



Net0 Pathways through improved IAMs across Sectors, dimensions, and scales

Deliverable 4.3

*Final scenario data of
WP4 scenario analysis*

Deliverable 4.3

30 June 2026



This project has received funding from the European Union's Horizon Europe programme under grant agreement No 101081604 - PRISMA. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

Deliverable Title	Final scenario data of WP4 scenario analysis
Deliverable number	4.3
Brief Description	Scenario Explorer with WP4 scenario data on materials and ICT energy
WP number	4
Lead Beneficiary	IIASA
Author(s)	Volker Krey, Daniel Huppmann
Internal reviewer(s)	Leticia Magalar, CMCC
Deliverable Due Date	30 June 2026
Actual Delivery Date	30 June 2026
Nature of the Deliverable	R – Document, report
Dissemination Level	PU - Public
KeyWords	Integrated scenario modeling; Sustainable lifestyles; Digital transformation; Circularity;
Remarks	Note that the actual deliverable is the scenario dataset, deposited on Zenodo and distributed via the Scenario Explorer infrastructure. This document provides relevant background information and context to the pathway data. To do so, it partly reproduces previously published information, including from other deliverables which is referenced in this document. Note that an LLM was used for generating the abstract and summary

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Abstract

This deliverable presents the final scenario data developed in Work Package 4 (WP4) of the PRISMA project, covering integrated scenarios of materials use and information and communication technology (ICT) sector energy demand. The dataset is made available through two complementary channels: the PRISMA Scenario Explorer (<https://prisma.apps.ece.iiasa.ac.at/>), a web-based user interface for interactive data visualization and comparison, and a Zenodo deposit for long-term archival (<https://doi.org/10.5281/zenodo.21035260>). The scenario data follow the Integrated Assessment Modeling Consortium (IAMC) reporting standard, a community-developed tabular time-series format widely adopted in the integrated assessment modelling community and is made available under the Creative Commons Attribution license (CC-BY).

Because WP4 addresses dimensions underrepresented in existing community definitions, the project has developed extensions covering material flows and stocks relevant to Circular Economy (CE) strategies, as well as energy and emissions of digital infrastructure. These extensions were developed in coordination with other Horizon Europe projects and are intended to eventually become new community standards. WP4 encompasses two scenario exercises. The bulk material scenarios compare material flows and stocks across four integrated assessment models under current policies and 2°C-compatible trajectories, focusing on base year alignment and sector-level demands for key bulk materials. The ICT sector scenarios explore electricity demand of data centres and network infrastructure across five models under varying assumptions about ICT demand levels, climate policy ambition, and socio-economic development pathways. The Scenario Explorer infrastructure, built on the open-source ixmp4 backend and connected to the pyam Python package for scenario analysis, supports automated data validation and enables efficient downstream reuse of results in alignment with open science principles.



1 Introduction

For the dissemination of pathways developed under the PRISMA project, the reporting standards defined by the Integrated Assessment Modeling Consortium (IAMC) and the web-based tools developed by the International Institute for Applied Systems Analysis (IIASA), the so-called Scenario Explorer infrastructure¹, are used.

For more than 15 years, the IAMC is developing and maintaining data reporting standards that have been widely adopted in the Integrated Assessment Modeling community for sharing and disseminating scenario information^{2,3}. More recently, the so-called common-definitions repository has been established to consolidate the reporting standards⁴. The PRISMA project adopts this reporting format as well as extensions of it that have been developed that cater to specific needs of the project. The extensions concern in particular variables related to material flows and stocks that are essential for the characterization of Circular Economy (CE) strategies as well as the energy and emissions implications of digitalization which are a key aspect of the PRISMA WP4 scenarios.

The Scenario Explorer infrastructure is currently the most widely used data hub for global, regional and national integrated assessment modelling comparisons and has been adopted by the IPCC WG3 scenario assessments during the 5th and 6th Assessment Report cycles (AR6 Scenario Explorer⁵, SR1.5 Scenario Explorer⁶, AR5 Scenario Database⁷). It has also been applied in many projects with a global (e.g., Horizon2020 projects CD-LINKS, ENGAGE, NAVIGATE) and European focus (e.g., SET-Nav, ECEMF, ARIADNE, openENTRANCE, iDesignRES). It serves as a central destination for modellers, facilitating cooperation and exchange across countries and modelling groups. The main feature is an intuitive web user interface that enables not just experts but a wider audience to visualize and compare scenario

¹ <https://docs.ece.iiasa.ac.at>

² <https://www.iamconsortium.org/scientific-working-groups/data-protocols-and-management/>

³ <https://docs.ece.iiasa.ac.at/iamc.html>

⁴ <https://github.com/IAMconsortium/common-definitions>

⁵ <https://data.ece.iiasa.ac.at/ar6/>

⁶ <https://data.ene.iiasa.ac.at/iamc-1.5c-explorer/>

⁷ <https://ar5.legacy.ece.iiasa.ac.at/legacy-ar5/>



results and input data. The infrastructure also supports automated validation steps to ensure consistency and completeness of scenarios submitted to the database by modelling teams, and it provides several possibilities to efficiently retrieve data for subsequent use by modelling.

In addition to making the pathway data available via this web-based tool, data snapshots of the pathways data are deposited on Zenodo. Metadata of the snapshots contain all relevant licensing, versioning and related publications or previous datasets. Any upgraded or newer versions of data will be issued with a new DOI that includes information on any previous versions. Within the repository older versions can be deprecated and users will be directed to the updated information.

2 Scenario description

As part of WP4, several scenario sets have been developed. Table 1 provides an overview of the scenario sets and the following subsections provide a brief description of the scenario design.

Scenario	Short Description	Models
Bulk Material Comparison		
SSP2 – Medium Emissions	Current Policies until 2030 and equivalent efforts extrapolated until 2100	IMAGE, MESSAGEix, REMIND
SSP2 – Low Emissions	likely 2°C scenario with mitigation starting mitigation after 2025	
ICT Sector Comparison		
SSPX - Current Policies - High ICT	Current Policies extrapolated + High ICT sector demand	IMAGE (SSP2), MESSAGEix (SSP1-5), OPEN-PROM (SSP2), REMIND (SSP1/2/3) WITCH (SSP2)
SSPX - Current Policies - Medium ICT	Current Policies extrapolated + Medium ICT sector demand	

SSPX - Current Policies - Low ICT	Sector Current Policies extrapolated + Low ICT sector demand	
SSPX - Net-Zero - High ICT	Net-zero CO2 emissions + High ICT sector demand	
SSPX - Net-Zero - Medium ICT	Net-zero CO2 emissions + Medium ICT sector demand	
SSPX - Net-Zero - Low ICT	Net-zero CO2 emissions + Low ICT sector demand	
SSP2 - Current Policies - Medium ICT - Convergence	Current Policies extrapolated + Medium ICT sector demand + regional demand convergence	
SSP2 - Net-Zero - Medium ICT - Convergence	Net-zero CO2 emissions + Medium ICT sector demand + regional demand convergence	

Table 1: Overview of WP4 scenarios.

2.1 Bulk material scenarios

The goal of this exercise is a comparison of bulk material flows, including demand by sector, primary and secondary production, recycling options, and accumulation in stocks. However, as very few model intercomparisons have compared bulk material flows and stocks, particular attention is paid to base year alignment as a first step towards meaningfully comparing scenario trends over time. For this reason, two simple diagnostic climate policy scenarios with the following specifications are analyzed:

- a current policies scenario with “equivalent efforts” continuing until 2100; and
- a likely 2°C scenario with mitigation starting mitigation after 2025.

As the development of policy scenarios within PRISMA is still on the way in Work

Package 6, the definitions of the Medium Emissions and Low Emissions scenarios used in CMIP7/ScenarioMIP (van Vuuren et al. 2025)⁸ that all four participating modeling teams are part of, have been used. Table 2 and Table 3 below provide an overview of the sectors in which the participating models endogenously capture material demands and the types of bulk and strategic materials that are represented.

	Power sector	Transport sector	Buildings
IMAGE	yes	yes	yes
MESSAGEix-GLOBIOM	yes	partly (infrastructure only)	yes
REMIND-MAgPIE	no	(planned)	no
WITCH	yes	yes	no

Table 2: Sector-specific material demands covered in participating IAMs.

	Steel	Cement	Chemicals	Aluminum	Copper
IMAGE	yes	yes	yes	yes	yes
MESSAGEix-GLOBIOM	yes	yes	yes	yes	no
REMIND-MAgPIE	yes	yes	yes	no	no
WITCH*	yes	yes	no	yes	yes

Table 3: Types of bulk and strategic materials covered in participating IAMs.

2.2 ICT Sector scenarios

The objective of the PRISMA ICT sector scenario activity is four-fold, (i) to represent electricity demand of data centres and network infrastructure explicitly in IAMs, (ii) quantify energy and GHG emissions implications of ICT sector demand under

⁸ Van Vuuren et al. (2026) The Scenario Model Intercomparison Project for CMIP7 (ScenarioMIP-CMIP7), Geosci. Model Dev., 19, 2627–2656, <https://doi.org/10.5194/gmd-19-2627-2026>

different boundary conditions, (iii) understanding uncertainties of energy demand and implied GHG emissions and their drivers, and (iv) to put the ICT sector demand into context of demand categories related to decarbonization strategies (e.g., heat pumps, EVs).

In order to achieve these objectives, the scenario design distinguishes three dimensions, i.e. the evolution of ICT sector demand, climate policy and socio-economic development.

- ICT sector (data centres + networks) demand provided by University of Oxford
 - High
 - Medium
 - Low
- Socio-economic development based on the latest revision of projections
 - SSP2 (default)
 - SSP1/3/4/5 (optional)
- Climate policy
 - Current policies with “equivalent efforts” continuing until 2100
 - NDC + net-zero target + extension implemented via a 900 GtCO₂ budget between 2021 and reaching net-zero CO₂ emissions
- Regional Convergence
 - Alternative regional demand growth projection with stronger convergence of data center deployment compared to the default case that largely reproduces the currently observed pattern

Regarding climate policy, the current policies scenario includes a representation of implemented policies at the regional level with an extrapolation of the effort via a carbon price. To explore strong regional differences in ICT sector demand growth, it is essential to reflect implemented climate policies and future ambition at the regional level as opposed to having stylized climate policy.

3 Scenario data infrastructure

For the PRISMA project a public Scenario Explorer has been established through which the scenario data are distributed via a web-based user interface at <https://prisma.apps.ece.iiasa.ac.at/>. The scenario data is deposited on Zenodo until the following DOI <https://doi.org/10.5281/zenodo.21035260> for long-term archival.



3.1 Data template

The IAMC developed a standardized tabular timeseries format to exchange scenario data related to energy systems modelling, land-use change, demand sectors, and economic indicators in the context of climate change mitigation pathways with a link to a much broader set of sustainability dimensions. Previous high-level use cases include reports by the IPCC and model comparison exercises within national, regional and global activities, including European Horizon projects, Stanford University's Energy Modeling Forum (EMF) and others.

After 15 years of developing and maintaining this data template, the scale of its utilization required a more coordinated approach. Therefore, the IAM community has developed a central location to facilitate reuse of definitions and mappings across projects through which the variable and region definitions are shared, developed and maintained. The *common-definitions repository*⁹ holds definitions and mappings for model-comparison projects using the IAMC data format. The aim is to provide a central location to facilitate reuse of definitions and mappings across projects. In addition, each project can define extensions of the centrally managed common-definitions to support new use cases that, at a later point in time, can be submitted for community review and integrated into the common-definitions repository.

For the PRISMA WP4 scenarios that include novel elements such as circular economy measures and digitalization, important extensions relate to material flows and stocks which are affected by CE strategies and energy and emissions of digital infrastructure. Such variables are underrepresented in the common-definitions repository which was established as part of PRISMA Task 1.3. In collaboration with the CircEular project¹⁰, additional variables that cover these dimensions have been developed and are available in the PRISMA workflow repository¹¹.

Since both scenario exercises explore new dimensions that IAMs have not been widely applied to previously, an extension of the reporting data template was necessary.

⁹ <https://github.com/IAMconsortium/common-definitions/>

¹⁰ <https://circeular.org/>

¹¹ <https://github.com/iiasa/prisma-workflow/tree/main/definitions>

For the bulk material scenarios, reporting variables that describe materials flows, stocks and scrap generation and recovery have been developed¹². Researchers from the Industrial Ecology community have been involved in these discussions to ensure consistency with standards used in Material Flow Analysis (MFA) and Life Cycle Assessment (LCA). Further, coordination with two other Horizon Europe projects that develop circular economy scenarios, CIRCOMOD (<https://circomod.eu/>) and CircEular (<https://circeular.org/>) is on the way to avoid the development of different reporting standards across projects so that these can eventually establish new community standards and merge the new definitions into the common-definitions community repository¹³.

For the ICT sector scenarios, establishing final energy variables to report direct energy consumption of the ICT sectors, separated by data centres and network infrastructure have been established¹⁴. To guarantee consistency with statistical data, sector definitions established by the International Standard Industrial Classification (ISIC)¹⁵ have been used. As for the material reporting extensions, the goal is to eventually establish a new community reporting standard for ICT sector energy demand.

3.2 Scenario Explorer and related tools for validation and analysis

The Scenario Explorer frontend is a web-based user interface that provides access to modelling results. The frontend is connected to a backend database infrastructure using the open-source Python Package ixmp4¹⁶, running on a PostgreSQL database cluster hosted by IIASA on premise. The database backend can also be accessed directly via a RestAPI, and IIASA is currently developing a TypeScript package to facilitate building web user interfaces with data visualizations and infographics querying data directly from the database.

The IAMC data format and the Scenario Explorer are tightly integrated to the

¹² <https://github.com/iiasa/prisma-workflow/tree/main/definitions/variable/industry>

¹³ <https://github.com/IAMconsortium/common-definitions/>

¹⁴ <https://github.com/iiasa/prisma-workflow/tree/main/definitions/variable/energy>

¹⁵ ISIC (2008) International Standard Industrial Classification of All Economic Activities Revision 4, United Nations, New York, https://unstats.un.org/unsd/demographic-social/census/documents/isic_rev4.pdf

¹⁶ <https://docs.ece.iiasa.ac.at/ixmp4>

open-source Python package `pyam`¹⁷, a suite of tools for scenario analysis and visualization. The `pyam` package allows to directly query the IIASA database backend via the RestAPI so that users can load relevant scenario data efficiently into their working environment.

For most projects, including PRISMA, IIASA sets up two database instances and related Scenario Explorer apps: first, a project-internal app¹⁸ is used within the consortium to develop scenarios, analyse results, and write manuscripts in the various workpackages; then, a public app¹⁹ is set up to make final scenario results accessible to all users when the manuscripts are published. Scenario results in the public app are released under a CC-BY license and usually also deposited on Zenodo for long-term archival. This trilateral approach (scientific manuscript, interactive Scenario Explorer, deposit on Zenodo) ensures alignment with best-practices of open science. The use of the IAMC format and the availability of open-source tools to work with the data facilitates reuse by other consortia and research communities.

To ensure consistency of the scenario results, IIASA has implemented workflows for validation and vetting of scenario results. These workflows are executed as part of the submission of results to the project-internal app (i.e., early in the scenario analysis and diagnostics phase).

The processing workflow when submitting scenarios to the project-internal database can also be connected to post-processing tools to derive additional information about the scenario results, beyond the scope of the original integrated-assessment or energy-systems model. One standard post-processing module used in many projects is the MAGICC simple climate model to translate emissions into temperature change indicators.

4 Summary

This document provides background information and context for the PRISMA WP4 final scenario dataset (Deliverable 4.3). The scenario data themselves constitute the primary deliverable and are accessible through two channels: the PRISMA Scenario Explorer at <https://prisma.apps.ece.iiasa.ac.at/> and a Zenodo deposit (DOI: <https://doi.org/10.5281/zenodo.21035260>).

¹⁷ <https://pyam-iamc.readthedocs.io/>

¹⁸ <https://prisma-internal.apps.ece.iiasa.ac.at/>

¹⁹ <https://prisma.apps.ece.iiasa.ac.at/>



Scenario content. WP4 has produced two complementary scenario sets. The bulk material scenarios examine material flows—including demand by sector, primary and secondary production, recycling, and stock accumulation—across four IAMs (IMAGE, MESSAGEix-GLOBIOM, REMIND-MAGPIE, WITCH) under a current policies baseline and a 2°C-compatible trajectory. A central focus is base year alignment to enable meaningful cross-model comparison of trends over time. The ICT sector scenarios systematically explore the energy and emission implications of digital infrastructure across five models (IMAGE, MESSAGEix-GLOBIOM, OPEN-PROM, REMIND-MAGPIE, WITCH) by varying three dimensions: ICT sector demand (low, medium, high, based on University of Oxford projections), climate policy (current policies or net-zero), and socio-economic development (SSP1–5). An additional regional convergence variant examines the effect of stronger convergence in data centre deployment across regions.

Reporting standards. All scenarios use the IAMC tabular time-series format. The project has developed extensions for material flows and stocks aligned with Material Flow Analysis and Life Cycle Assessment conventions, and for ICT sector energy demand disaggregated by data centres and network infrastructure in line with ISIC sector definitions. Both sets of extensions are being coordinated with the CircEular and CIRCOMOD Horizon Europe projects with the aim of eventual integration into the IAMC common-definitions community repository.

Infrastructure. The PRISMA Scenario Explorer is a web-based interface backed by an ixmp4 PostgreSQL database hosted at IIASA, complemented by a REST API for programmatic access. The open-source pyam Python package allows users to query the database directly for scenario analysis and visualization. IIASA operates two instances: a project-internal app used during scenario development and vetting, and a public app for disseminating final results. Scenario data are released under a CC-BY licence and archived on Zenodo, consistent with open science best practices. Automated validation workflows are integrated into the submission process to ensure consistency and completeness of submitted results.

