Climate change mitigation & sustainable development

Qualitative and quantitative analysis in the IPCC's "Special Report on Global Warming of 1.5°C"

Young Scientist Symposium
Institute of Science and Technology (IST) Austria
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Please consider the environment before printing this slide deck

A Special Report on Global Warming of 1.5°C

Assessing climate change in the context of the SDGs

Harry Taylor, 6, played with the bones of dead livestock in Australia, which has faced severe drought.

Brook Mitchell/Getty Images

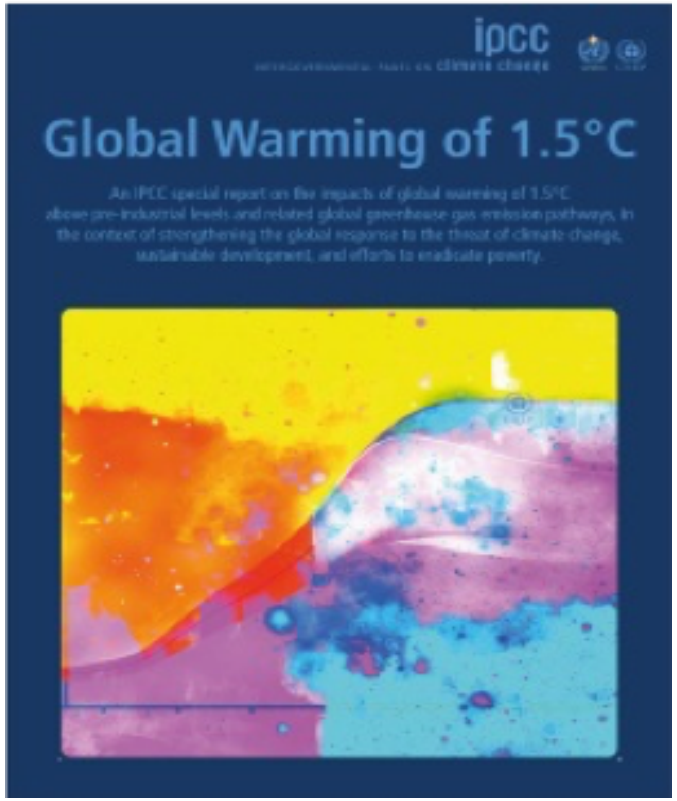
The New York Times

Major Climate Report Describes a Strong Risk of Crisis as Early as 2040

[…] To prevent 2.7 degrees of warming, the report said, greenhouse pollution must be reduced by 45 percent from 2010 levels by 2030, and 100 percent by 2050. It also found that, by 2050, use of coal as an electricity source would have to drop from nearly 40 percent today to between 1 and 7 percent. Renewable energy such as wind and solar, which make up about 20 percent of the electricity mix today, would have to increase to as much as 67 percent. […]

www.nytimes.com/2018/10/07/climate/ipcc-climate-report-2040.html

The IPCC *Special Report on Global Warming of 1.5°C* (SR15) was published in the fall of 2018.



www.ipcc.ch/sr15

A Special Report on Global Warming of 1.5°C

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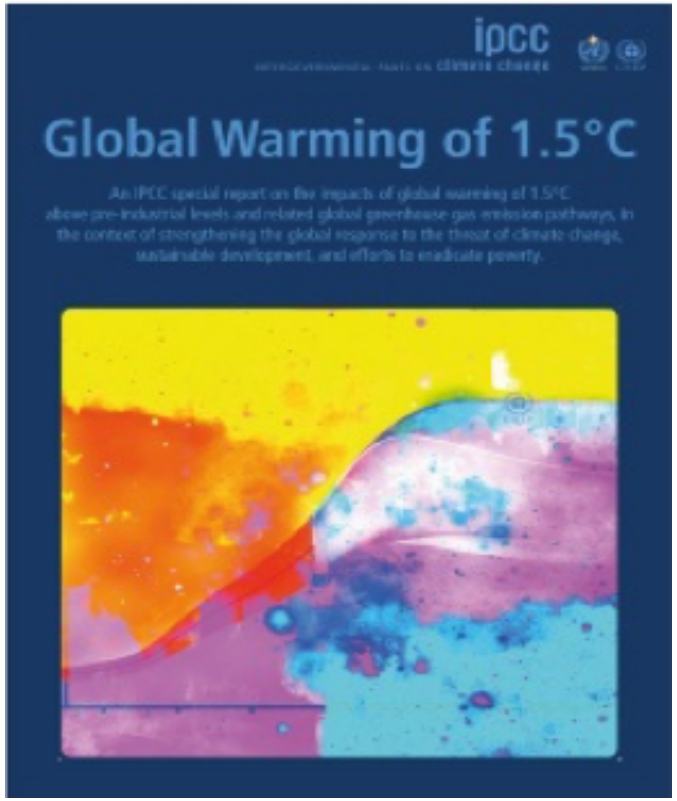


www.ipcc.ch/sr15

Agenda

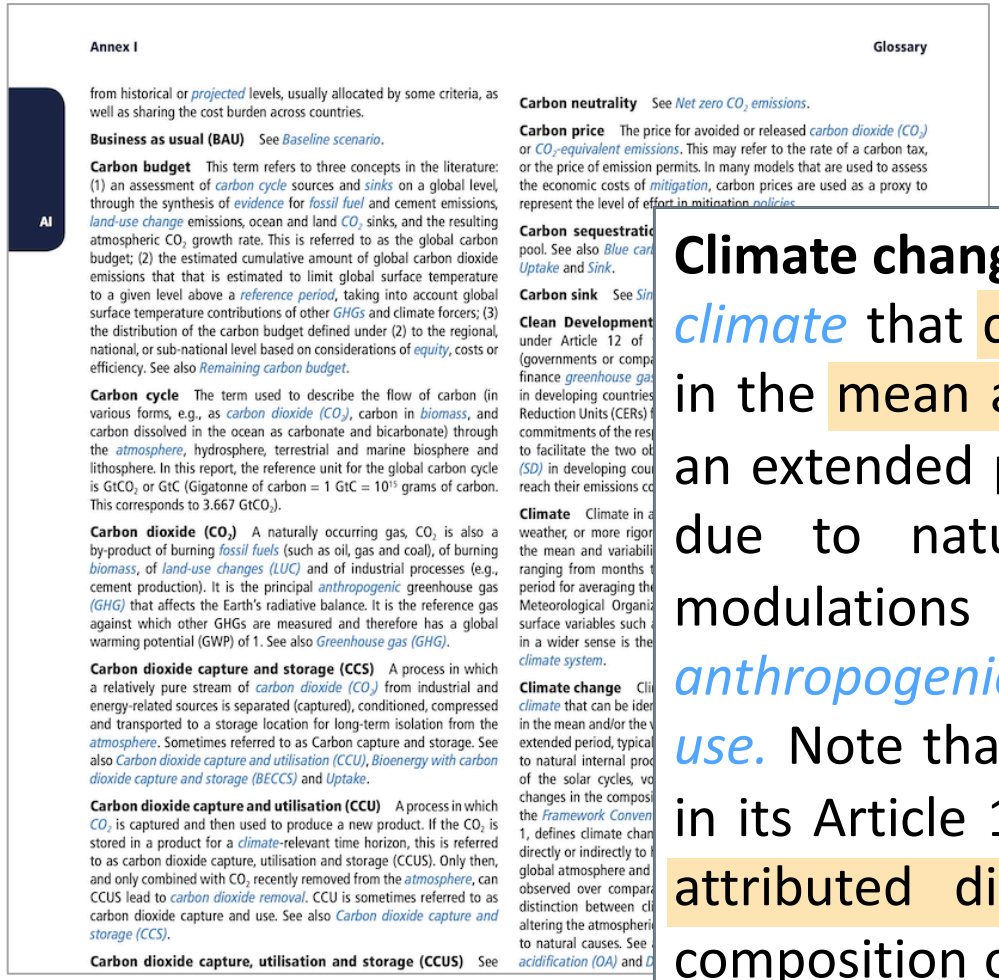
- Introduction to climate change and the Sustainable Development Goals
- Qualitative assessment of mitigation options in the SR15
- Assessment of quantitative, model-based pathways with a focus on transparency, reproducibility & FAIRness
- Using the scenario ensemble to gain insights on the SDGs
- Near-term policy outlook

Part 1

A short introduction to climate change and sustainable development

A definition of climate change

It's not only about the mean but also about (increasing) variability



Annex I Glossary

AI

from historical or *projected* levels, usually allocated by some criteria, as well as sharing the cost burden across countries.

Business as usual (BAU) See *Baseline scenario*.

Carbon budget This term refers to three concepts in the literature: (1) an assessment of *carbon cycle* sources and *sinks* on a global level, through the synthesis of *evidence* for *fossil fuel* and cement emissions, *land-use change* emissions, ocean and land CO_2 sinks, and the resulting atmospheric CO_2 growth rate. This is referred to as the global carbon budget; (2) the estimated cumulative amount of global carbon dioxide emissions that that is estimated to limit global surface temperature to a given level above a *reference period*, taking into account global surface temperature contributions of other *GHGs* and climate forcers; (3) the distribution of the carbon budget defined under (2) to the regional, national, or sub-national level based on considerations of *equity*, costs or efficiency. See also *Remaining carbon budget*.

Carbon cycle The term used to describe the flow of carbon (in various forms, e.g., as *carbon dioxide (CO_2)*, carbon in *biomass*, and carbon dissolved in the ocean as carbonate and bicarbonate) through the *atmosphere*, hydrosphere, terrestrial and marine biosphere and lithosphere. In this report, the reference unit for the global carbon cycle is $GtCO_2$ or GtC (Gigatonne of carbon = 1 GtC = 10^{15} grams of carbon. This corresponds to 3.667 $GtCO_2$).

Carbon dioxide (CO_2) A naturally occurring gas, CO_2 is also a by-product of burning *fossil fuels* (such as oil, gas and coal), of burning *biomass*, of *land-use changes (LUC)* and of industrial processes (e.g., cement production). It is the principal *anthropogenic* greenhouse gas *(GHG)* that affects the Earth's radiative balance. It is the reference gas against which other GHGs are measured and therefore has a global warming potential (GWP) of 1. See also *Greenhouse gas (GHG)*.

Carbon dioxide capture and storage (CCS) A process in which a relatively pure stream of *carbon dioxide (CO_2)* from industrial and energy-related sources is separated (captured), conditioned, compressed and transported to a storage location for long-term isolation from the *atmosphere*. Sometimes referred to as Carbon capture and storage. See also *Carbon dioxide capture and utilisation (CCU)*, *Bioenergy with carbon dioxide capture and storage (BECCS)* and *Uptake*.

Carbon dioxide capture and utilisation (CCU) A process in which CO_2 is captured and then used to produce a new product. If the CO_2 is stored in a product for a *climate*-relevant time horizon, this is referred to as carbon dioxide capture, utilisation and storage (CCUS). Only then, and only combined with CO_2 recently removed from the *atmosphere*, can CCUS lead to *carbon dioxide removal*. CCU is sometimes referred to as carbon dioxide capture and use. See also *Carbon dioxide capture and storage (CCS)*.

Carbon dioxide capture, utilisation and storage (CCUS) See

Carbon neutrality See *Net zero CO_2 emissions*.

Carbon price The price for avoided or released *carbon dioxide (CO_2)* or *CO_2-equivalent emissions*. This may refer to the rate of a carbon tax, or the price of emission permits. In many models that are used to assess the economic costs of *mitigation*, carbon prices are used as a proxy to represent the level of effort in mitigation *policies*.

Carbon sequestrati pool. See also *Blue car Uptake* and *Sink*.

Carbon sink See *Sin*

Clean Development under Article 12 of (governments or compa finance *greenhouse ga* in developing countries Reduction Units (CERs) commitments of the res to facilitate the two ob *(SD)* in developing cou reach their emissions c

Climate Climate in a weather, or more rigor the mean and variabili ranging from months period for averaging th Meteorological Organiz surface variables such in a wider sense is the *climate system*.

Climate change Cli *climate* that can be ider in the mean and/or the extended period, typical to natural internal proc of the solar cycles, v changes in the composi the *Framework Conven* 1, defines climate chan directly or indirectly to global atmosphere and observed over compara distinction between cl altering the atmospheri to natural causes. See *acidification (OA)* and

Definitions in the Glossary, Annex 1,
Special Report on Global Warming of 1.5°C (SR15)

Climate change Climate change refers to a change in the state of the *climate* that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external *forcings* such as modulations of the solar cycles, volcanic eruptions and persistent *anthropogenic* changes in the composition of the *atmosphere* or in *land use*. Note that the *Framework Convention on Climate Change (UNFCCC)*, in its Article 1, defines climate change as: 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.'

The trajectory of climate change

Cumulative emissions of CO2 and future non-CO2 radiative forcing determine the probability of limiting warming to 1.5°C

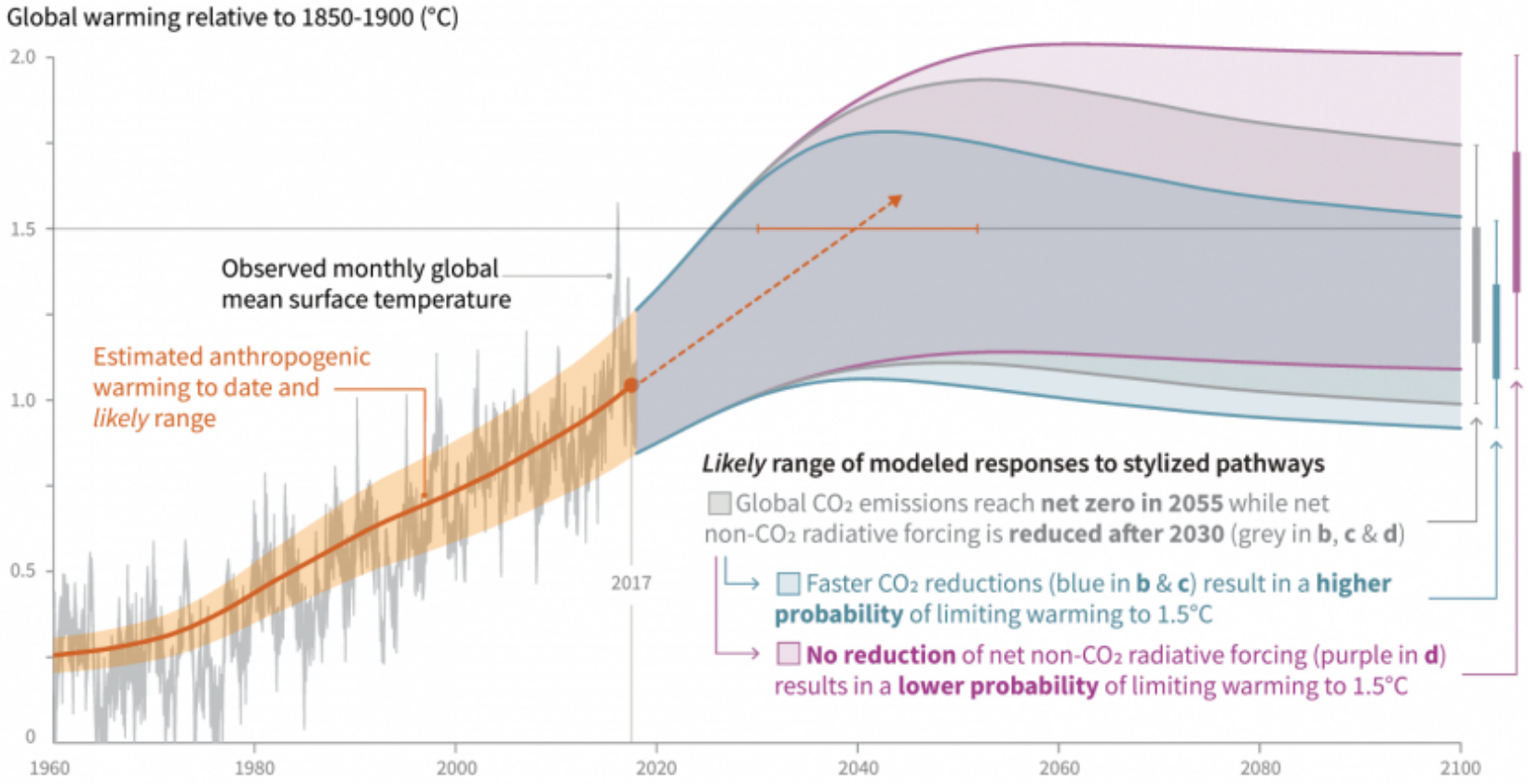
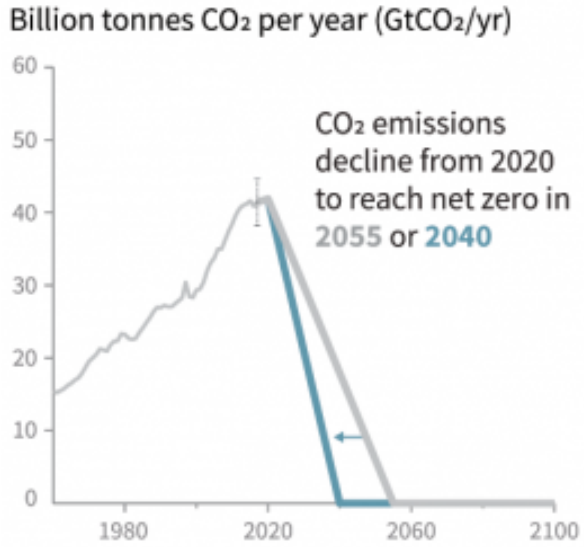


Figure 1, Summary for Policymakers,
Special Report on Global Warming of 1.5°C (SR15)

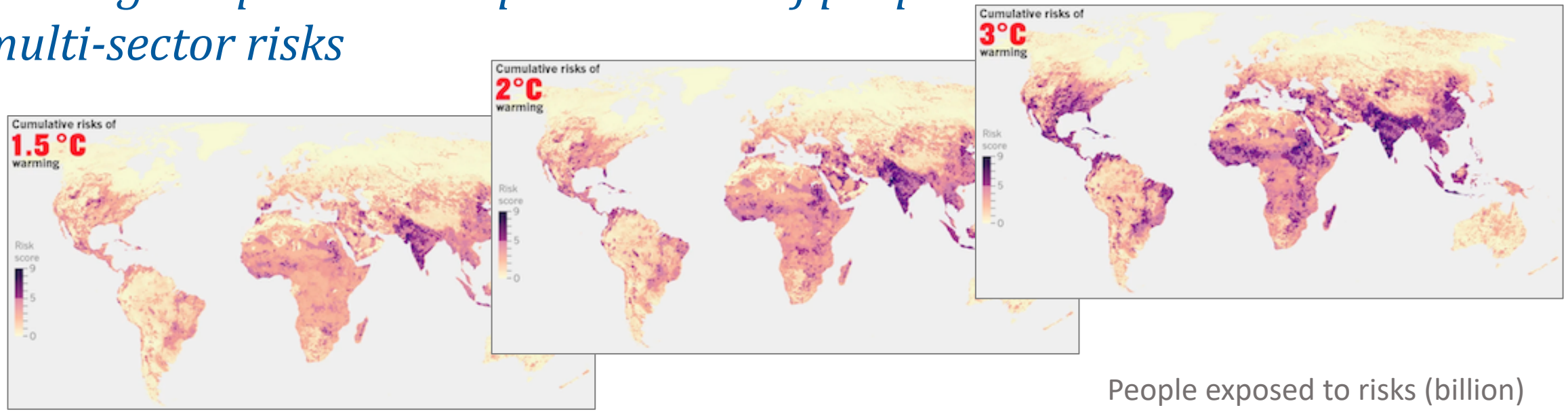
Reducing CO2 emissions to net-zero until **2055** or **2040** result in different probability of temperature change.

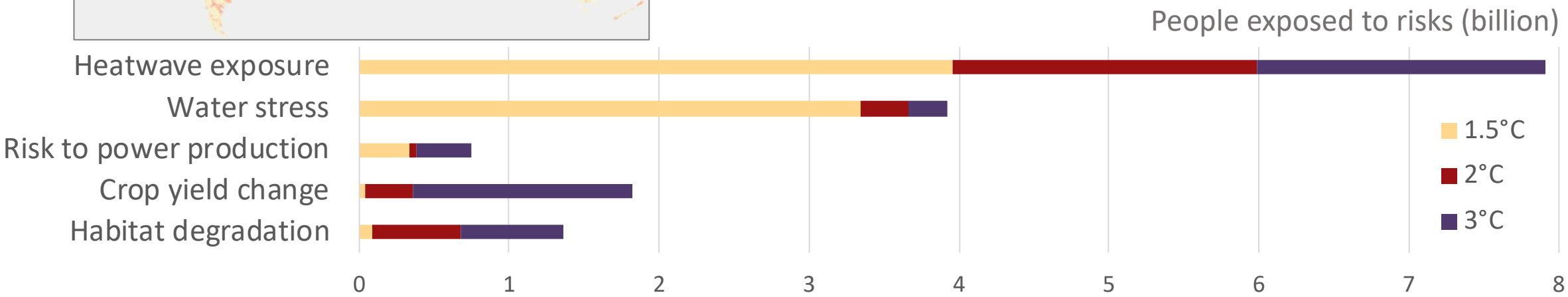
The ranges are computed from stylized emissions pathways.



The impacts of climate change

Increasing temperatures expose billions of people to multi-sector risks





Source: "The hard truths of climate change — by the numbers" (Nature 573:324, September 19, 2019) based on Byers et al. (2019, doi: 10.1088/1748-9326/aabf45)

Climate change and sustainable development

Two landmark agreements in 2015 define the policy agenda

SUSTAINABLE DEVELOPMENT GOALS

The **"2030 Agenda for Sustainable Development"** was adopted at the UN Sustainable Development Summit on September 25, 2015.

It specifies 17 goals linked to 169 targets and 232 indicators.

PARIS2015
UN CLIMATE CHANGE CONFERENCE
COP21·CMP11

The **„Paris Agreement"** was adopted at the 21st Conference of the Parties (COP21) of the UNFCCC in Paris on December 12, 2015.

It aims to keep global warming to "well below 2 °C" relative to pre-industrial levels and to "pursue efforts to" limit the temperature increase to 1.5 °C.

An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty

Part 2

Qualitative analysis of climate change mitigation and sustainable development in the SR15

A qualitative analysis of climate change mitigation options

Chapter 5 aimed to provide a review of synergies & trade-offs between various mitigation strategies and sustainable development

Dozens of scientific manuscripts and meta-studies were classified according to ...

- 17 Sustainable Development Goals
- 23 mitigation options
  - ⇒ Grouped in three domains: Energy demand, energy supply, land & oceans
  - ⇒ Including efficiency, fuel switch, nuclear, carbon capture & storage (CCS) ...
- Indicators for the direction and strength of the interaction
  - ⇒ From "Inextricably linked" (+3) to "Makes it impossible to reach" (-3)
- Level of confidence (evidence and agreement)

A qualitative assessment of mitigation options & SDGs

Demand-focused mitigation strategies have many synergies and few trade-offs with SDGs

For each combination of mitigation option and SDG, SR15 authors made a detailed assessment based on the literature.

The entire analysis is available as a table in the Supplementary Material.

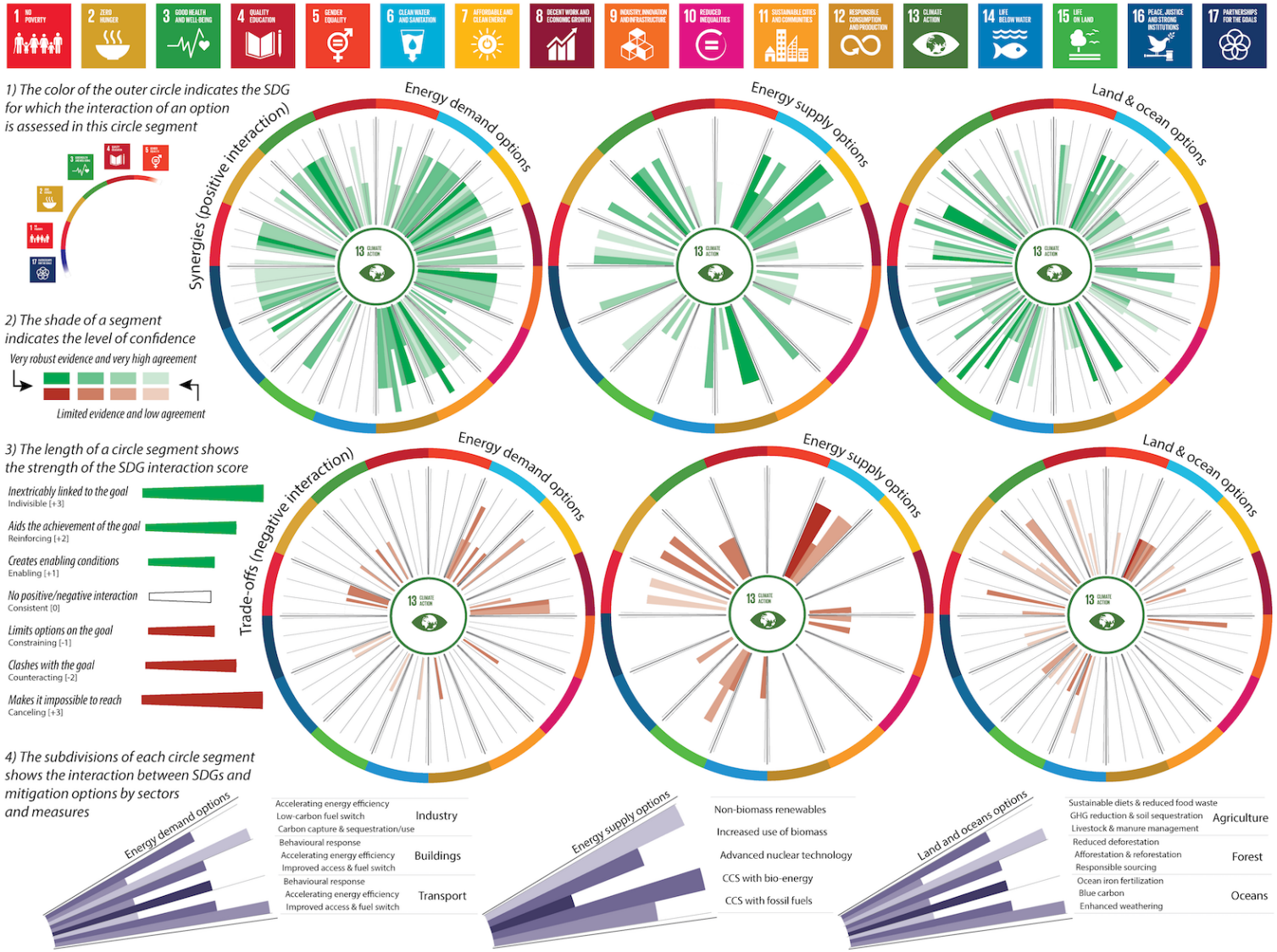


Figure 5.2. Synergies and trade-offs of individual mitigation options with the SDGs Special Report on Global Warming of 1.5°C (SR15)

Part 3

An ensemble of quantitative pathways

A Special Report on Global Warming of 1.5°C

Assessing climate change in the context of the SDGs

Harry Taylor, 6, played with the bones of dead livestock in Australia, which has faced severe drought.

Brook Mitchell/Getty Images

The New York Times

Major Climate Report Describes a Strong Risk of Crisis as Early as 2040

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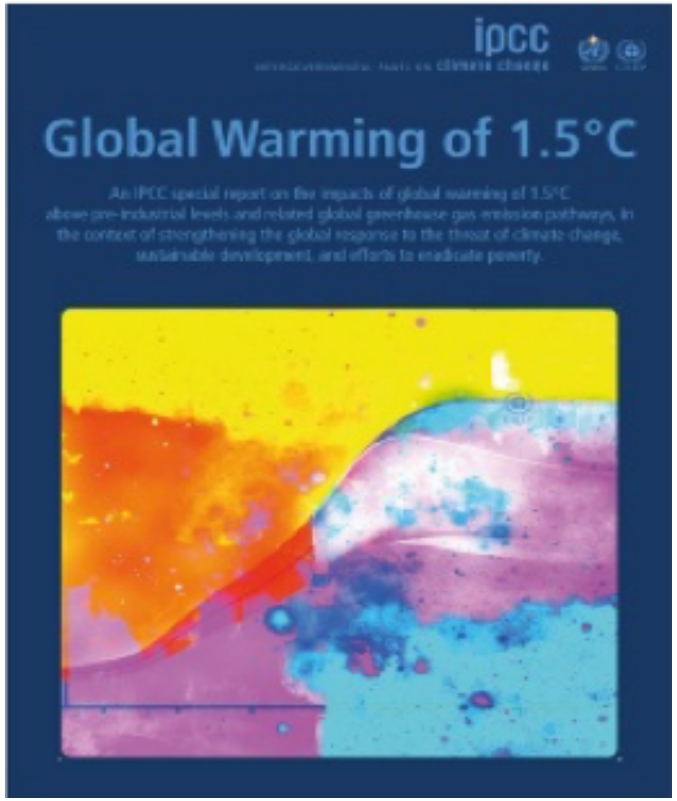
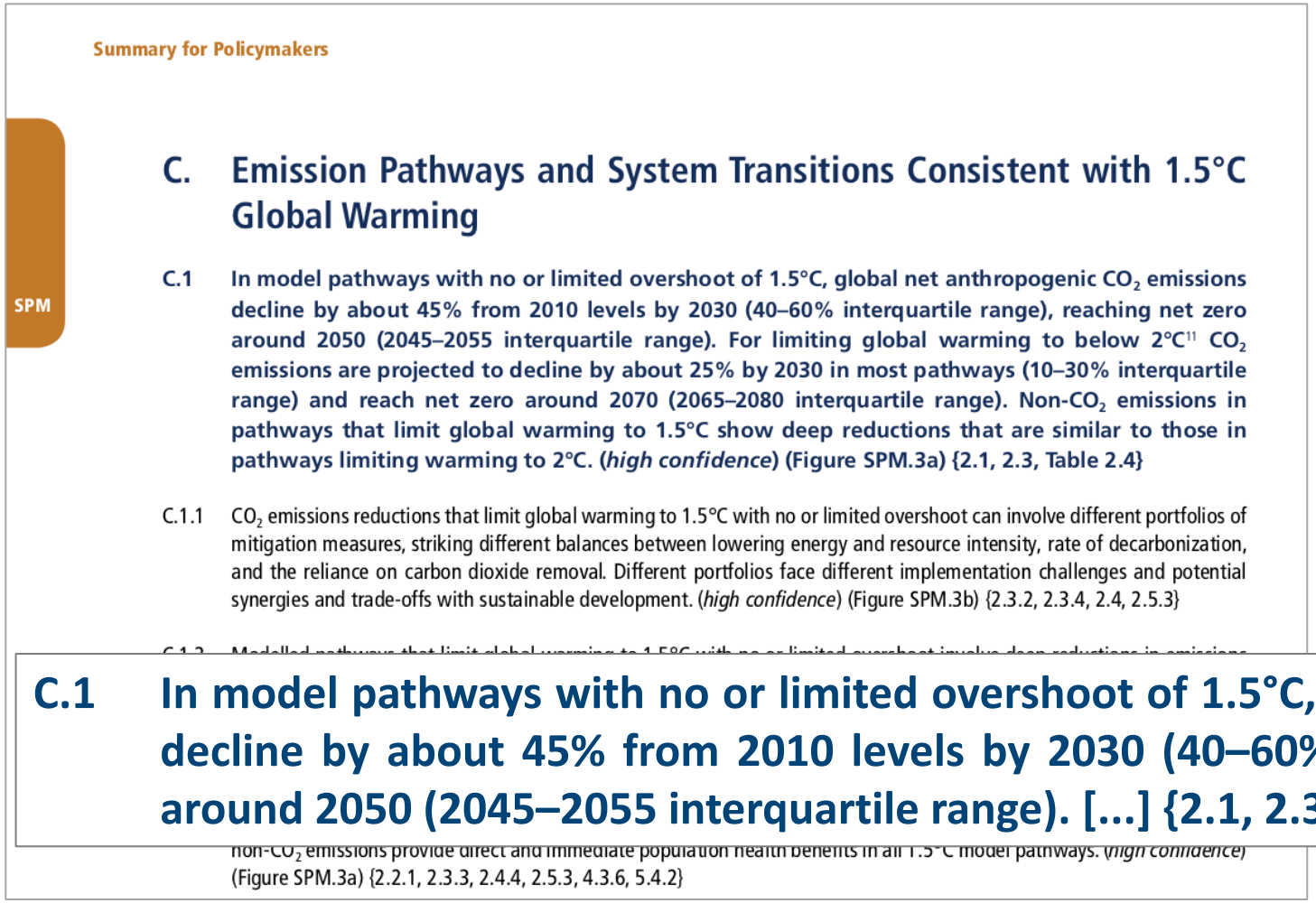


www.ipcc.ch/sr15

Diving into the 'Summary for Policymakers' (SPM)

The IPCC assessed a large ensemble of emissions pathways



Summary for Policymakers

SPM

C. Emission Pathways and System Transitions Consistent with 1.5°C Global Warming

C.1 In model pathways with no or limited overshoot of 1.5°C, global net anthropogenic CO_2 emissions decline by about 45% from 2010 levels by 2030 (40–60% interquartile range), reaching net zero around 2050 (2045–2055 interquartile range). For limiting global warming to below 2°C[11] CO_2 emissions are projected to decline by about 25% by 2030 in most pathways (10–30% interquartile range) and reach net zero around 2070 (2065–2080 interquartile range). Non-CO_2 emissions in pathways that limit global warming to 1.5°C show deep reductions that are similar to those in pathways limiting warming to 2°C. (*high confidence*) (Figure SPM.3a) {2.1, 2.3, Table 2.4}

C.1.1 CO_2 emissions reductions that limit global warming to 1.5°C with no or limited overshoot can involve different portfolios of mitigation measures, striking different balances between lowering energy and resource intensity, rate of decarbonization, and the reliance on carbon dioxide removal. Different portfolios face different implementation challenges and potential synergies and trade-offs with sustainable development. (*high confidence*) (Figure SPM.3b) {2.3.2, 2.3.4, 2.4, 2.5.3}

C.1.2 Modelled pathways that limit global warming to 1.5°C with no or limited overshoot involve deep reductions in emissions

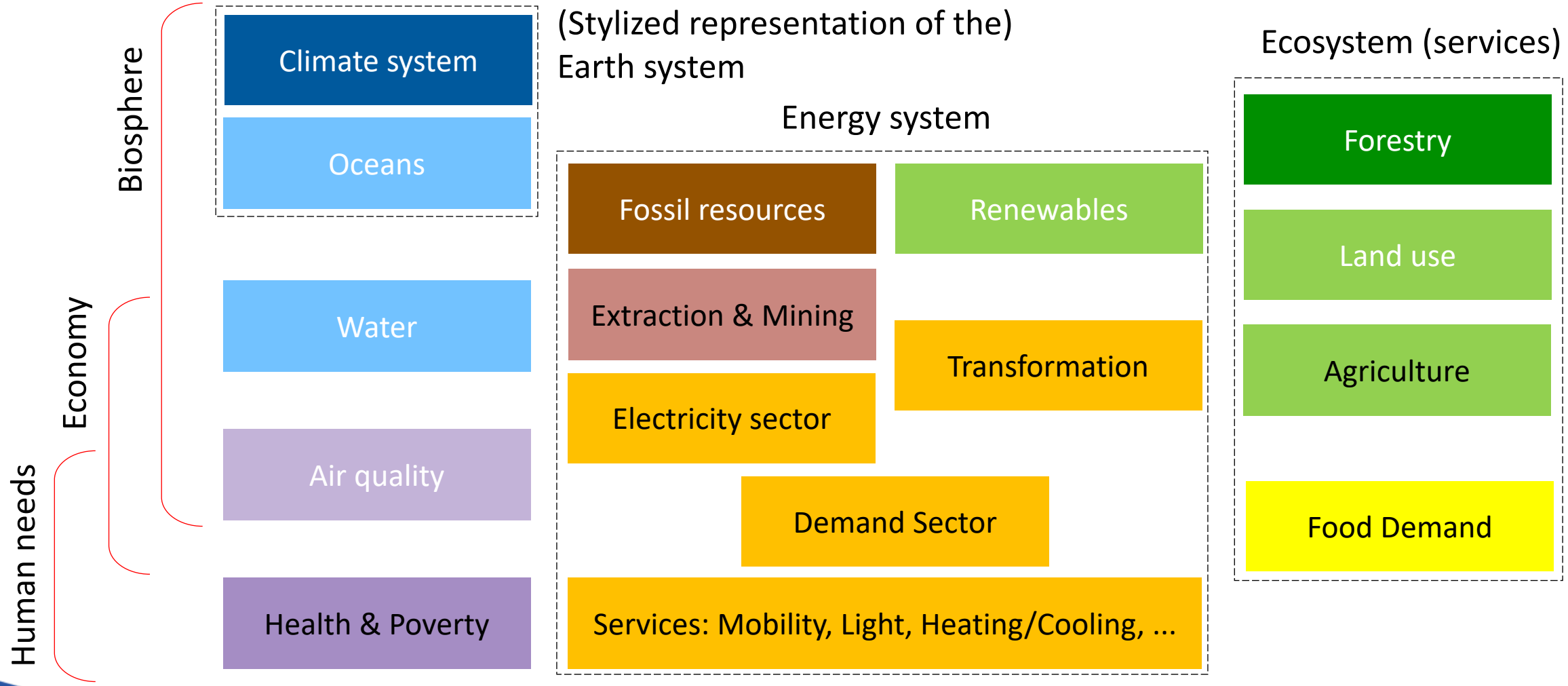
non-CO_2 emissions provide direct and immediate population health benefits in all 1.5°C model pathways. (*high confidence*) (Figure SPM.3a) {2.2.1, 2.3.3, 2.4.4, 2.5.3, 4.3.6, 5.4.2}

The Summary for Policymakers of the IPCC *Special Report on Global Warming of 1.5°C* (SR15).

C.1 In model pathways with no or limited overshoot of 1.5°C, global net anthropogenic CO_2 emissions decline by about 45% from 2010 levels by 2030 (40–60% interquartile range), reaching net zero around 2050 (2045–2055 interquartile range). […] {2.1, 2.3, Table 2.4}

The scope of integrated assessment models

IAMs (aim to) encompass the entire human & earth systems



Where do the "model pathways" come from? (I)

A rigorous assessment of quantitative, model-based pathways requires more information than what is available in the publication

The IPCC assesses available scientific, technical and socio-economic literature relevant to understanding the scientific basis of climate change

- ⇒ Published in peer-reviewed journals or eligible grey literature (e.g., IEA, industry reports)
- ⇒ In most cases, it is sufficient to extract relevant insights from manuscripts or reports

But relying only on published manuscripts & supplementary material for quantitative scenarios across studies and projects is challenging

- ⇒ Numerical model results are not presented in the same data format
- ⇒ Only a selection of numerical results presented in manuscript and supplements e.g., only indicators of interest in relation to the specific research question
- ⇒ Definitions and units differ across models and studies

Where do the "model pathways" come from? (II)

We conducted a "call for scenarios" to collect an ensemble of pathways to facilitate the quantitative assessment

The "Integrated Assessment Modeling Consortium" (IAMC), the IPCC and IIASA launched a systematic community effort

- ⇒ Building on the process used for the Fifth Assessment Report (AR5)
- ⇒ To provide SR15 authors with a curated set of internally consistent and validated scenarios
- ⇒ Increase transparency & reproducibility of the assessment

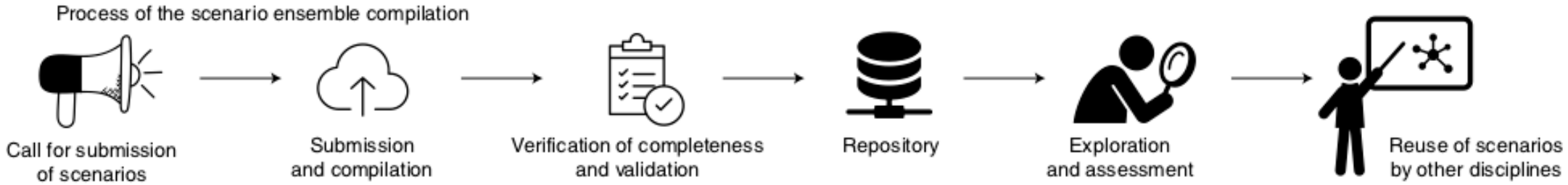


Figure 1, Huppmann et al., *Nature Climate Change* 8:1027-1030 (2018). doi: 10.1038/s41558-018-0317-4

The "line of sight" of the SR15 scenario ensemble

We developed a suite of open tools to dive into the SR15 analysis

Interactive online scenario explorer at
data.ene.iiasa.ac.at/iamc-1.5c-explorer

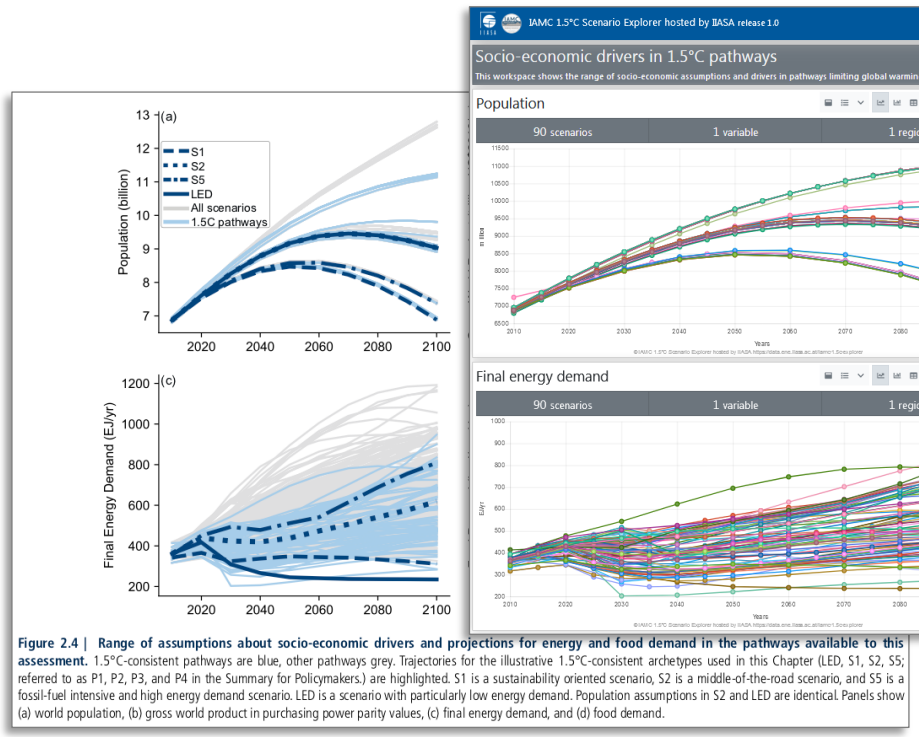
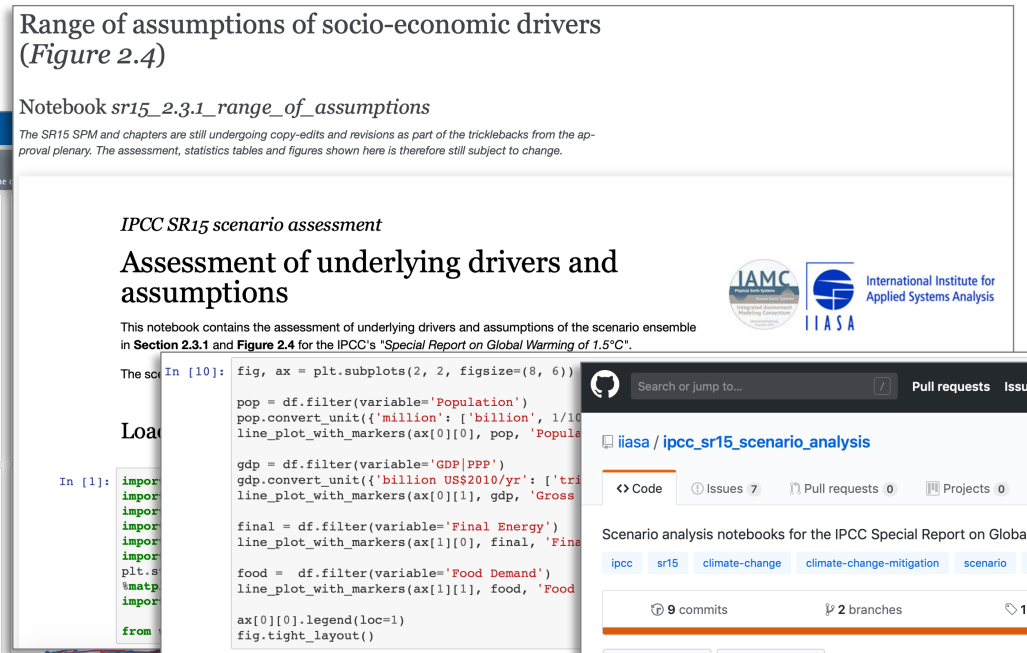
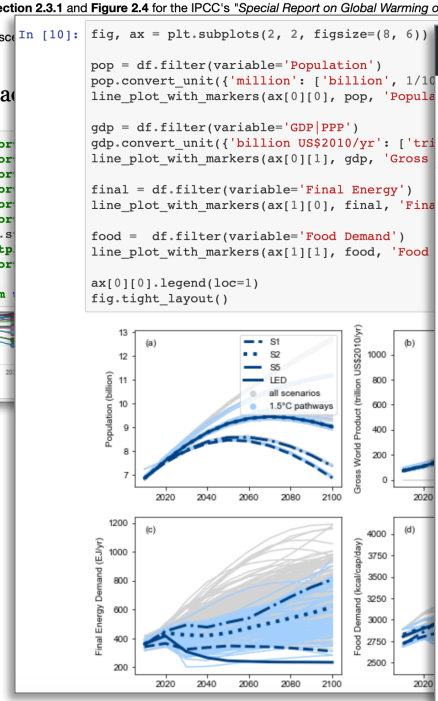
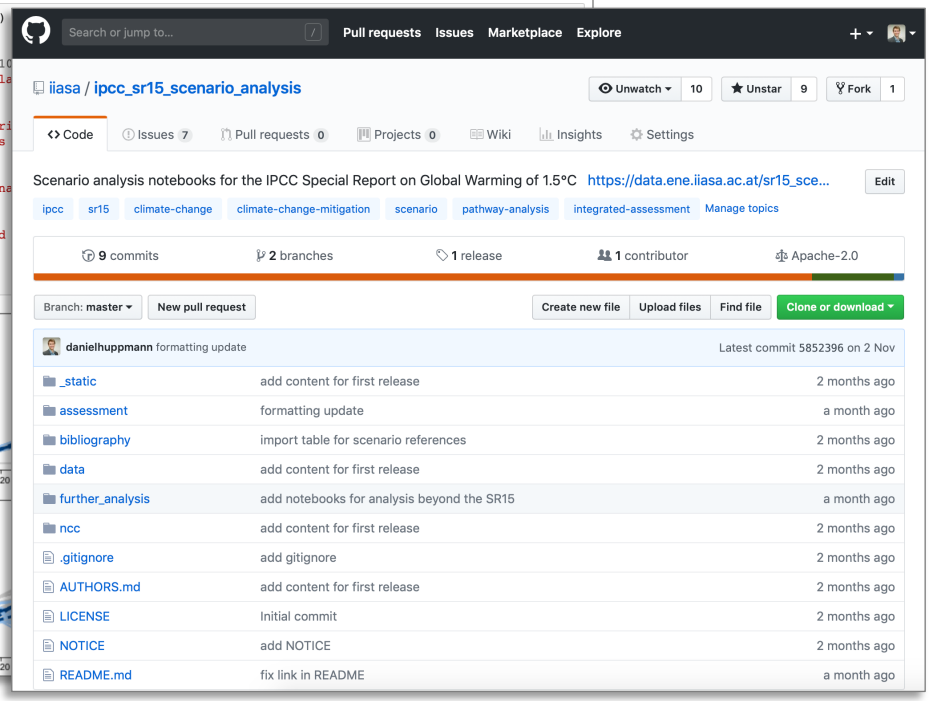


Figure 2.4 | Range of assumptions about socio-economic drivers and projections for energy and food demand in the pathways available to this assessment. 1.5°C-consistent pathways are blue, other pathways grey. Trajectories for the illustrative 1.5°C-consistent archetypes used in this Chapter (LED, S1, S2, S5; referred 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 fossil-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 (a) world population, (b) gross world product in purchasing power parity values, (c) final energy demand, and (d) food demand.

Figure 2.4 as printed in the SR15 (www.ipcc.ch/sr15)







Rendered notebooks to generate figures and tables at
data.ene.iiasa.ac.at/sr15_scenario_analysis

```
$ git clone git@github.com:iiasa/ipcc_sr15_scenario_analysis.git
```

Increasing the "FAIRness" of the IPCC assessment

Going beyond efforts in AR5, we followed the FAIR principles to increase transparency and reproducibility of the scenario assessment

Goal	Implemented measures
Findable	Use proper recommended references including DOIs for data and notebooks
Accessible	Make data and notebooks available for multiple levels of user sophistication as well as via common machine-readable API's
Interoperable	Use common data template developed by the IAMC Analysis using open-source Python package pyam
Reusable	Data and assessment notebooks released under licenses that enable follow-up research

Wilkinson, M. D., et al. (2016). Scientific Data 3:160018. doi: 10.1038/sdata.2016.18

Findable

Use appropriate references & metadata for each item

Separate treatment for distinct pieces of the scientific "supply chain"

- Scientific assessment: Chapter 2 of the SR15 and Annex
- Scenario ensemble (data)
- Notebooks for scenario assessment
- Scientific software package
- Journal manuscript on scenario ensemble compilation and user guidelines

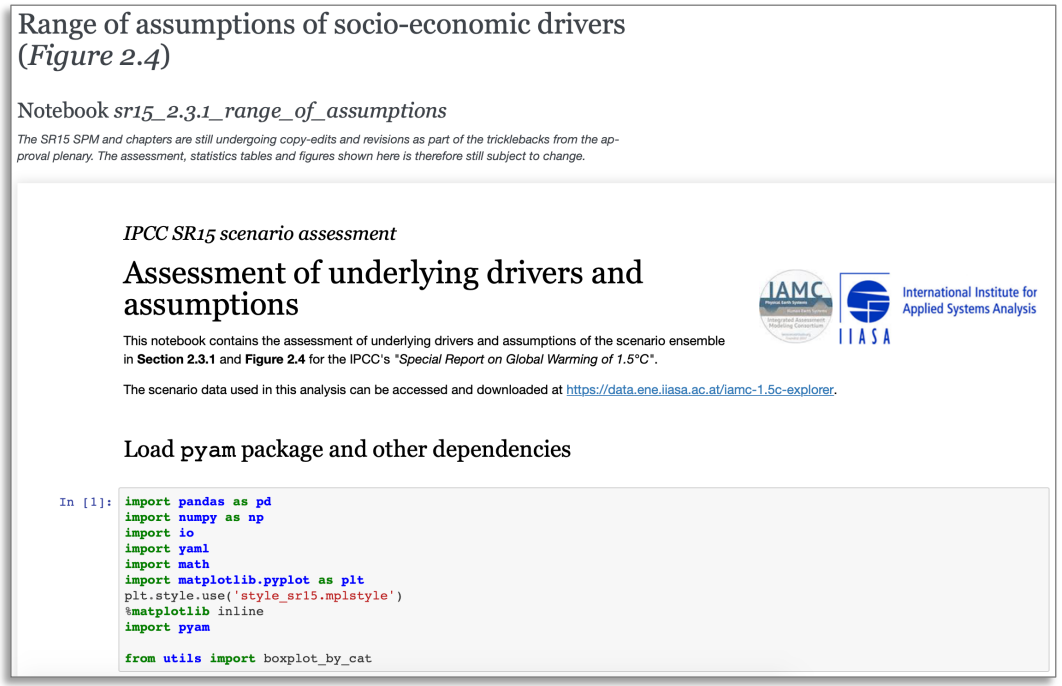
⇒ Each item has its own recommended citation and DOI

⇒ Use proper versioning for each item (data & software release cycle)

Accessible (I) – machine-readable formats

The infrastructure provides multiple entry points & interfaces

- Scenario ensemble data:
  - ⇒ Downloadable as `xlsx` and `csv`
  - ⇒ Accessible via a `RestAPI` from the Scenario Explorer backend
- Assessment notebooks
  - ⇒ Distributed via GitHub
  - ⇒ Also available as rendered notebooks
- Scientific software
  - ⇒ Maintained on GitHub
  - ⇒ Available via `conda` & `pypi`


Range of assumptions of socio-economic drivers (*Figure 2.4*)

Notebook *sr15_2.3.1_range_of_assumptions*

The SR15 SPM and chapters are still undergoing copy-edits and revisions as part of the tricklebacks from the approval plenary. The assessment, statistics tables and figures shown here is therefore still subject to change.

IPCC SR15 scenario assessment

Assessment of underlying drivers and assumptions

International Institute for Applied Systems Analysis

This notebook contains the assessment of underlying drivers and assumptions of the scenario ensemble in **Section 2.3.1** and **Figure 2.4** for the IPCC's "*Special Report on Global Warming of 1.5°C*".

The scenario data used in this analysis can be accessed and downloaded at https://data.ene.iiasa.ac.at/iamc-1.5c-explorer.

Load `pyam` package and other dependencies

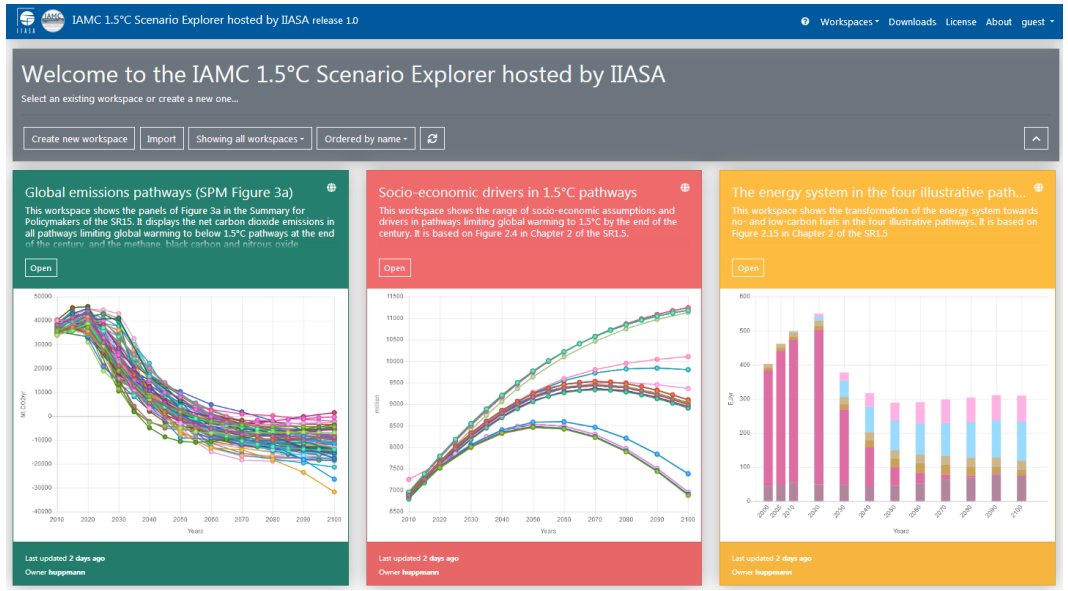
```
In [1]: import pandas as pd
        import numpy as np
        import io
        import yaml
        import math
        import matplotlib.pyplot as plt
        plt.style.use('style_sr15.mplstyle')
        %matplotlib inline
        import pyam

        from utils import boxplot_by_cat
```

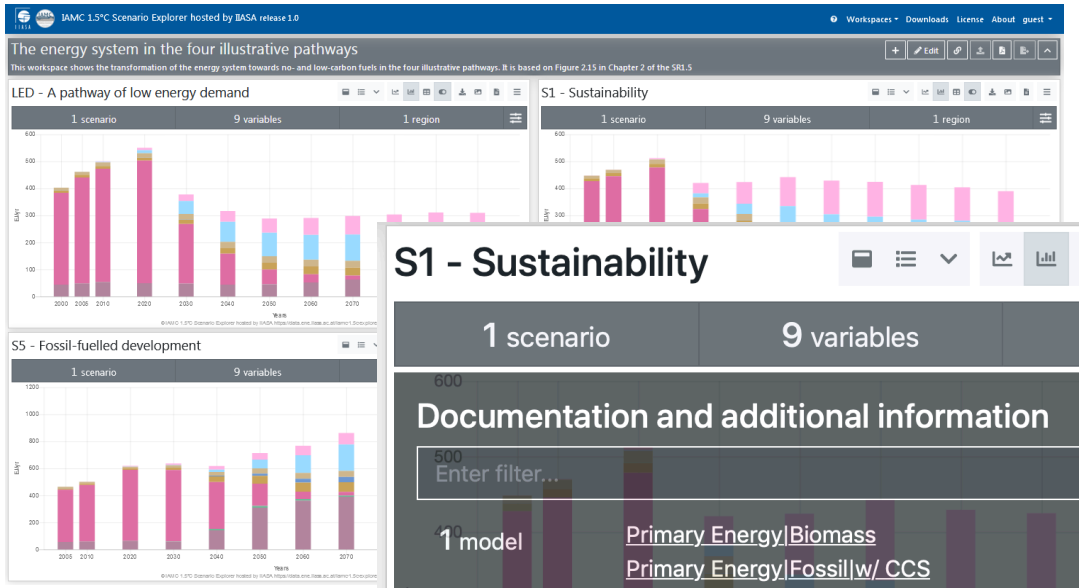
Rendered notebooks to generate figures and tables at data.ene.iiasa.ac.at/sr15_scenario_analysis

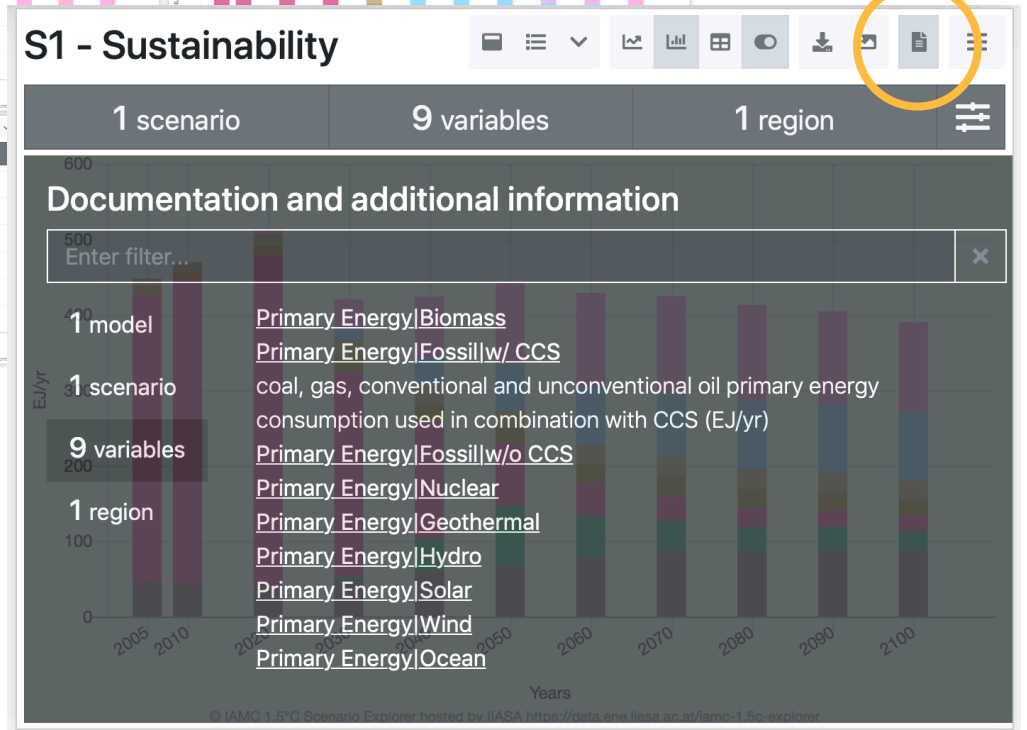
Accessible (II) – for human users

A new "IAMC 1.5°C Scenario Explorer hosted by IIASA"

Using "workspaces" to manage figures & data tables including pre-defined panels replicating SR15 figures







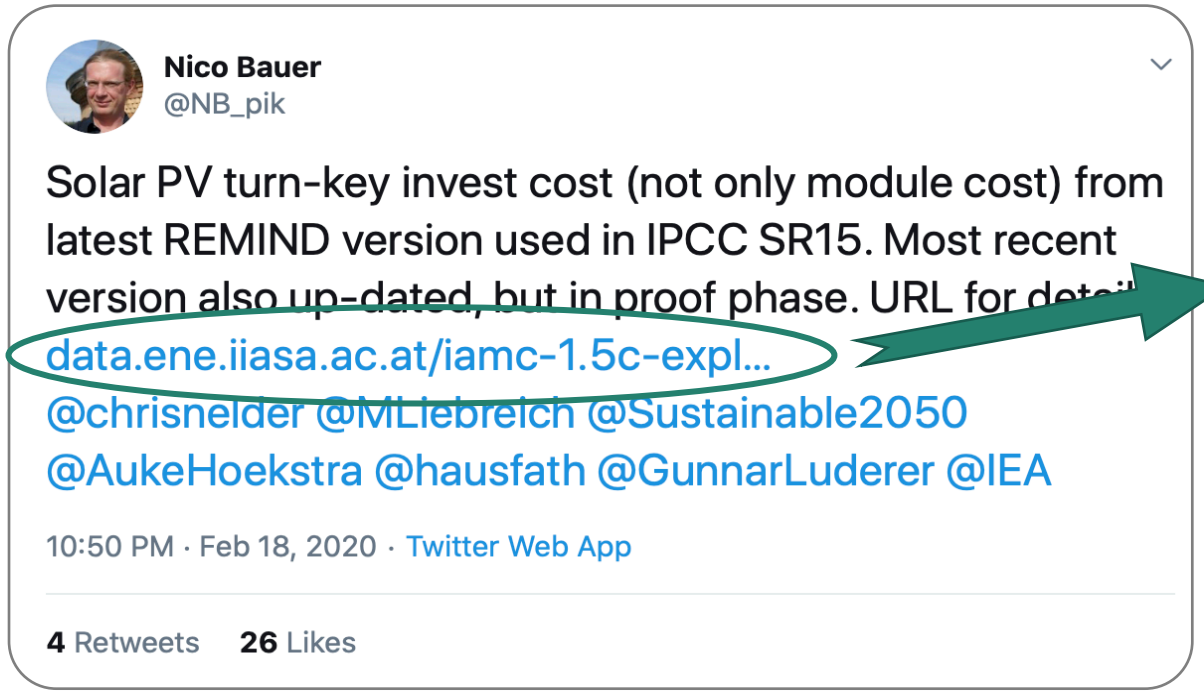
The scenario explorer provides documentation and references for models, scenarios & variables

Visit the IAMC 1.5°C Scenario Explorer at
https://data.ene.iiasa.ac.at/iamc-1.5c-explorer

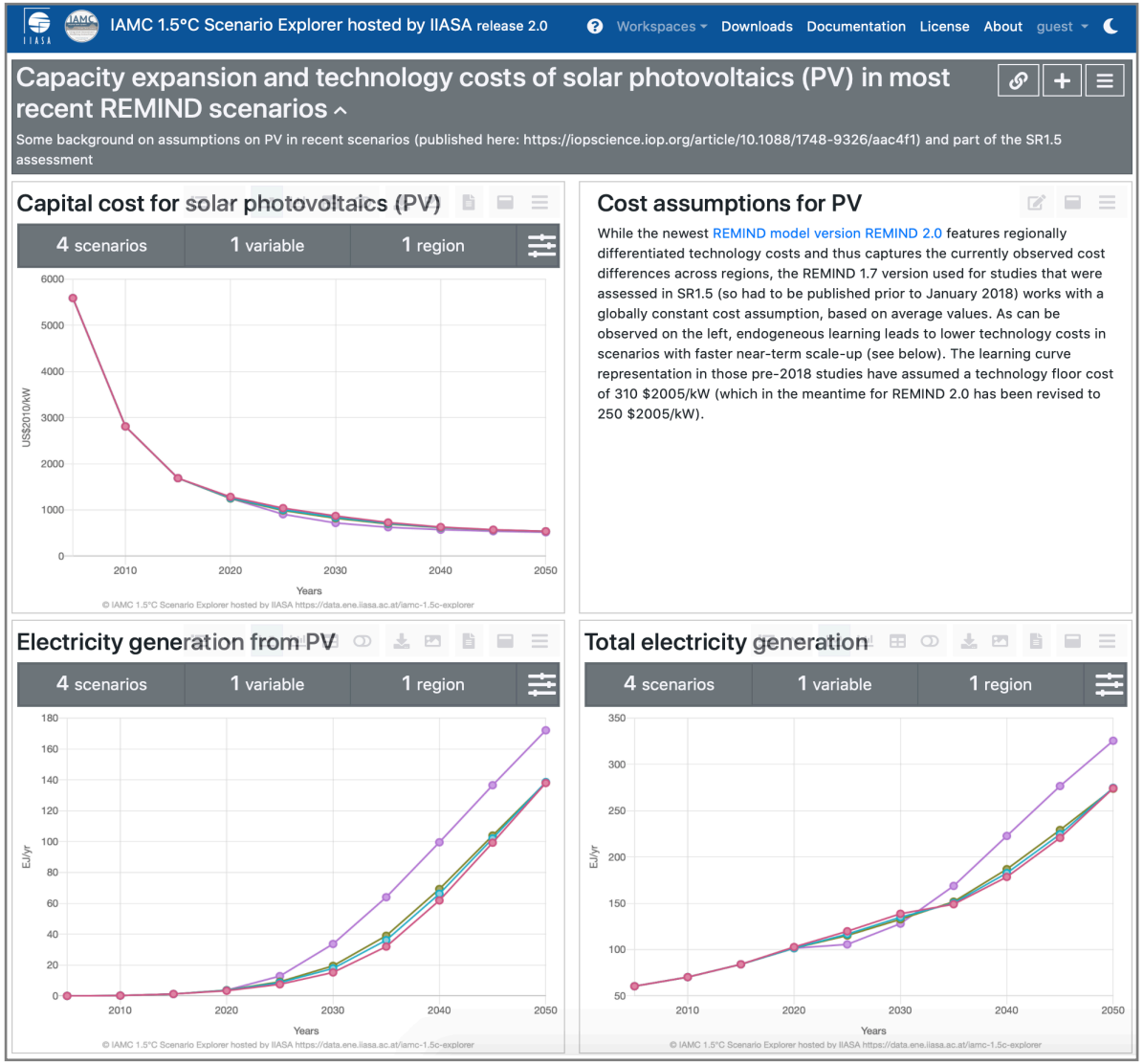
Scenario explorer workspaces "in the wild"

A few weeks ago on Twitter...

Discussion in the scientific literature (and on Twitter) about assumptions of PV costs in models used in SR15...



Thread at https://twitter.com/NB_pik/status/...



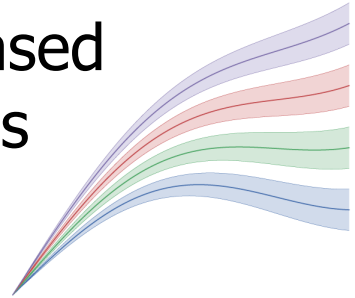
Interoperable

Apply common data standards and open-source packages

- Use common data template developed by the IAMC
  - ⇒ High-profile use case: IPCC Reports (AR5, SR15), EMF
  - ⇒ Used by ~50 research teams globally

	A	B	C	D	E	F	G	H
1	**Model**	**Scenario**	**Region**	**Variable**	**Unit**	**2005**	**2010**	**2015**
2	MESSAGE	CD-LINKS 400	World	Primary Energy	EJ/y	462.5	500.7	...

- Assessment using an open-source Python package
  - ⇒ Scenario analysis & visualization toolbox based on collaborative scientific-software practices
  - ⇒ Documentation: pyam-iamc.readthedocs.io



***pyam*: analysis and visualization of integrated assessment scenarios**

License Apache 2.0 | passing | docs passing | coverage 85%

DOI 10.5281/zenodo.1470400 | JOSS 10.21105/joss.01095

Repository hosted on GitHub | Community supported by Groups.io, slack | Documentation hosted by Read the Docs

pyam-iamc.readthedocs.io

Reusable (I)

All items of the scientific supply chain are released under licenses that enable follow-up research and re-use

Scenario ensemble data:

- ⇒ Custom license modified from Creative Commons CC-BY 4.0
- ⇒ Aim: allow re-use for scientific research and science communication but keep IAMC 1.5°C Scenario Explorer as "gateway" for entire dataset
- ⇒ Why? anticipating updates, we want to avoid multiple out-of-sync versions

- Assessment notebooks (Licensed under Apache 2.0, distributed via GitHub)

- Scenario ensemble manuscript:
  - ⇒ Bound by Springer-Nature policy
  - ⇒ But: distribute Readcube link for free access on personal website and social media, share post-print version on IIASA website after embargo period

Reusable (II)

The scenario set is an unstructured "ensemble of opportunity"

The data was compiled from studies & reports addressing various research questions and based on differing scenario designs and underlying assumptions.

A user's guide to the analysis and interpretation of scenario ensembles

Don't interpret the scenario ensemble as a statistical sample or as likelihood/agreement.

Don't focus only on the medians, but consider the full range over the scenario set.

Don't cherry-pick individual scenarios to make general conclusions.

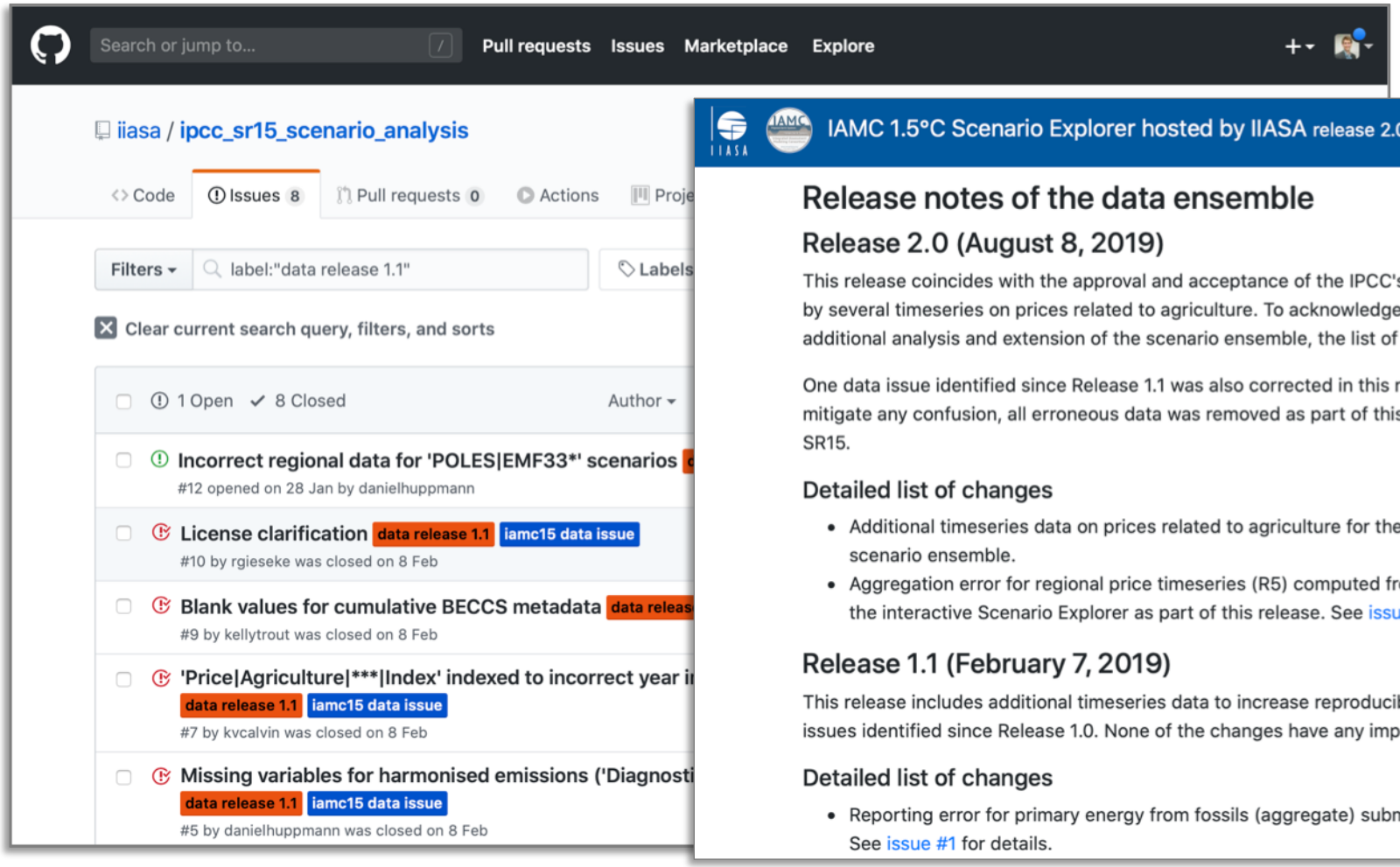
Don't over-interpret scenario results and don't venture too far from the original question.

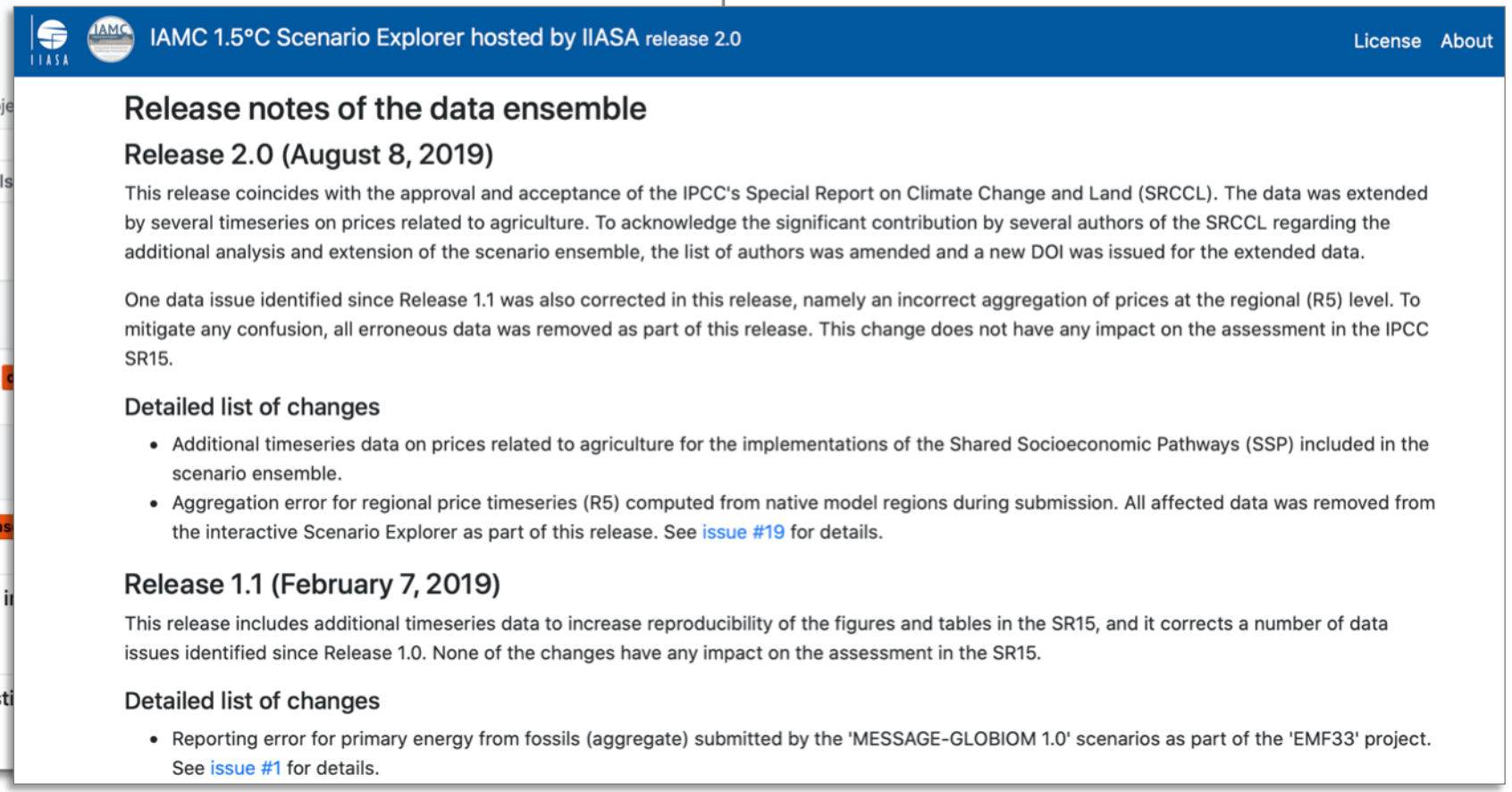
Don't conclude that the absence of a particular scenario (necessarily) means that this scenario is not feasible or possible.

Based on Box 1, Huppmann et al., *Nature Climate Change* 8:1027-1030 (2018).
doi: 10.1038/s41558-018-0317-4 | paywall-free access: rdcu.be/9i8a

Dealing with data errors (after publication)

Using GitHub "Issues" to track errors in the scenario ensemble





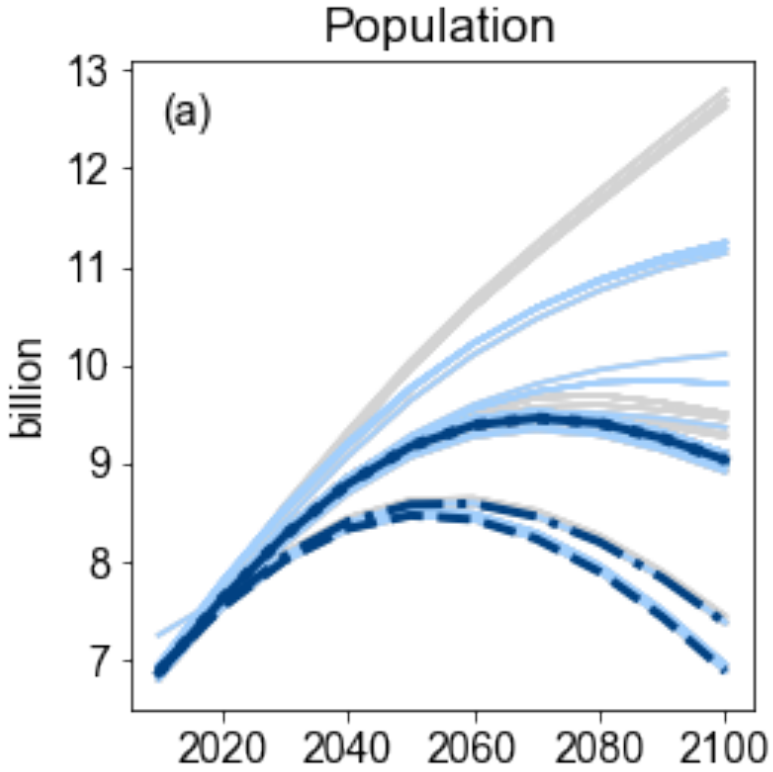
See github.com/iiasa/ipcc_sr15_scenario_analysis/issues and data.ene.iiasa.ac.at/iamc-1.5c-explorer/#/about for more information

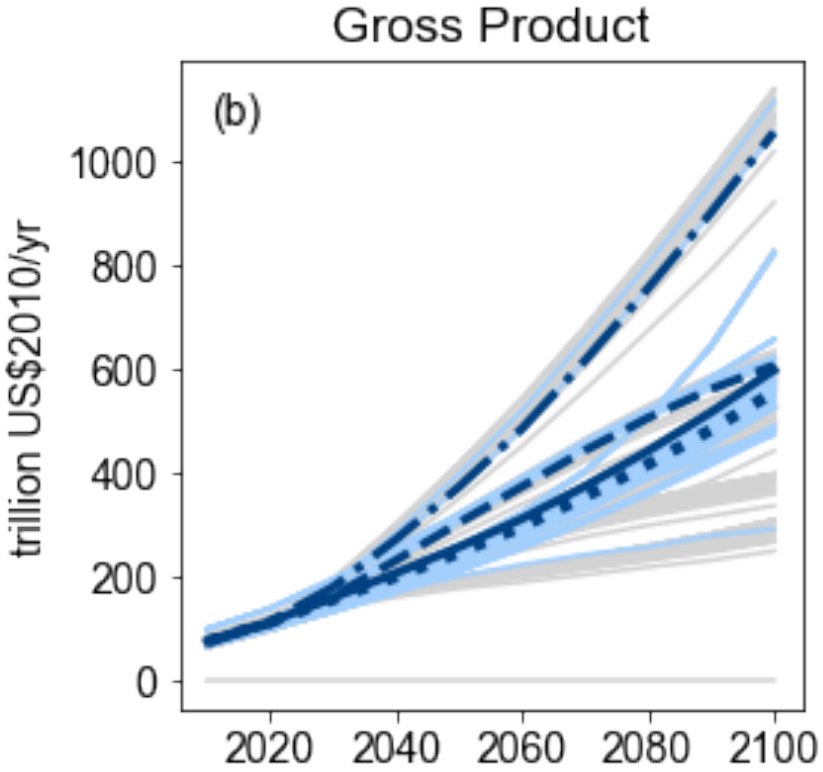
Part 4

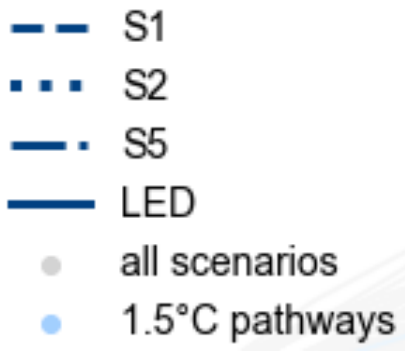
Using the scenario ensemble to gain insights on the SDGs

Assumptions & drivers across the scenario ensemble

There are pathways reaching the Paris 1.5°C temperature goal across a broad range of socio-economic development





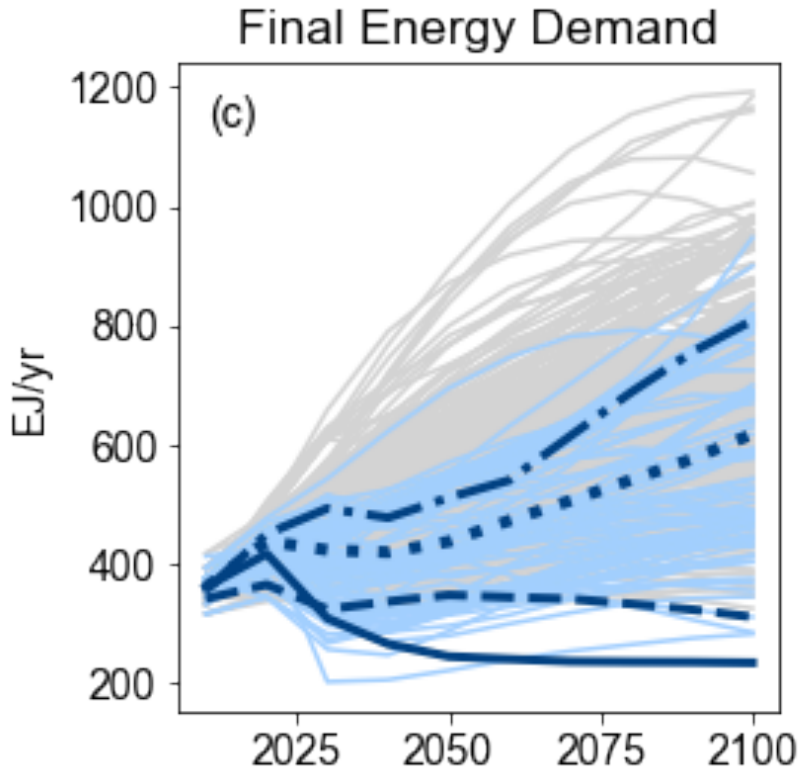


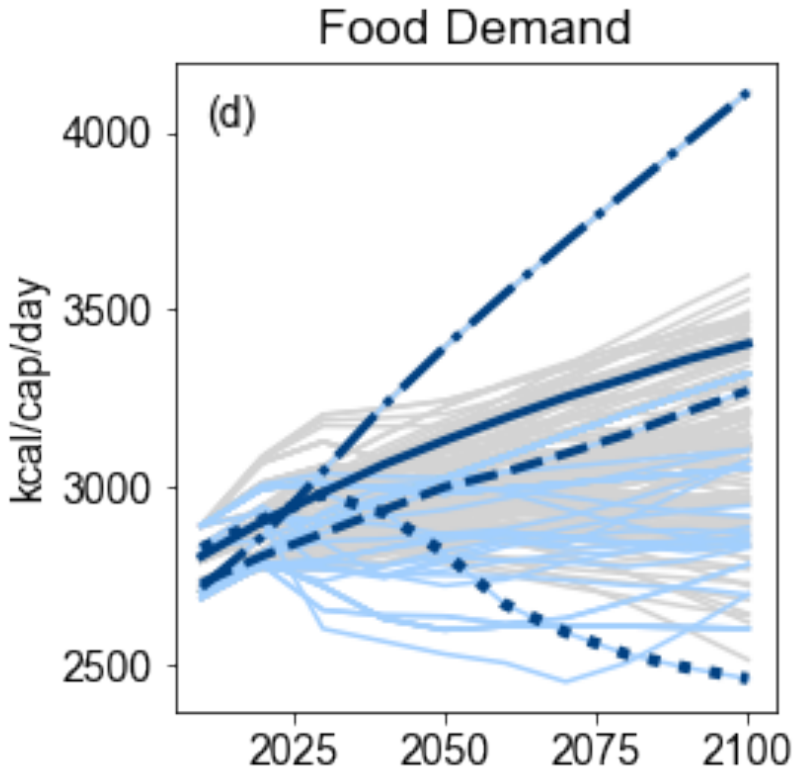
Based on Figure 2.4 IPCC SR15 (2018)
Source code to generate this figure available at
github.com/iiasa/ipcc_sr15_scenario_analysis

More information on the scenario ensemble, the SDGs, and open tools supporting the IPCC SR15 at https://pure.iiasa.ac.at/15824

Assumptions & drivers across the scenario ensemble

There are pathways reaching the Paris 1.5°C temperature goal across a broad range of socio-economic development





S1
S2
S5
LED
all scenarios
1.5°C pathways

Based on Figure 2.4 IPCC SR15 (2018)
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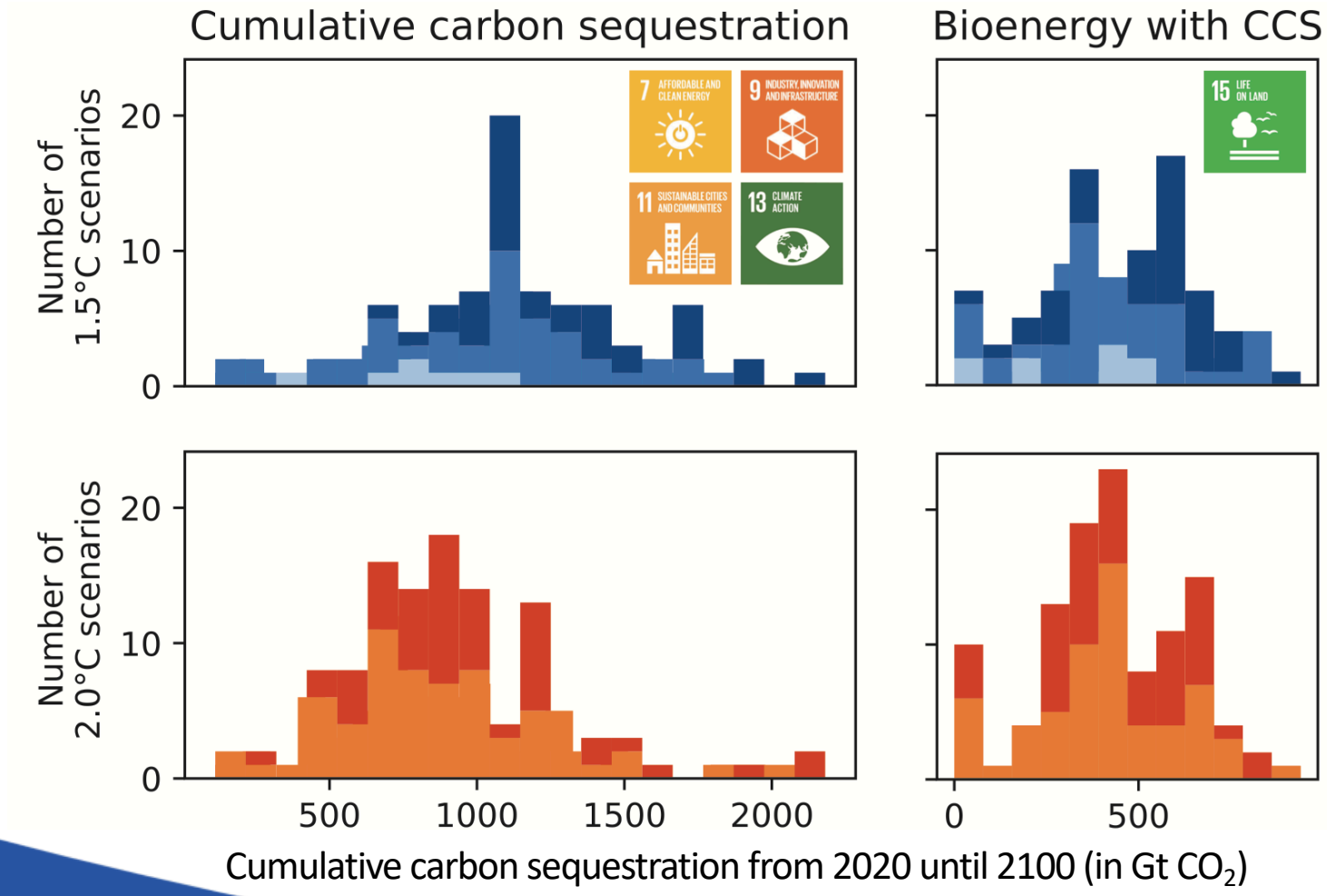
Bioenergy and carbon capture & sequestration (CCS)

Many pathways consistent with the Paris temperature goal use bioenergy in conjunction with CCS – but not all scenarios!



Based on Figure 1, Huppmann et al., *Nature Climate Change* 8:1027-1030 (2018).
Source code to generate this figure
github.com/iiasa/ipcc_sr15_scenario_analysis

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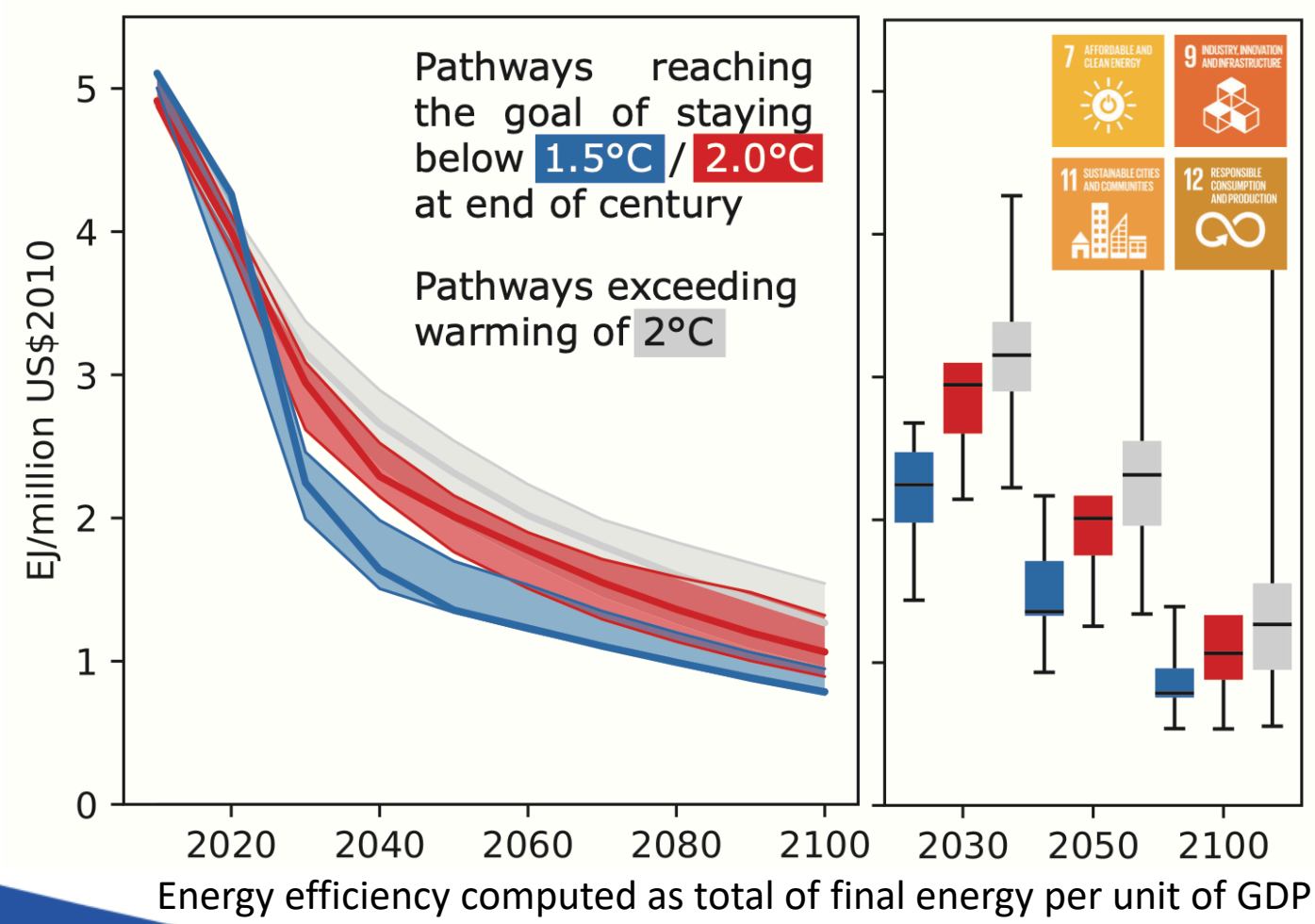
Energy efficiency improvements

All pathways consistent with the ambitious Paris temperature goal exhibit much faster energy efficiency improvements than 2°C scenarios



Huppmann et al., Conference Poster (2019).
https://pure.iiasa.ac.at/15824

Source code to generate this figure
github.com/iiasa/ipcc_sr15_scenario_analysis

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Part 5

Near-term policy outlook

Policy implications for near-term developments

We need fundamental socio-economic transformation in key sectors to avert dangerous global temperature increase with potentially irreversible impacts

- Current policies are insufficient to meet 2°C target
- More ambitious climate pledges are needed as part of the "ratcheting up" process
  - ⇒ Specific short-term measures:
    1) Increase efficiency
    2) Electrify
    3) Decarbonise power
    4) Replace residual fuels

"United in Science" high-level synthesis report of latest climate science by the Science Advisory Group of the UN Climate Action Summit 2019

public.wmo.int/en/resources/united_in_science

PSA: The Young Scientist Summer Program at IIASA

Every summer, dozens of PhD students spend three months in Laxenburg to work on their dissertation – supported and mentored by IIASA researchers!

If...

... you are a PhD student and

... working on a dissertation topic related to the SDGs
(or methodologies that can be applied in that context)

⇒ Visit iiasa.ac.at/yssp and mark your calendars to apply for summer 2021
Deadline: January 11, 2021

⇒ Reach out to researchers at IIASA well before the deadline to receive feedback on your ideas!

Thank you very much for your attention!

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Appendix

Supplementary slides

A suite of open tools to work with 1.5°C scenarios

Making it easy and FAIR to dive into the SR15 scenario assessment

- A new interactive online scenario explorer: data.ene.iiasa.ac.at/iamc-1.5c-explorer

  D. Huppmann, E. Kriegler, V. Krey, K. Riahi, J. Rogelj, S.K. Rose, J. Weyant, et al. (2018) *IAMC 1.5°C Scenario Explorer and Data hosted by IIASA.* doi: 10.22022/SR15/08-2018.15429

- Assessment and generation of figures & tables using open-source Jupyter notebooks
  - ⇒ Rendered notebooks: data.ene.iiasa.ac.at/sr15_scenario_analysis
  - ⇒ GitHub repository: github.com/iiasa/ipcc_sr15_scenario_analysis
  - ⇒ Based on open-source package pyam: pyam-iamc.readthedocs.io

  D. Huppmann et al. (2018) *Scenario analysis notebooks for the IPCC SR15.* doi: 10.22022/SR15/08-2018.15428

- Description of ensemble compilation and assessment process

  D. Huppmann et al. (2018). A new scenario resource for 1.5 °C research. *Nature Climate Change*, 8:1027-1030. doi: 10.1038/s41558-018-0317-4 | paywall-free access: rdcu.be/9i8a

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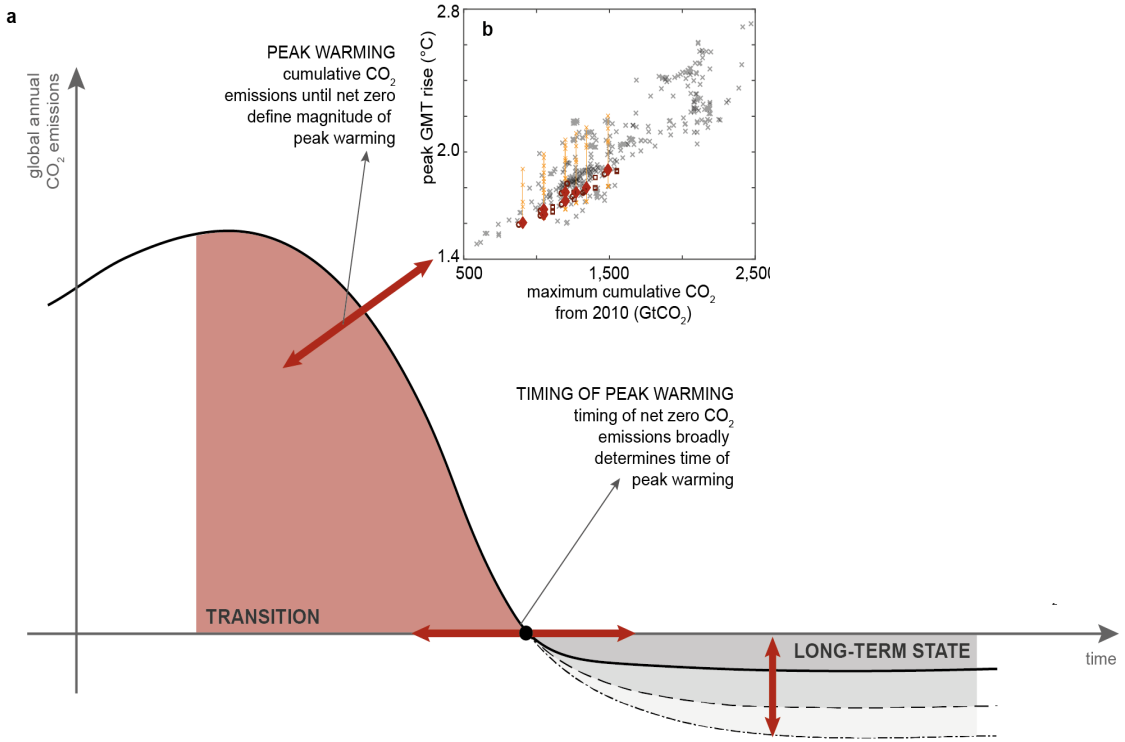
A new scenario logic for the Paris long-term temperature goal

Going beyond bounds on cumulative emissions to specific policy choices

Previously, many IAM studies used a constraint on cumulative GHG emissions.



Rogelj, Huppmann, et al. (2019). *Nature* 573(7774):357-363.
doi: 10.1038/s41586-019-1541-4
paywall-free: rdcu.be/bRpWa

This emphasised end-of-century warming and it puts a lot of (implicit) weight on discount rates, future technology availability, CDR, BECCS, etc.

We propose a new scenario logic closely following the text of the Paris Agreement.

Policy choice	Corresponding to
Year of net-zero	Year of peak warming
Ambition until net-zero	Level of peak warming
Long-term CO2 removal	Temperature reduction rate