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A new scenario resource for integrated 1.5°C research in the context of climate change and sustainable development

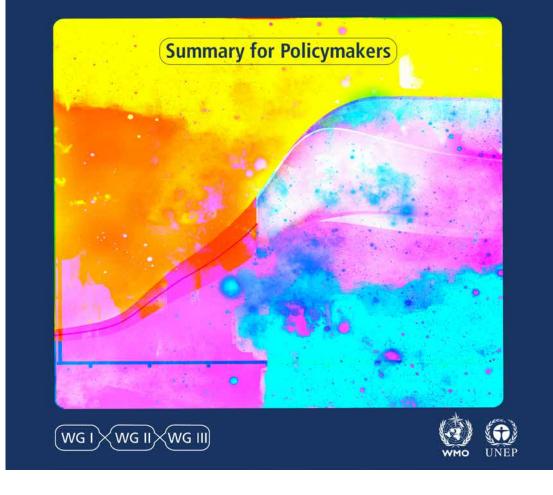
Daniel Huppmann*, Joeri Rogelj, Elmar Kriegler, Volker Krey & Keywan Riahi as well as authors of the IPCC SR15 and members of global modeling teams



A scenario ensemble for the IPCC's Special Report on Global Warming of 1.5°C (SR15)

Following the Paris Agreement in 2015 to "...pursue efforts to limit the Upon approval of the report by the IPCC plenary in Incheon, South Korea temperature increase to 1.5°C above pre-industrial levels", the Inter- in October 2018, the scenario ensemble and the suite of open tools

thening the global response to the threat of climate change inable development, and efforts to eradicate poverty



governmental Panel on Climate Change (IPCC) prepared a Special Report on global warming of 1.5°C and related global greenhouse gas emission pathways (SR15 [1]). Among other topics, the report assessed the required system transitions and options for strengthening the global response to climate change in the context of the Sustainable Development Goals (SDG).

To support the assessment, the Integrated Assessment Modeling *Consortium* (IAMC) facilitated a coordinated and systematic community effort to compile a consolidated ensemble of quantitative, model-based scenarios with a high degree of internal consistency. [3]

developed for the assessment were released to increase transparency and reproducibility of the scientific findings. The publicaction of this resource also encourages the reuse of scenario data by other research communities.

The ensemble consists of **414** scenarios based on **17** scientific studies submitted by **13 research teams**, categorized by climate

impact and other characteristics. The data release and the suite of open tools follows the FAIR principles for open, collaborative science (see box).



Modeling Consortium

nconsortium.org

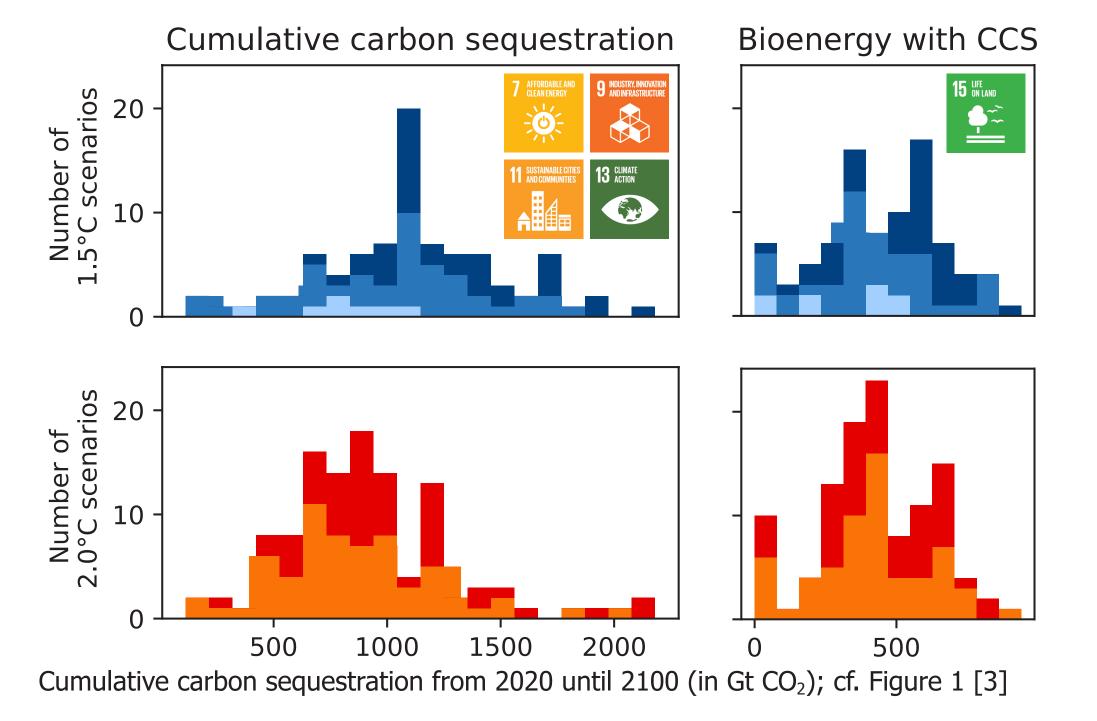
The IAMC is the umbrella organization of modelling teams conducting climate change mitigation analyses (<u>www.globalchange.umd.edu/iamc</u>)



Two illustrative angles of analysis based on the scenario ensemble

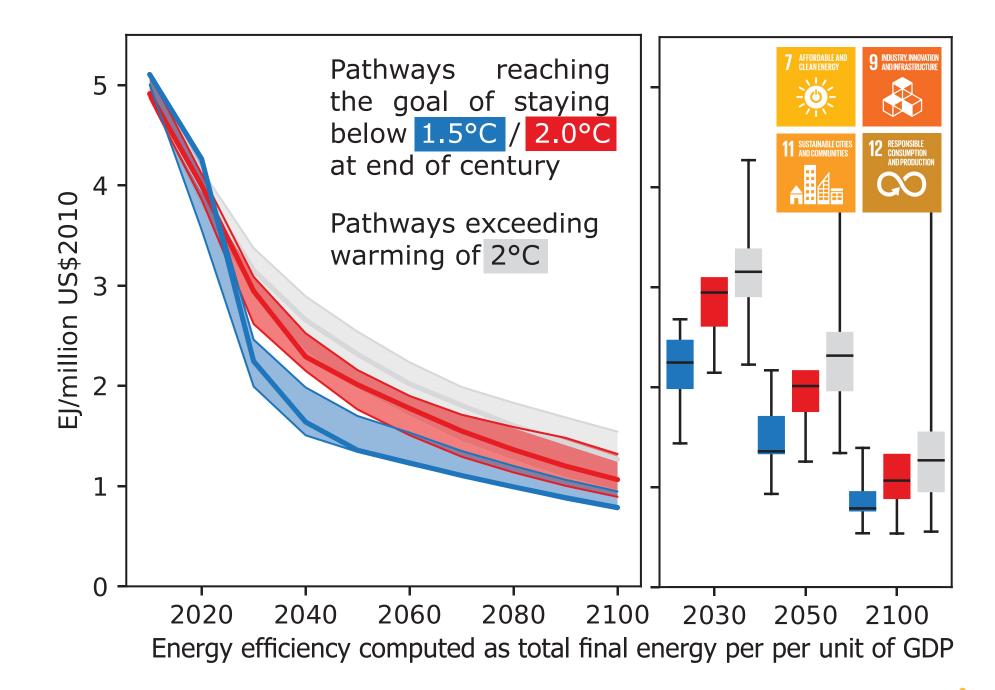
Negative emissions and the 1.5°C goal

Many scenarios use negative emissions technologies such as carbon capture and sequestration (CCS) in the second half of the century to a substantial extent. The ensemble shows that not all pathways require the use of (bioenergy) CCS to reach the temperature goal.



Decoupling of economic growth and energy demand

All scenarios meeting the goal to keep warming below 1.5°C at the end of the century exhibit rapid decoupling of GDP and energy consumption. Decreasing energy intensity indicates higher efficiency and suggests that demand reduction is a critical mitigation policy.



FAIRness for open research

The FAIR Guiding Principles [6] are domainindependent desiderata that can be applied to a wide range of scholarly outputs. To assist transparency and reproducibility, data and metadata (including source code) must be:

- Findable (unique persisten identifier, rich metadata) - Accessible (retrievable using standard protocols)

- Interoperable (formal vocabularies, references)

- Reusable (clear licence, community standards)

The IAMC data template

The scenario data was collected in the data format used by the IAM community for model comparison projects.

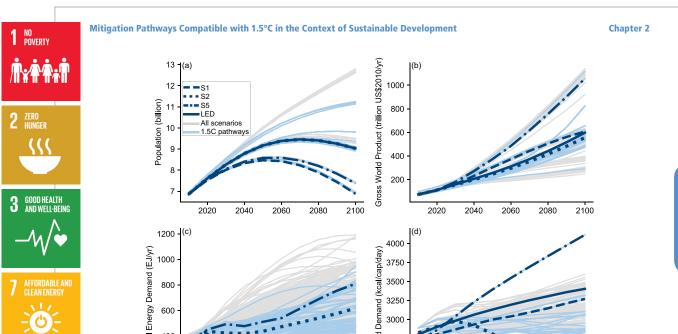
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1	Model	Scenario	Region	Variable	Unit	2005	2010	2015	2020
2	MESSAGE	CD-LINKS 400	World	Primary Energy	EJ/y	454.5	479.6		

python™

Open tools to facilitate exploration and analysis

Scenario assessment in the SR15

The Special Report [1] draws on quantitative pathways to evaluate synergies & trade-offs of mitigation policies across many indicators related to sustainable development.



An interactive scenario explorer

The online explorer [4] provides an intuitive entrypoint to the scenario ensemble, including metadata, documentation and cross-references to underlying publications.

IAMC 1.5°C Scenario Explorer hosted by IIASA	A release 1.1 📀 W	'orkspaces 👻 Downloads Documentation License About guest 🁻
Welcome to the IAMC 1.5°C Select an existing workspace or create a new one	Scenario Explorer hosted by I	IASA
Create new workspace Import Showing all workspaces -	Ordered by name •	<u>^</u>
Global emissions pathways (SPM Figure This workspace shows the panels of Figure 3a in the Summary for Policymakers of the SR15. It displays the net carbon dioxide emissions in all pathways limiting global warming to below 1.5°C nathways at the end of the century, and the methane Open	Socio-economic drivers in 1.5°C pathw This workspace shows the range of socio-economic assumptions and drivers in pathways limiting global warming to 1.5°C by the end of the century. It is based on Figure 2.4 in Chapter 2 of the SR15.	The energy system in the four illustrativ This workspace shows the transformation of the energy system towards no- and low-carbon fuels in the four illustrative pathways. It is based on Figure 2.15 in Chapter 2 of the SR1.5
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Open-source analysis notebooks

The scripts and notebooks used to generate many figures and tables in the SR15 are available on GitHub under the open-source APACHE 2.0 license. [5]

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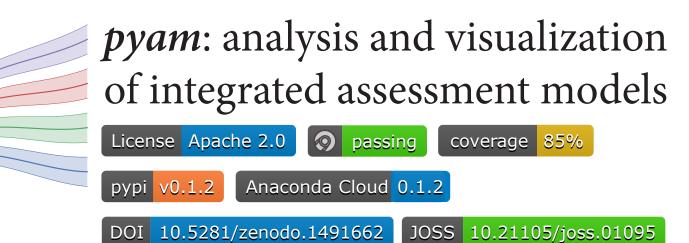
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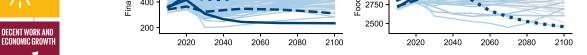
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IPC	C SR15 scenario assessment		
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	otebook contains the assessment of underlying drivers and assumptions of the scenario ensemble tion 2.3.1 and Figure 2.4 for the IPCC's _"Special Report on Global Warming of 1.5°C"	Hodeling Consertion	
The so	cenario data used in this analysis can be accessed and downloaded at https://data.ene.iiasa.ac.at/ia	mc-1.5c-explorer.	
Load	d pyam package and other dependencies		

A Python package for the IAM community



The *pyam* package [2] facilitates open, collaborative analysis of integrated assessment and climate models. Repository: <u>github.com/IAMconsortium/pyam</u> Documentation: pyam-iamc.readthedocs.io

References



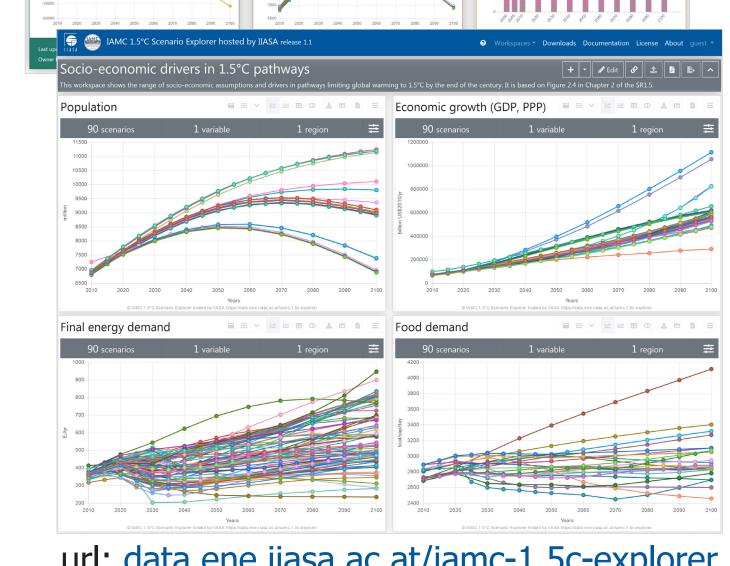
gure 2.4 | Range of assumptions about socio-economic drivers and projections for energy and food demand in the pathways available to thi sment. 1.5°C-consistent pathways are blue, other pathways grey. Trajectories for the illustrative 1.5°C-consistent archetypes used in this Chapter (LED, S1, S2, S5; ferred to as P1, P2, P3, and P4 in the Summary for Policymakers.) are highlighted. S1 is a sustainability oriented scenario, S2 is a middle-of-the-road scenario, and S5 is a sil-fuel intensive and high energy demand scenario. LED is a scenario with particularly low energy demand. Population assumptions in S2 and LED are identical. Panels show) world population, (b) gross world product in purchasing power parity values, (c) final energy demand, and (d) food demand

its techno-economic characteristics and future prospects, and the 2018; Holz et al., 2018b; Kriegler et al., 2018a; Liu et al., 2018; Rogelj et computational challenge of representing the measure, e.g., in terms of al., 2018; Strefler et al., 2018b; van Vuuren et al., 2018). However, ther are a few potentially disruptive technologies that are typically not yet required spatio-temporal and process detail. well covered in IAMs and that have the potential to alter the shape of

This elicitation (Supplementary Material 2.SM.1.2) confirms that mitigation pathways beyond the ranges in the IAM-based literature. IAMs cover most supply-side mitigation options on the process level, Those are also included in Supplementary Material 2.SM.1.2. The while many demand-side options are treated as part of underlying configuration of carbon-neutral energy systems projected in mitigation assumptions, which can be varied (Clarke et al., 2014). In recent years, pathways can vary widely, but they all share a substantial reliance there has been increasing attention on improving the modelling on bioenergy under the assumption of effective land-use emissions of integrating variable renewable energy into the power system control. There are other configurations with less reliance on bioenergy (Creutzig et al., 2017; Luderer et al., 2017; Pietzcker et al., 2017) and that are not yet comprehensively covered by global mitigation pathway of behavioural change and other factors influencing future demand modelling. One approach is to dramatically reduce and electrify energy for energy and food (van Sluisveld et al., 2016; McCollum et al., 2017; demand for transportation and manufacturing to levels that make Weindl et al., 2017), including in the context of 1.5°C-consistent residual non-electric fuel use negligible or replaceable by limited pathways (Grubler et al., 2018; van Vuuren et al., 2018). The literature amounts of electrolytic hydrogen. Such an approach is presented in on the many diverse CDR options only recently started to develop a first-of-its kind low-energy-demand scenario (Grubler et al., 2018) strongly (Minx et al., 2017) (see Chapter 4, Section 4.3.7 for a detailed which is part of this assessment. Other approaches rely less on energy assessment), and hence these options are only partially included in demand reductions, but employ cheap renewable electricity to push IAM analyses. IAMs mostly incorporate afforestation and bioenergy the boundaries of electrification in the industry and transport sectors with carbon capture and storage (BECCS) and only in few cases also (Breyer et al., 2017; Jacobson, 2017). In addition, these approaches include direct air capture with CCS (DACCS) (Chen and Tavoni, 2013; deploy renewable-based Power-2-X (read: Power to "x") technologies Marcucci et al., 2017: Strefler et al., 2018b). to substitute residual fossil-fuel use (Brynolf et al., 2018). An important element of carbon-neutral Power-2-X applications is the combination

Several studies have either directly or indirectly explored the of hydrogen generated from renewable electricity and CO, captured dependence of 1.5°C-consistent pathways on specific (sets of) from the atmosphere (Zeman and Keith, 2008). Alternatively, algae mitigation and CDR technologies (Bauer et al., 2018; Grubler et al., are considered as a bioenergy source with more limited implications

Page 111 and Figure 2.4 of Chapter 2, SR15 [1]

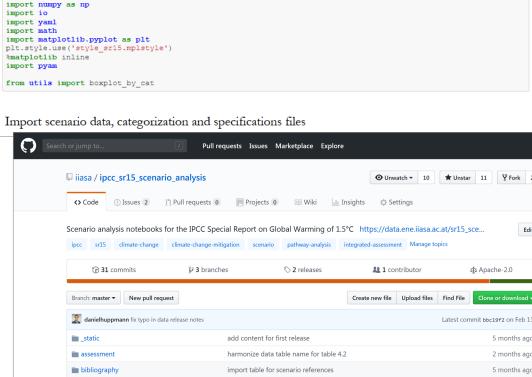


ClimateWorks

url: data.ene.iiasa.ac.at/iamc-1.5c-explorer



The work presented on this poster has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642147 (CD-LINKS).



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for the *IPCC Special Report on Global Warming of 1.5°C*

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[1] IPCC (2018) *Global warming of 1.5°C*. World Meteorological Organization, Geneva, Switzerland. url: www.ipcc.ch/report/sr15/

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[6] Wilkinson, M.D., et al. (2016). The FAIR Guiding Principles for scientific data management and stewardship. Scientific Data 3:160018. doi: 10.1038/sdata.2016.18

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