-18.
Reference Source

43. Guivarch C, Le Gallic T, Bauer N, *et al.*: **Using large ensembles of climate change mitigation scenarios for robust insights.** *Nat Clim Change.* 2022; **12**(5): 428–435.
Publisher Full Text

44. Pirani A, Fuglestvedt JS, Byers E, *et al.*: **Scenarios in IPCC assessments: lessons from AR6 and opportunities for AR7.** *NPJ Clim Action.* 2024; **3**(1): 1.
Publisher Full Text

45. Peters GP, Al Khourdajie A, Sognnaes I, *et al.*: **AR6 scenarios database: an assessment of current practices and future recommendations.** *NPJ Clim Action.* 2023; **2**(1): 31.
Publisher Full Text

46. Stockhause M, Huard D, Al Khourdajie A, *et al.*: **Implementing FAIR data principles in the IPCC seventh assessment cycle: lessons learned and future prospects.** *PLOS Clim.* 2024; **3**(12): e0000533.
Publisher Full Text

47. Byers E, Brutschin E, Sferra F, *et al.*: **Scenarios processing, vetting and feasibility assessment for the european scientific advisory board on climate change**. Technical Report, International Institute for Applied Systems Analysis and Potsdam Institute for Climate Imact research, 2023.
Reference Source

48. Rinaldi L, Ghezzi D, Colombo E, *et al.*: **Assessing environmental and market implications of steel decarbonisation strategies: a hybrid input-output model for the European Union.** *Environ Res Lett.* 2024; **19**(7): 074059.
Publisher Full Text

49. Sampedro J, Van De Ven DJ, Horowitz R, *et al.*: **Energy system analysis of cutting off Russian gas supply to the European Union.** *Energy Strateg Rev.* 2024; **54**: 101450.
Publisher Full Text

50. Wilson C, Guivarch C, Kriegler E, *et al.*: **Evaluating process-based integrated assessment models of climate change mitigation.** *Climatic Change.* 2021; **166**(1–2): 3.
Publisher Full Text

51. Robertson S: **Transparency, trust, and integrated assessment models: an ethical consideration for the Intergovernmental Panel on Climate Change.** *WIREs Climate Change.* 2021; **12**(1): e679.
Publisher Full Text

52. Skea J, Shukla P, Al Khourdajie A, *et al.*: **Intergovernmental Panel on Climate Change: transparency and integrated assessment modeling.** *WIREs Climate Change.* 2021; **12**(5): e727.
Publisher Full Text

53. Melero R, Boté-Vericad JJ, López-Borrull A: **Perceptions regarding open science appraised by editors of scholarly publications published in Spain.** *Learn Publ.* 2023; **36**(2): 178–193.
Publisher Full Text

54. Rodés Bachs C, Sampedro J, Natasha F, *et al.*: **open_science_iams_dataset (si_material_v1).** *Zenodo.* 2024.
http://www.doi.org/10.5281/zenodo.13970492

55. IAM COMPACT: **IAM COMPACT: expanding integrated assessment modelling: comprehensive and comprehensible science for sustainable, co-created climate action**. 2022; Accessed: 2024-09-18.
Publisher Full Text

56. DIAMOND: **DIAMOND: Delivering the next generation of open Integrated Assessment Models for Net-zero, sustainable Development**. 2022; Accessed: 2025-05-15.
Publisher Full Text

57. IAMC: **IAMC time-series data template**. 2009; Accessed: 2024-09-13.
Reference Source

58. Moreno J, Campagnolo L, Boitier B, *et al.*: **The impacts of decarbonization pathways on Sustainable Development Goals in the European Union.** *Commun Earth Environ.* 2024; **5**(1): 136.
Publisher Full Text

59. Nikas A, Frilingou N, Heussaff C, *et al.*: **Three different directions in which the European Union could replace Russian natural gas.** *Energy.* 2024; **290**: 130254.
Publisher Full Text

60. Fragkos P, Van De Ven DJ, Horowitz R, *et al.*: **Analysing the transformative changes of nationally determined contributions and long-term targets.** *Climate.* 2024; **12**(6): 87.
Publisher Full Text

61. Van Vuuren D, O'Neill B, Tebaldi C, *et al.*: **The Scenario Model Intercomparison Project for CMIP7 (ScenarioMIP-CMIP7).** *EGUsphere.* 2025; **2025**: 1–38.
Publisher Full Text

62. Weigmann P, Richters O, Lécuyer F: **piamValidation: validation tools for PIK-PIAM (Version 0.7.4)**. [Computer software]. 2025.
Reference Source

63. DIAMOND: **Iam2paris validation tool**. 2009; Accessed: 2024-09-13.

64. Reisinger A, Cowie AL, Geden O, *et al.*: **Science-based targets miss the mark.** *Commun Earth Environ.* 2024; **5**(1): 383.
Publisher Full Text

65. Gidden MJ, Huppmann D: **pyam: a Python package for the analysis and visualization of models of the interaction of climate, human, and environmental systems.** *J Open Source Softw.* 2019; **4**(33): 1095.
Publisher Full Text

66. Strachan N, Fais B, Daly H: **Reinventing the energy modelling–policy interface.** *Nat Energy.* 2016; **1**(3): 16012.
Publisher Full Text

67. Enke N, Thessen A, Bach K, *et al.*: **The user's view on biodiversity data sharing — investigating facts of acceptance and requirements to realize a sustainable use of research data.** *Ecol Inform.* Publisher: Elsevier, 2012; **11**: 25–33.
Publisher Full Text

68. Tenopir C, Allard S, Douglass K, *et al.*: **Data sharing by scientists: practices and perceptions.** *PLoS One.* 2011; **6**(6): e21101.
PubMed Abstract | **Publisher Full Text** | **Free Full Text**

69. Bertram MG, Sundin J, Roche DG, *et al.*: **Open science.** *Curr Biol.* Publisher: Elsevier, 2023; **33**(15): R792–R797.
PubMed Abstract | **Publisher Full Text**

70. Open Science Collaboration: **PSYCHOLOGY. Estimating the reproducibility of psychological science.** *Science.* 2015; **349**(6251): aac4716.
PubMed Abstract | **Publisher Full Text**

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Version 2

Reviewer Report 23 July 2025

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✔ **Anne Fouilloux**
Simula Research Laboratory, Oslo, Norway

The authors have made substantial revisions that successfully address the major concerns raised in my initial review.
The revised manuscript demonstrates significant improvement in scientific rigor and practical applicability:
- The addition of a dedicated Methods section with clear survey design details;
- The expansion from 9 to 13 responses is modest but I acknowledge the effort.
- The expanded background section now provides good coverage of FAIR and TRUST principles with extensive literature review and examples from related modeling communities.
- Table 1 provides concrete examples and recommended tools for each protocol step, transforming abstract recommendations into actionable guidance.
- Figure quality improvements and data format enhancements address reproducibility concerns.

Minor Limitation:
- The sample size remains modest (n=13), though the authors have appropriately contextualized this within their target IAM modeling communities.

The revised manuscript successfully addresses my concerns and provides a valuable resource for promoting open science practices in integrated assessment modeling.

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: FAIR and Open Science with a focus on Climate Science and more recently Climate Change Adaptation.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Reviewer Report 15 July 2025

https://doi.org/10.21956/openreseurope.22308.r56055

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David Resnik
National Institute of Environmental Health Sciences, Durham, USA

This study provides useful results for open sciences practice with integrated assessment modeling teams. The methodology and survey are sound, the results are significant, and the paper is well written and well referenced. The authors have mode appropriate revisions in response to the recommendations from the first round of review. I recommended indexing.

Is the work clearly and accurately presented and does it engage with the current literature?
Yes

Is the study design appropriate and is the work technically sound?
Yes

Are sufficient details of methods and analysis provided to allow replication by others?
Yes

Are all the source data and materials underlying the results available?
Yes

If applicable, is the statistical analysis and its interpretation appropriate?
Yes

Are the conclusions drawn adequately supported by the results?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: research ethics

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Reviewer Report 23 June 2025

https://doi.org/10.21956/openreseurope.22308.r55620

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Marc-André Simard
Université de Montréal, Québec,, Canada

I want to thank the authors for addressing all my comments and suggestions. I also appreciated all the improvements to the github repository, incluing the README file as well as the data format which both increase the paper's openness and reproducibility.

From an accessibility perspective (e.g. colors, text, etc.), I would make sure that all the figures are compatible with best accessibility practices to ensure that they can be viewed by a maximum number of people. Other than that, I believe that the paper is ready for indexing.

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Information science, bibliometrics, science of science, open access, science policy

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Version 1

Reviewer Report 26 April 2025

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Anne Fouilloux
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[2] Simula Research Laboratory, Oslo, Norway

Summary of the article:

This paper presents an **Open Science Protocol** specifically tailored for the **Integrated Assessment Modeling (IAM)**community, based on a survey of IAM teams. The protocol is designed to improve the **transparency, accessibility, and reusability** of IAM models and outputs by aligning with the **FAIR** (Findable, Accessible, Interoperable, Reusable) and **TRUST** (Transparency, Responsibility, User focus, Sustainability, Technology) principles. The study highlights current challenges in implementing open science within IAMs—such as inconsistent

documentation, limited vetting of outputs, and barriers to sharing data—and offers practical guidance to overcome these. By fostering better communication and usability of models, especially for policymakers, the protocol aims to enhance the **credibility and impact** of IAM-based climate assessments.

Details related to the questions above (where I answered partly):
The paper acknowledges the importance of the FAIR (Findability, Accessibility, Interoperability, and Reusability) and TRUST (Transparency, Responsibility, User focus, Sustainability, and Technology) principles but does not fully explore their practical implementation within Integrated Assessment Models (IAMs). A deeper engagement with recent literature and case studies specific to IAMs and these principles would strengthen both the theoretical foundation and practical relevance.
While the survey design is appropriate for gathering qualitative insights, the methodology section lacks sufficient detail. Key elements such as the full survey instrument, sample size, and selection process are missing, which limits transparency and hampers replicability. Providing this information, along with a clearer description of how responses were analyzed, would enhance the robustness of the conclusions.
The protocol presented is promising, with clearly outlined steps. However, it would benefit from further elaboration, particularly regarding practical challenges encountered, strategies for adaptation across IAM contexts, and concrete examples of successful implementation. Additional data—such as more detailed documentation, case studies, or checklists—would improve the transparency and reusability of the work.
Although the interpretation of survey results is reasonable, it relies heavily on qualitative insights. Incorporating statistical analysis or quantitative data could provide stronger support for the findings. The conclusions align with the presented results but could be made more compelling through the inclusion of real-world applications that demonstrate the protocol's effectiveness and impact.

Other information related to data/code availability and figure:
- The GitHub repository: https://github.com/klau506/open_science_iams does not detail how to use the R code and with which data.

- The data is deposited in Zenodo as xlsx file which is not an open format. csv file (text file) would be better for reuse.

- Figure 1 is unreadable on my laptop (too small).

- The survey results file (available at https://zenodo.org/records/13970492) contains 9 entries, suggesting that fewer than 10 individuals responded to the survey.

Recommendation:

There are a few areas where additional details and refinement could help to strengthen the scientific rigor of your paper. Below are some specific suggestions:
1. **Strengthen the Theoretical Framework**
It would be beneficial to gain a deeper understanding of how the FAIR and TRUST principles can be practically applied to IAMs (in detail because in the paper, the 15 FAIR principles are not addressed with sufficient details). This will help better align the theoretical foundation of your protocol with current best practices in Open Science and ensure its relevance to the IAM

community.
2. **Enhance Methodological Transparency**
The methodology section could be improved by providing more **detailed information about the survey design**. For instance, explain why the **sample size** and the **selection process** of survey participants were sufficient for this work.
3. **Improve the GitHub Repository**
The **GitHub repository** could be enhanced by providing clear **documentation** on how to use the R code and apply it to the provided data. Additionally, I suggest switching the data format from **XLSX** to an **open format like CSV** to facilitate easier reuse and interoperability with other tools.
4. **Enhance Visual Accessibility**
Figure 1 is not easily readable on standard devices. I recommend increasing the **resolution** and **size** of the figures to improve accessibility, ensuring that they are clearly visible to a broader audience.
5. **Increase Survey Sample Size**
Given that the survey currently includes fewer than 10 responses, I suggest reaching out to more IAM teams to **increase the sample size**. A larger sample would improve the **representativeness** of the findings. It would also be helpful to acknowledge the potential limitations posed by the small sample size and how these might affect the interpretation of your results.

Is the work clearly and accurately presented and does it engage with the current literature?
Partly

Is the study design appropriate and is the work technically sound?
Partly

Are sufficient details of methods and analysis provided to allow replication by others?
Partly

Are all the source data and materials underlying the results available?
Yes

If applicable, is the statistical analysis and its interpretation appropriate?
Yes

Are the conclusions drawn adequately supported by the results?
Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: FAIR and Open Science with a focus on Climate Science and more recently Climate Change Adaptation.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 06 Jun 2025

Clàudia Rodés-Bachs

Dear Anne Fouilloux, Thank you so much for the time devoted to the manuscript and your insightful comments. They have been a key resource in improving the manuscript and study. Detailed responses below:

Summary of the article: This paper presents an Open Science Protocol specifically tailored for the Integrated Assessment Modeling (IAM)community, based on a survey of IAM teams. The protocol is designed to improve the transparency, accessibility, and reusability of IAM models and outputs by aligning with the FAIR (Findable, Accessible, Interoperable, Reusable) and TRUST (Transparency, Responsibility, User focus, Sustainability, Technology) principles. The study highlights current challenges in implementing open science within IAMs—such as inconsistent documentation, limited vetting of outputs, and barriers to sharing data—and offers practical guidance to overcome these. By fostering better communication and usability of models, especially for policymakers, the protocol aims to enhance the credibility and impact of IAM-based climate assessments. Details related to the questions above (where I answered partly): The paper acknowledges the importance of the FAIR (Findability, Accessibility, Interoperability, and Reusability) and TRUST (Transparency, Responsibility, User focus, Sustainability, and Technology) principles but does not fully explore their practical implementation within Integrated Assessment Models (IAMs). A deeper engagement with recent literature and case studies specific to IAMs and these principles would strengthen both the theoretical foundation and practical relevance. Thank you for your comment. We agree that providing additional context will help further motivate the study. In response, we have expanded the Introduction by incorporating specific examples to better illustrate recent developments in the field and in other modeling communities, and to more clearly highlight the existing gaps our work aims to address. Updated paragraph: “The development of all these tools facilitates multi-model comparison studies, which are crucial for improving the consistency and robustness of policy recommendations 26, 40 . Open science strengthens the understanding and integration of models, while also streamlining data analysis by providing comprehensive documentation of model linkages 25 . Recently, several reports examining methodologies used in large-scale initiatives, such as the IPCC AR6, have highlighted valuable lessons and opportunities for future research 42,63,64. In parallel, several research teams are making substantial efforts to openly share their workflows, methodologies, data, and code [65– 67], crucial steps to prevent models from being perceived as “black boxes”. However, the implementation of open science practices varies widely across modeling teams and is often hindered by various factors, which can slow scientific progress, limit the reporting and reuse of research findings, and hamper the reliability of the representation of real-world complex systems 8, 41– 45 . To fill this gap, this study proposes a protocol for the IAM community, grounded in the current state of open science efforts and obstacles encountered by modeling teams.” Updated paragraph: “Open science is rapidly transforming research practices across disciplines [21– 24] , including the energy and climate modeling communities. In recent years, Energy System Optimization Models (ESOMs) like OSeMOSYS[30] and Power System Models (PSMs) like PyPSA[75] have embraced transparency by releasing their model code under open-source licenses. Some PSMs go a step further by providing fully reproducible workflows and interactive examples through Jupyter notebooks, making them not only

more accessible but also valuable tools for education and capacity building. At the same time, the integrated assessment modeling (IAM) community is increasingly adopting open science principles to improve the transparency, accessibility, and understanding of the scenarios they generate [25, 26].”

While the survey design is appropriate for gathering qualitative insights, the methodology section lacks sufficient detail. Key elements such as the full survey instrument, sample size, and selection process are missing, which limits transparency and hampers replicability. Providing this information, along with a clearer description of how responses were analyzed, would enhance the robustness of the conclusions. Thank you for raising this important point. A new Methods section has been created to provide a comprehensive account of the survey design and implementation. This includes the full survey instrument, the sampling strategy, the number and background of participants, and the approach used for analyzing the responses. These additions aim to improve both the transparency and reproducibility of our study. We have addressed it in detail below.

The protocol presented is promising, with clearly outlined steps. However, it would benefit from further elaboration, particularly regarding practical challenges encountered, strategies for adaptation across IAM contexts, and concrete examples of successful implementation. Additional data—such as more detailed documentation, case studies, or checklists—would improve the transparency and reusability of the work. Thank you for your thoughtful suggestions. In response, we have introduced concrete examples of successful implementation of the protocol steps in the newly added Table 1, which illustrates how the protocol has been applied in practice. Additionally, practical challenges encountered during implementation are now discussed in greater detail in the Survey Results section, as they were directly derived from participant responses. To further support reusability, we also provide a checklist to guide implementation of the protocol. This checklist is openly available through our GitHub repository. Due to journal constraints, we are unable to include it as part of the Supplementary Material, but we have clearly referenced the link within the manuscript.

Protocol section	Protocol step	Example/s	Suggested tool/s
1. Model and data documentation process	Model documentation	GCAM[28], MEDEAS[29] documentations	Tailor made documentation page
1. Model and data documentation process	Model interconnections documentation	Moreno et al. 2024[68], Nikas et al. 2024[69]	Supplementary Information of the related paper
1. Model and data documentation process	Input harmonization documentation	Moreno et al. 2024[68]	Supplementary Information of the related paper
2. Open management of project outcomes	Output standardization	Fragkos et al. 2024[70]	Tailor made tools, e.g., gcamreport [32]
2. Open management of project outcomes	Output validation	Van Vuuren et al. 2025[74]	gcamreport [32], piamValidation [71], I²AMPARIS Validation tool [49],
2. Open management of project outcomes	Output files storage	Reisinger et al. 2024[72], Rinaldi & Ghezzi, 2024[73], Sampdero et al. 2024[67],	Zenodo [22]
2. Open management of project outcomes	Visualization tools	Khan et al. 2022[31]	Tailor made user friendly interfaces (e.g., WILIAM web base [32], witch-plot [39]), external platforms (e.g., I²AMPARIS platform [32]), libraries (e.g., pyam [36])

Table 1. Examples of studies aligned with each protocol step and recommended tools to support their implementation.

Although the interpretation of survey results is reasonable, it relies heavily on qualitative insights. Incorporating statistical analysis or quantitative data could provide stronger support for the findings. The conclusions align with the presented results but could be made more compelling through the inclusion of real-world applications that demonstrate the protocol's effectiveness and impact. Thank you for this valuable comment. Our analysis was designed to incorporate both qualitative and quantitative elements. While the survey primarily gathered qualitative insights, we complemented this with a quantitative overview of community practices, as shown in Figure 1 and discussed in the accompanying analysis. Importantly, the protocol is not static as it is currently being implemented and tested in practice. It forms part of the IAM COMPACT project and will be adopted in the latest modeling round, which will provide further opportunities for refinement and evaluation. These ongoing efforts will allow us to assess the protocol's practical effectiveness and impact in real-world settings. We consider this an iterative and collaborative process and look forward to engaging with the broader community to further discuss, validate, and improve the protocol over time. Other information related to data/code availability and

figure: - The GitHub repository: https://github.com/klau506/open_science_iams does not detail how to use the R code and with which data. Thank you for your comment. The README file has been updated to better detail how to use the R code and on which data it relies. More details below. - The data is deposited in Zenodo as xlsx file which is not an open format. csv file (text file) would be better for reuse. Thank you for your comment. The data format has been changed to CSV to allow interoperability and reusability. The metadata is also available as TXT. More details below. - Figure 1 is unreadable on my laptop (too small). Thank you for your comment. We agree that Figure 1 was slightly too small. Thus, we have increased the text size and the pie charts dimensions. We have also reduced some pie chart's text to better fit the space. More details below. - The survey results file (available at https://zenodo.org/records/13970492) contains 9 entries, suggesting that fewer than 10 individuals responded to the survey. Thank you for your comment. We have extended the survey invitation to the partners from the DIAMOND project, reaching a total of 13 answers. More details below.

Recommendation: There are a few areas where additional details and refinement could help to strengthen the scientific rigor of your paper. Below are some specific suggestions:
1. Strengthen the Theoretical Framework
It would be beneficial to gain a deeper understanding of how the FAIR and TRUST principles can be practically applied to IAMs (in detail because in the paper, the 15 FAIR principles are not addressed with sufficient details). This will help better align the theoretical foundation of your protocol with current best practices in Open Science and ensure its relevance to the IAM community. Thank you for your comment. We agree that this aspect could benefit from further detail. While the provided checklist already adheres to both the FAIR (Findable, Accessible, Interoperable, and Reusable) and TRUST (Transparency, Responsibility, User focus, Sustainability, and Technology) principles, we recognize the importance of making these connections more explicit for the reader. To address this, we have revised the manuscript to clearly state how the checklist operationalizes these principles. Specifically, we now provide concrete guidance on how both data and metadata should be uploaded, curated, and shared. This includes direct references to the 15 FAIR guiding principles, outlining expectations for persistent identifiers, rich metadata, usage of standard vocabularies, and protocols for accessibility and long-term preservation. Furthermore, the checklist has been designed as a living tool, hosted on GitHub, where it can be refined and expanded as best practices evolve. We have also emphasized that the checklist is intended to support practical implementation across different IAM contexts by offering a structured, step-by-step framework that complements the protocol. Although the journal's policy limits our ability to include the full checklist as Supplementary Material, we have clearly referenced its location in the manuscript and encourage the community to use and contribute to its ongoing development. Updated paragraph: To facilitate the protocol application and boost the implementation of open science principles, we provide a checklist to modeling teams [47], available at Zenodo [22]. This comprehensive list, structured in the same blocks as the protocol, serves as a useful tool to ensure that no steps are overlooked and acts as a reminder of best practices in open science. In the same line, to ensure that uploaded data and metadata follow the FAIR principles, we recommend ensuring that it is rich, retrievable through an open protocol, uses a broadly applicable language and assigned to a unique persistent identifier [34].

2. Enhance Methodological Transparency
The methodology section could be improved by providing more detailed information about the survey design. For instance, explain why the sample size and the selection process of survey participants were sufficient for this work. Thank you for your comment. We agree that the provided methodological information could be improved. Therefore, we have created a dedicated Methodological section, where the survey design, structure, distribution, and analysis are detailed. Besides, we detail why the sample size and selected modeling teams offer a broad overview of the IAM community, as well as detail that this might be a possible limitation in the Discussion section. New section (Methods): "Methods To identify the open science practices employed by various modeling teams, as well as the main challenges and barriers they face, we designed a survey [47] . The survey was structured into three sections aligned with the traditional IAM modeling steps: (1) model(s) development, calibration, and interconnection; (2) model(s) output analysis and dissemination; and (3) tools used throughout the process. Specifically, the first section focused on the documentation process, including model documentation, input harmonization, and potential multi-model connectivities. The second section examined the management of project outcomes, addressing output standardization, the vetting process, output storage, and results presentation. Finally, the third section investigated the tools used or developed to support open science principles. This survey was sent to all modeling teams from the IAM COMPACT [46] and DIAMOND [56] consortia, gathering a total of 13 responses. IAM COMPACT, a Horizon Europe research project, aims to support the assessment of global climate goals and the design of the next round of Nationally Determined Contributions and policy planning beyond 2030. At its core are diverse multi-model analyses that emphasize the adoption and standardization of open science practices to ensure that model outputs are reliable, accessible, transparent, and reusable. On the other hand, the Horizon Europe DIAMOND project focuses on developing open-source IAMs, which stand to benefit significantly from open science principles by enhancing usability and broadening access across modeling teams. With this broad representation of models, institutions, and project scopes, our survey captures a robust and representative sample of the IAM community. The quantitative and qualitative survey results were analyzed both individually and collectively to identify patterns within specific modeling teams and to highlight common practices shared across the broader community. This dual approach allowed us to capture both the diversity of experiences and the overarching trends in how open science principles are being implemented." Updated Discussion: "... To address this gap, this paper introduces a protocol for the entire IAM community that offers a structured framework for modeling teams and related projects. While it is built on the challenges faced by specific modeling teams and may not capture all perspectives, the protocol aims to serve as a valuable resource for the broader community...."

3. Improve the GitHub Repository
The GitHub repository could be enhanced by providing clear documentation on how to use the R code and apply it to the provided data. Additionally, I suggest switching the data format from XLSX to an open format like CSV to facilitate easier reuse and interoperability with other tools. Thank you for your comment. The responses file extension has been switched to CSV to improve reusability and interoperability for other tools. The metadata that was provided in the previous XLSX file, is now a standalone TXT.

4. Enhance Visual Accessibility
Figure 1 is not easily readable on standard devices. I recommend increasing the resolution and size of the figures to improve accessibility, ensuring that they are clearly visible to a broader audience. Thank you for comment. We have improved the figure's readability by increasing the font size, the pie charts' size, and shortening some names.

5. Increase Survey Sample Size
Given that the survey currently includes fewer than 10 responses, I suggest reaching out to more IAM teams to increase the sample size. A larger sample would improve the representativeness of the findings. It would also be helpful to acknowledge the potential limitations posed by the small sample size and how these might affect the interpretation of your results. Thank you for your comment. We acknowledge that the number of survey responses was relatively limited. To broaden the perspective, we incorporated responses from an additional Horizon Europe consortium, DIAMOND, bringing the total to 13 responses. This project focuses on upgrading open-source versions of six IAMs, serving as an ideal complement to the initial group of responses, which were related to the use of IAMs for informing climate policy design. Together, these responses offer a well-rounded overview of the IAM community. Nevertheless, as noted in the discussion, we recognize that the sample could be further expanded to capture an even wider range of perspectives. Updated Discussion: "... To address this gap, this paper introduces a protocol for the entire IAM community that offers a structured framework for modeling teams and related projects. While it is built on the challenges faced by specific modeling teams and may not capture all perspectives, the protocol aims to serve as a valuable resource for the broader community. ..."

Competing Interests: No competing interests were disclosed.

Reviewer Report 26 February 2025

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Marc-André Simard
[1] Université de Montréal, Québec,, Canada
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Overall:

Using survey data, this manuscript investigates open science practices (including barriers and challenges) in integrated assessment modeling (IAM) teams. Furthermore, this manuscript proposes an open science protocol to address some key challenges and barriers (such as data weight, lack of time, awareness or knowledge, etc.) in the use of open science within integrated

assessment modeling. The protocol is built around validated principles such as FAIR and TRUST. The authors provide sufficient context and information (e.g. packages, checklist, softwares, plaforms, etc.) for their model to be adaptable and usable in a wide range of contexts.

I do believe that this manuscript would make a great addition to the body of literature on open science, but I believe that there are some things that could be addressed before it is ready to be indexed.

While I understand that the intention of the authors is most likely to keep the introduction/review of literature brief while attempting to cover the massive landscape of OS, it can sometimes feel like some of these issues are tackled in a slightly superficial manner. For instance, a few of the paragraphs could be more fleshed out and expanded into proper sections (e.g. open data, benefits of OS) which could cover some recent empirical research results/literature on these topics.

Further, while I also greatly appreciate the transparency and the sharing of the data, codes, protocols, etc., I think the manuscript would also benefit to have a dedicated methodology section; most of the information is already available in the "Survey Results" section. I would just separate it into two sections and flesh it out a little bit more if/when needed with some descriptive information about the methods, participants, etc.

Some more specific comments:

Introduction/review of literature:

- Regarding OS initiatives in the second paragraph: I would clarify a couple of things regarding the US' policies. Many US OS policies (including the NIH's) are normally called "public access policies" because they have slightly different criteria from OA policies. The Nelson Memo (Refer 1) has also sparked a new generation of OS policies in the US; the NIH's latest policy was recently released. In short, I would cover the Nelson Memo and then would give some of the newest policies as examples instead of the NIH's previous 2021 policy.
- In the third paragraph (resources) I would also mention an OA repository, given how important they have been. OpenAIRE/CERN's Zenodo or PubMed Central would be a good example.

OS practices in IAMs:

- As someone who is not too familiar with IAMs, I would have appreciated a sentence or two on their background. A Google search helped me catch up quickly, but the additional information wouldn't hurt.

Results:

- The figures are beautifully done, but the text in the pie charts (Figure 1) is tiny and can be hard to read on a laptop. I am also not sure if the colours are on par with accessibility standards (e.g. colours, black and white for print, etc.). I would verify that if it hasn't already been done.

References

1. Alondra Nelson: MEMORANDUM FOR THE HEADS OF EXECUTIVE DEPARTMENTS AND AGENCIES.

2022 https://bidenwhitehouse.archives.gov/wp-content/uploads/2022/08/08-2022-OSTP-Public-Access-Memo.pdf.

Is the work clearly and accurately presented and does it engage with the current literature?
Partly

Is the study design appropriate and is the work technically sound?
Yes

Are sufficient details of methods and analysis provided to allow replication by others?
Partly

Are all the source data and materials underlying the results available?
Yes

If applicable, is the statistical analysis and its interpretation appropriate?
Yes

Are the conclusions drawn adequately supported by the results?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Information science, bibliometrics, science of science, open access, science policy

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 06 Jun 2025

Clàudia Rodés-Bachs

Dear Marc-André Simard,

Thank you so much for the time devoted to the manuscript and your insightful comments. They have been a key resource in improving the manuscript and study. Detailed responses below: Overall: Using survey data, this manuscript investigates open science practices (including barriers and challenges) in integrated assessment modeling (IAM) teams. Furthermore, this manuscript proposes an open science protocol to address some key challenges and barriers (such as data weight, lack of time, awareness or knowledge, etc.) in the use of open science within integrated assessment modeling. The protocol is built around validated principles such as FAIR and TRUST. The authors provide sufficient context and information (e.g. packages, checklist, softwares, platforms, etc.) for their model to be adaptable and usable in a wide range of contexts. I do believe that this manuscript would make a great addition to the body of literature on open science, but I believe that there are

some things that could be addressed before it is ready to be indexed. While I understand that the intention of the authors is most likely to keep the introduction/review of literature brief while attempting to cover the massive landscape of OS, it can sometimes feel like some of these issues are tackled in a slightly superficial manner. For instance, a few of the paragraphs could be more fleshed out and expanded into proper sections (e.g. open data, benefits of OS) which could cover some recent empirical research results/literature on these topics.

Response: Thank you for your thoughtful comment. We appreciate your interest in the literature review at the beginning of the introduction. While having a broader scope, our intention is to keep the general overview concise in order to maintain focus on open science practices within the IAMs community. For this reason, we prefer not to introduce subdivisions in this section. That said, the topics of open data, associated benefits, and relevant tools are presented as standalone paragraphs to improve clarity. Additionally, we have included further examples from other scientific disciplines and modeling communities to strengthen the contextual background, while extending the open science practices in the IAMs context review. Updated lines: “While this new research paradigm and the new sharing and publication rhythm raised concerns about the potential impact on the quality of research output [18], it also encouraged the development of additional guidelines and specific protocols to guarantee the successful deployment of open science practices, which have been maintained in the post-pandemic era in a wide range of scientific disciplines (e.g., sustainable transport [60], criminology [61], and artificial intelligence [62]). Updated paragraph: “The development of all these tools facilitates multi-model comparison studies, which are crucial for improving the consistency and robustness of policy recommendations [26, 40] . Open science strengthens the understanding and integration of models, while also streamlining data analysis by providing comprehensive documentation of model linkages [25] . Recently, several reports examining methodologies used in large-scale initiatives, such as the IPCC AR6, have highlighted valuable lessons and opportunities for future research [42,63,64]. In parallel, several research teams are making substantial efforts to openly share their workflows, methodologies, data, and code [65– 67], crucial steps to prevent models from being perceived as “black boxes”. However, the implementation of open science practices varies widely across modeling teams and is often hindered by various factors, which can slow scientific progress, limit the reporting and reuse of research findings, and hamper the reliability of the representation of real-world complex systems [8, 41– 45] . To fill this gap, this study proposes a protocol for the IAM community, grounded in the current state of open science efforts and obstacles encountered by modeling teams.” Updated paragraph: “Open science is rapidly transforming research practices across disciplines [21– 24] , including the energy and climate modeling communities. In recent years, Energy System Optimization Models (ESOMs) like OSeMOSYS[30] and Power System Models (PSMs) like PyPSA[75] have embraced transparency by releasing their model code under open-source licenses. Some PSMs go a step further by providing fully reproducible workflows and interactive examples through Jupyter notebooks, making them not only more accessible but also valuable tools for education and capacity building. At the same time, the integrated assessment modeling (IAM) community is increasingly adopting open science principles to improve the transparency, accessibility, and understanding of the scenarios they generate [25, 26] .” 8 Tenopir C, Dalton ED, Allard S, et al.: Changes in data sharing and data reuse practices and perceptions among scientists worldwide. PLoS One, Publisher: Public Library of Science San

Francisco, CA USA,2015;10(8):e0134826. 26308551 10.1371/journal.pone.0134826 4550246 18 Besançon L, Peiffer-Smadja N, Segalas C, et al.: Open science saves lives: lessons from the COVID-19 pandemic. BMC Med Res Methodol. 2021;21(1): 117. 34090351 10.1186/s12874-021-01304-y 8179078 21 Nielsen AF, Michelmann J, Akac A, et al.: Using the future wheel methodology to assess the impact of open science in the transport sector. Sci Rep. 2023;13(1): 6000. 37046066 10.1038/s41598-023-33102-5 10097618. 22 Branney P, Brooks J, Kilby L, et al.: Three steps to open science for qualitative research in psychology. 2022. 10.1111/spc3.12728 23 Chin JM, Pickett JT, Vazire S, Holcombe AO, et al.: Questionable research practices and open science in quantitative criminology. J Quant Criminol. Publisher: Springer,2023;39:21–51. 10.1007/s10940-021-09525-6 24 Brinkhaus HO, Rajan K, Schaub J, et al.: Open data and algorithms for open science in AI-driven molecular informatics. Curr Opin Struct Biol. 2023;79:102542. 36805192 10.1016/j.sbi.2023.102542 25 IAMC: IAMC Documentation Wiki. 2022. 26 Nikas A, Gambhir A, Trutnevyte E, et al.: Perspective of comprehensive and comprehensible multi-model energy and climate science in Europe. Energy. Publisher: Elsevier,2021;215: 119153. 10.1016/j.energy.2020.119153 40 Guivarch C, Le Gallic T, Bauer N, et al.: Using large ensembles of climate change mitigation scenarios for robust insights. Nat Clim Change. 2022;12(5):428–435. 10.1038/s41558-022-01349-x 41 Wilson C, Guivarch C, Kriegler E, et al.: Evaluating process-based integrated assessment models of climate change mitigation. Climatic Change. 2021;166(1–2):3. 10.1007/s10584-021-03099-9 42 Pirani A, Fuglestvedt JS, Byers E, et al.: Scenarios in IPCC assessments: lessons from AR6 and opportunities for AR7. npj Clim Action. 2024;3(1):1. 10.1038/s44168-023-00082-1 43 Robertson S: Transparency, trust, and integrated assessment models: an ethical consideration for the Intergovernmental Panel on Climate Change. WIREs Climate Change. 2021;12(1):e679. 10.1002/wcc.679 44 Skea J, Shukla P, Al Khourdajie A, et al.: Intergovernmental Panel on Climate Change: transparency and integrated assessment modeling. WIREs Climate Change. 2021;12(5):e727. 10.1002/wcc.727 45 Melero R, Boté-Vericad JJ, López-Borrull A: Perceptions regarding open science appraised by editors of scholarly publications published in Spain. Learn Publ. 2023;36(2):178–193. 10.1002/leap.1511 60 Nielsen, A. F., Michelmann, J., Akac, A., Palts, K., Zilles, A., Anagnostopoulou, A., & Langeland, O. (2023). Using the future wheel methodology to assess the impact of open science in the transport sector. Scientific Reports, 13(1), 6000. https://doi.org/10.1038/s41598-023-33102-5 61 Branney, P., Brooks, J., Kilby, L., Newman, K., Norris, E., Pownall, M., Talbot, C. V., Treharne, G. J., & Whitaker, C. (2022). Three Steps to Open Science for Qualitative Research in Psychology. 62 Brinkhaus, H. O., Rajan, K., Schaub, J., Zielesny, A., & Steinbeck, C. (2023). Open data and algorithms for open science in AI-driven molecular informatics. Current Opinion in Structural Biology, 79. https://doi.org/10.1016/j.sbi.2023.102542 65 Byers, E. et al. Scenarios Processing, Vetting and Feasibility Assessment for the European Scientific Advisory Board on Climate Change. Technical Report (International Institute for Applied Systems Analysis and Potsdam Institute for Climate Imact research, 2023). 66 Rinaldi, L., Ghezzi, D., Colombo, E., & Rocco, M. V. (2024). Assessing environmental and market implications of steel decarbonisation strategies: A hybrid input-output model for the European union. Environmental Research Letters, 19(7), 074059. https://doi.org/10.1088/1748-9326/ad5bf1 67 Sampedro, J., Van De Ven, D.-J., Horowitz, R., Rodés-Bachs, C., Frilingou, N., Nikas, A., Binsted, M., Iyer, G., & Yarlagadda, B. (2024). Energy system analysis of cutting off Russian gas supply to the European Union. Energy Strategy Reviews, 54, 101450. https://doi.org/10.1016/j.esr.2024.101450 75 Brown, T., Hörsch, J., & Schlachtberger, D.

(2017). PyPSA: Python for power system analysis. arXiv preprint arXiv:1707.09913.

Further, while I also greatly appreciate the transparency and the sharing of the data, codes, protocols, etc., I think the manuscript would also benefit to have a dedicated methodology section; most of the information is already available in the "Survey Results" section. I would just separate it into two sections and flesh it out a little bit more if/when needed with some descriptive information about the methods, participants, etc.

Response: Thank you for your comment. Sure, we agree that the manuscript will become clearer since this information is key. We have created a new section called "Methods" right before "Survey results", with the details of the survey structure and the surveyed modeling teams. New section (Methods): "Methods To identify the open science practices employed by various modeling teams, as well as the main challenges and barriers they face, we designed a survey [47] . The survey was structured into three sections aligned with the traditional IAM modeling steps: (1) model(s) development, calibration, and interconnection; (2) model(s) output analysis and dissemination; and (3) tools used throughout the process. Specifically, the first section focused on the documentation process, including model documentation, input harmonization, and potential multi-model connectivities. The second section examined the management of project outcomes, addressing output standardization, the vetting process, output storage, and results presentation. Finally, the third section investigated the tools used or developed to support open science principles. This survey was sent to all modeling teams from the IAM COMPACT [46] and DIAMOND [56] consortia, gathering a total of 13 responses. IAM COMPACT, a Horizon Europe research project, aims to support the assessment of global climate goals and the design of the next round of Nationally Determined Contributions and policy planning beyond 2030. At its core are diverse multi-model analyses that emphasize the adoption and standardization of open science practices to ensure that model outputs are reliable, accessible, transparent, and reusable. On the other hand, the Horizon Europe DIAMOND project focuses on developing open-source IAMs, which stand to benefit significantly from open science principles by enhancing usability and broadening access across modeling teams. With this broad representation of models, institutions, and project scopes, our survey captures a robust and representative sample of the IAM community. The quantitative and qualitative survey results were analyzed both individually and collectively to identify patterns within specific modeling teams and to highlight common practices shared across the broader community. This dual approach allowed us to capture both the diversity of experiences and the overarching trends in how open science principles are being implemented."

Some more specific comments:
Introduction/review of literature:
1. Regarding OS initiatives in the second paragraph: I would clarify a couple of things regarding the US' policies. Many US OS policies (including the NIH's) are normally called "public access policies" because they have slightly different criteria from OA policies. The Nelson Memo (Refer 1) has also sparked a new generation of OS policies in the US; the NIH's latest policy was recently released. In short, I would cover the Nelson Memo and then would give some of the newest policies as examples instead of the NIH's previous 2021 policy.
Response: Thank you very much for your comment and detailed explanation. We have revised the paragraph accordingly to more accurately reflect the recent developments in

Open Science and Open Access policies in the United States. Updated paragraph: "... Numerous initiatives and policies also drive the adoption of open science, such as the European Union's Horizon 2020 program, which have implemented open-access mandates [9]. Meanwhile, the European Commission created the EU's Open Science Policy Platform to provide high-level guidance on the development of its Open Science Policy [11]. Similarly, in the United States, a Memorandum [58] was issued to the Heads of Departments and Agencies, promoting the adoption of open science and public access policies across a broad range of institutions, such as the National Institutes of Health [59]."

2. In the third paragraph (resources) I would also mention an OA repository, given how important they have been. OpenAIRE/CERN's Zenodo or PubMed Central would be a good example.
Response: Thank you for the suggestion. We agree that these items were missing and have added them accordingly! We have also included computational collaborative platforms that allow data to be uploaded and work as standalone environments. Updated paragraph: "... open data repositories, such as the World Bank open data [2] or the World Health Organisation data [3]; open access repositories, such as Zenodo [22] and PubMed Central [27]; software for open-source computing and development, for instance, Unix [4] and Git [5]; collaborative data and computational platforms, such as MSD-Live [35]; ..."

OS practices in IAMs:

As someone who is not too familiar with IAMs, I would have appreciated a sentence or two on their background. A Google search helped me catch up quickly, but the additional information wouldn't hurt.
Response: Sure! Thank you for your point. We have added some words about IAMs and a citation to provide further information. Updated paragraph: "IAMs are essential tools for global scenario analysis and for exploring the systemwide impacts of climate policies [27]. These models represent the world energy, land, water, climate, and socio-economic systems and estimate plausible scenarios [57]. For instance, their outcomes and results have been used in the latest Intergovernmental Panel on Climate Change (IPCC) report (AR6; [28]), which required all contributors to homogenize their data to enable comparisons and ensure full transparency [29]." 27. Van Beek L, Hajer M, Pelzer P, et al.: Anticipating futures through models: the rise of integrated assessment modelling in the climate science-policy interface since 1970. Global Environ Chang. 2020;65: 102191. 10.1016/j.gloenvcha.2020.102191 28. Shukla PR, Skea J, Slade R, et al.: Climate change 2022 mitigation of climate change. Cambridge University Press, Cambridge, UK and New York, NY, USA,2022. Reference Source 29. Krey V, Masera O, Blanford G, et al.: Annex ii: metrics & methodology. In: O. Edenhofer, R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel, and J. C. Minx, editors, Climate change 2014: mitigation of climate change. Contribution of working group iii to the fifth assessment report of the intergovernmental panel on climate change. Cambridge University Press,2014. Reference Source 57. Weyant J. Some contributions of integrated assessment models of global climate change. Review of Environmental Economics and Policy. 2017; vol. 11(1), pages 115-137

Results:

The figures are beautifully done, but the text in the pie charts (Figure 1) is tiny and can be hard to read on a laptop. I am also not sure if the colours are on par with accessibility standards (e.g. colours, black and white for print, etc.). I would verify that if it hasn't already been done.
Response: Thank you for your comment. We have increased the font size in Figure 1 to enhance readability and ensure clarity. Regarding the color palette, we are fully open to the Editor's preference and will be happy to adjust it if suggested.

Competing Interests: No competing interests were disclosed.