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Authors	Zimm, Caroline;Mintz-Woo, Kian;Brutschin, Elina;Hanger-Kopp, Susanne;Hoffmann, Roman;Kikstra, Jarmo S.;Kuhn, Michael;Min, Jihoon;Muttarak, Raya;Pachauri, Shonali;Patange, Omkar;Riahi, Keywan;Schinko, Thomas
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Perspective

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Justice considerations in climate research

In the format provided by the authors and unedited

SUPPLEMENTARY INFORMATION

SUPPLEMENTARY METHODS and DISCUSSION including SUPPLEMENTARY FIGURES S1-S2 and SUPPLEMENTARY TABLES S1-4

S1. The Shared Socioeconomic Pathway (SSP) narrative elements

The SSP elements that are used to sketch out five different future trajectories are shown in Table S1, for more details please see.[1]

Table S1. SSP narrative elements from Tables 1-3 from[1].

SSP Element
Demographics: growth, fertility, mortality, migration, urbanization (type/level)
Human Development: education, health investments, access to health facilities, water, sanitation, gender equality, equity, social cohesion, societal participation
Economy & lifestyle: growth per capita, inequality, international trade, globalization, consumption & diet
Policies & Institutions: international cooperation, environmental policy, policy orientation, institutions
Technology: development, transfer, energy tech change, carbon intensity, energy intensity
Environment & natural resources: fossil constraints, environment, land use, agriculture

S2. Literature Review

We conducted a structured review (Figure S1) of two literature databases[2–4] on the Shared Socioeconomic Pathways (SSPs) which have been used by research to follow consistent data and storylines in their analyses.

The two databases contain close to 2,500 articles for the timeframe 2014-2019 (Version 1) and 2020-2021 (Version 2). We referred to the available coding for SDGs, health, poverty & livelihoods as well as impacts/vulnerability and emissions. For our focused analysis on justice, we used the following search terms for **TITLE** and **ABSTRACT** to scan the databases to identify articles that **explicitly** worked on justice issues.

- Fair*
- Just*
- Distribut*
- Equit*
- Equal*

This led to 533 articles (~21%). After a screening of the abstracts, 456 were discarded for various reasons [e.g., duplicates; the search terms yielded words with irrelevant meanings (especially true for the search term “just*”), the paper did not cover the topic itself but only claimed importance of the subject, the paper did not refer to mitigation scenarios, or natural climate impacts were studied (especially true for the term “distribut*”)].

This led to 77 papers (~3%) that entered the next step of coding according to our framework [see Excel file and Table S4]. Database version 1 covered six years and led to 43 unique entries, while version 2 covered two years and led to 34 entries.

As we were interested in aspects of wellbeing, we also scanned papers which were categorized under poverty and livelihoods. Some had already come up in the initial search, but 37 additional papers were identified, 24 were then reviewed in detail, and the remaining 13 turned out to be irrelevant. Coding according to our framework was not possible for many patterns and indicators. These articles informed our paper but did not enter in the analysis of studies that “explicitly relate to aspects of climate justice”. The same applies to papers covering different SDGs and SSP narratives.

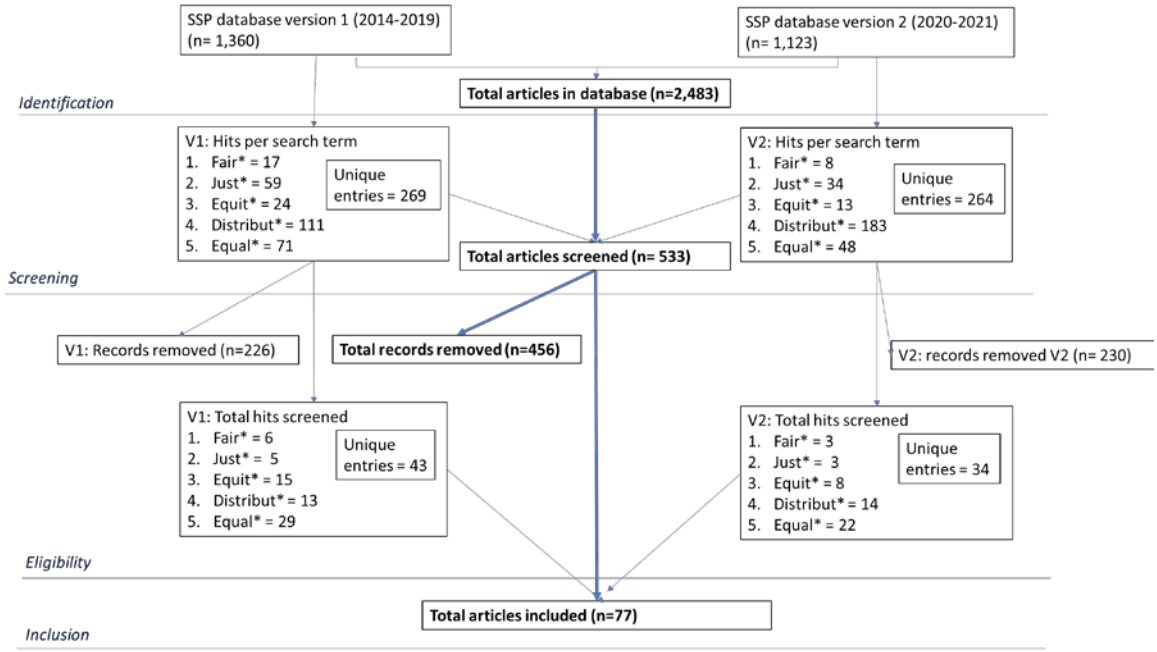


Figure S1. Literature Review. Unique entries, some appeared in several searches.

Figure S2 shows the cumulative spread of search terms for the included articles form the two literature databases, with equit* and equal* being more prevalent.

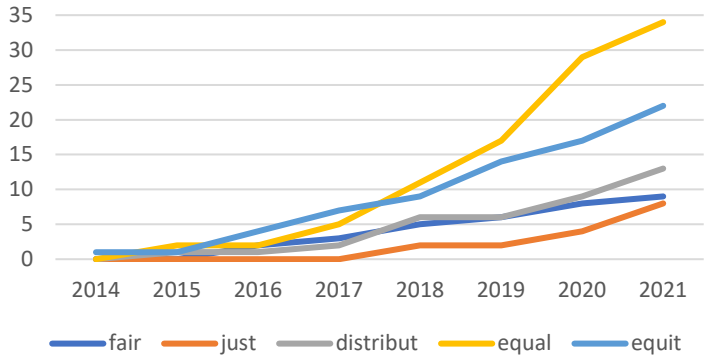


Figure S2. Hits per search term of included articles over the timeframe 2014-2019 (database version 1) and 2020-2021 (database version 2) from the two literature databases[2–4] on the Shared Socioeconomic Pathways. Search terms: fair*, just*, distribut*, equit*, equal*.

In the next step, we map articles to our justice framework to identify the dominant justice patterns, metrics (and indicators), and implementation approaches. Table S2 provides an overview per pattern and indicator. Table S3 by implementation approach and indicator.

Table S2. Patterns per indicator covered in the literature reviewed.[1]

Utilitarian/prioritarian	19	12	7	1	1	**28**
Egalitarian	21	11	5	2	1	**29**
Sufficientarian	8	7	5	4	0	**18**
Limitarian	0	0	0	2	0	**2**
Mix	5	0	1	1	0	**7**
Total	**34**	**35**	**19**	**10**	**4**	**Total**
	GHG emissions	GDP	Energy	Food	Health	

[1] Note: the number of unique studies does not match the total as some studies involved several patterns (for several metrics) and scenarios, and some studies involved patterns that were not easily defined.

Table S3. Implementations approaches per indicator covered in the literature reviewed. [1]

1. Scenario/model design & data input	5	8	10	5	1	**21**
2. Scenario output post-processing	14	4	0	0	0	**18**
3. Scenario evaluation	3	3	3	1	0	**6**
4. Methodological/ qualitative discussions	5	8	3	1	1	**12**
5. SSP-based projections	5	8	2	2	2	**14**
Total	**34**	**35**	**19**	**10**	**4**	**Total**
	GHG emissions	GDP	Energy	Food	Health	

For Figure 2 in the main text and Table S2 and S3, we coded our entries as follows (see Table S4 in Excel sheet), reflecting the following patterns.

- Utilitarian/prioritarian = For example, studies that follow cost-effective optimization.
- Sufficientarian = For example, studies that accounted for decent living services.
- Limitarian = For example, studies that introduced a cap on consumption.
- Egalitarian = For example, studies that reflected inequality indices (e.g., Gini).

The scenarios studies we cover are multidimensional and generally follow a narrative that aims to reflect the potential development of society. Such developments do not reflect stylized futures that map perfectly onto one of the theoretical patterns described here. In this light, we classify and categorize scenarios by how closely their key characteristics reflect a pattern, even if there are minor theoretical inconsistencies. However, we acknowledge that it is difficult to attribute a pattern to a particular trajectory. We conclude that future research could formalize the analysis of how to extract patterns from quantitative scenarios , an area in which we believe philosophers and scientists could engage in valuable interdisciplinary work.

Many studies on burden sharing follow the IPCC equity principles. which we matched to the patterns of distributive justice as follows:

- cost effectiveness = utilitarian
- capacity/ability to pay = utilitarian/prioritarian
- right to development = sufficientarian
- equal per capita = egalitarian
- responsibility/polluter pays = N.A. (related to corrective justice, not distributive justice)
- grandfathering/sovereignty = N.A. [we did not treat this as a pattern of justice, since we were concerned with intratemporal patterns, not intertemporal patterns (which we treat as part of transitional justice); furthermore, many philosophers deny that there are justice-based reasons to adopt grandfathering principles [5,6]]

Implementation

1. Scenario/model design & data input:
    - Considering justice elements at the level of input (exogenous) assumptions or key assumptions driving the model results
    - For example, assumptions about regional convergence of GDP per capita, food consumption, final energy consumption levels etc.
2. Scenario output post-processing (i.e., LCA, carbon budget equity assessments)
    - Additional indicators are derived, for example, to assess the implications of certain technology trajectories on jobs, water consumption, land use etc.
3. Scenario evaluation

- No new indicators are derived but scenarios are assessed across many indicators (typical for example for the growing feasibility assessments or technology growth-rates)
- Scenario benchmarking to other lines of evidence

4. Methodological/conceptual (qualitative/narrative) discussions
    - For example, discussion about how the objective function could be adjusted but not the implementation
5. SSP based projections
    - This could be considered as additional post-processing method but based on SSP scenarios and projections
    - For example, studies estimating implications of different SSP trajectories for hunger

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Table S4. Literature included.

No	DISTRIBUTIONAL JUSTICE																PROCEDURAL AND RECOGNITIONAL JUSTICE	
					Metrics					Patterns of Justice					Implementation Approach		
	Author	DOI	Year	Which justice term?	Food 1	Energy 2	Health 3	Economy 4	GHG 6	Utilitarian/ Prioritarian 1	Sufficientarian 2a	Limitarian 2b	Egalitarian 3	MIX 4	1-scenario/model design & data input 2-scenario output post-processing (i.e. LCA, carbon budget equity assessments) 3-scenario evaluation 4-methodological /conceptual (qualitative/narrative) discussions 5- SSP based projections	Procedural or recognitional justice element (explicit) 1- yes	Explanation on procedural or recognitional justice in scenario process
1	Lucas et al	https://doi.org/10.1016/j.gloenvcha.2019.102017	2020	fair distribution					6	1			3		2		
2	Fyson et al	https://doi.org/10.1038/s41558-020-0857-2	2020	equity					6	1			3		2		
3	Pozo et al	https://www.nature.com/articles/s41558-020-0802-4	2020	equity					6	1			3		2		
4	Pachauri et al	https://www.nature.com/articles/s41560-021-00914-9	2021	equity		2					2a				3		
5	Kikstra et al	https://iopscience.iop.org/article/10.1088/1748-9326/ac1c27/meta	2021	equity	1	2		4			2a				1		
6	Allen et al.	https://doi.org/10.1017/sus.2021.13	2021	just (operating space)	1	2			6			2b			1		
7	Chen et al.	https://doi.org/10.1016/j.energy.2021.121024	2021	just distribution of burdens		2			6	1			3		1		
8	Lenzi	https://doi.org/10.1080/21550085.2021.1895249	2021	justice		2		4	6						4		
9	Robiou du Pont et al.	https://doi.org/10.1088/1748-9326/11/5/054005	2016	equity		2		4	6	1	2a		3		3		
10	Chaturvedi et al	https://www.sciencedirect.com/science/article/abs/pii/S0360544219324035	2021	equity				4	6	1	2a				5		
11	Bauer et al	https://www.nature.com/articles/s41586-020-2982-5	2020	equity/fairness				4	6				3		1		
12	Pye et al	https://doi.org/10.1038/s41467-020-17679-3	2021	equity		2				1				4	1		
13	Liu et al.	https://iopscience.iop.org/article/10.1088/1748-9326/11/11/114004	2016	inter-generational and inter-regional equity				4					3		3		
14	Anthoff and Emmerling	https://doi.org/10.1086/701900	2019	equity				4		1					4		
15	Hasegawa et al.	https://doi.org/10.1038/s41893-019-0371-6	2019	equality	1						2a				3		
16	Díaz et al.	https://www.science.org/doi/10.1126/science.aax3100	2019	equality	1	2	3	4							4	1	indigenous consultation
17	Davide, Marinella	http://dspace.unive.it/handle/10579/14063	2018	equity, SDGs					6					4	3		
18	Hasegawa et al.	https://doi.org/10.1088/1748-9326/10/1/014010	2015	equality	1										5		
19	Emerling J.	https://doi.org/10.1017/S1355770X17000365	2017	equity				4		1					4		
20	Lenzi, D.	https://doi.org/10.1017/sus.2018.5	2018	ethical concerns, justice					6						4		
21	Nicole J. van den Berg, Hel	https://link.springer.com/article/10.1007/s10584-019-02368-y	2019	fairness					6		2a		3		2		
22	Xunzhang Pan, Jie Tao & K	https://www.tandfonline.com/doi/full/10.1080/10042857.2018.1510079?scro	2018	fairness					6	1	2a		3	4	2		
23	Xunzhang Pan, Michel den	https://doi.org/10.1016/j.envsci.2017.04.020	2017	equity, fairness					6	1	2a		3	4	2		
24	Davide, P Vesco	https://deliverypdf.ssrn.com/delivery.php?ID=532027087112026080900700831	2016	fairness, equity					6	review of different other papers, qualitative, not always explicit.					4		
25	Hof, MGJ Den Elzen, AM B	https://link.springer.com/article/10.1007/s10784-016-9317-x	2016	fairness					6				3	4	2		
26	Meinshausen, Yr Du Pont	https://www.researchgate.net/profile/Yann_Robiou_Du_Pont/publication/33	2018	fairness					6	1			3		2		
27	Maxim and E Grubert	https://doi.org/10.1088/2634-4505/ac33ef	2021	justice [social]				4							4		
28	Robiou du Pont et al.	https://www.nature.com/articles/nclimate3186	2017	equity					6	1	2a		3		2		
29	Rogelj et al	https://www.nature.com/articles/s41586-019-1541-4	2019	equity					6						4		
30	Emmerling et al.	https://iopscience.iop.org/article/10.1088/1748-9326/ab3cc9/meta	2019	intergenerational equity				4	6						4		
31	Markandya et al.	https://doi.org/10.1016/S2542-5196(18)30029-9	2018	equity			3		6	1			3		1		
32	Rozenberg et al	https://link.springer.com/article/10.1007/s10584-013-0904-3	2014	equity				4							4		
33	Leimbach & Giannousakis	https://link.springer.com/article/10.1007/s10584-019-02469-8	2019	equity				4	6	1			3		2		
34	Sun et al.	https://doi.org/10.3390/su11123341	2019	equity		2		4	6	1					3		
35	Fragkos	https://doi.org/10.3390/en14071879	2021	distribution		2			6	1					1		
36	Campagnolo and De Cian	https://doi.org/10.1016/j.eneco.2022.106020	2022	distribution		2					2a				1		
37	Strefler et al	https://doi.org/10.1088/1748-9326/ac0a11	2021	fairness					6	1			3		1		
38	Kartha et al.	https://cdn.sei.org/wp-content/uploads/2020/09/research-report-carbon-ine	2020	inequality					6				3		2		
39	Ameli et al	https://www.nature.com/articles/s41467-021-24305-3	2021	equity		2				1					1		
40	Turgut et al	https://doi.org/10.1016/j.jclepro.2021.129437	2021	distribution		2		4		1					1		
41	Wei et al	https://www.nature.com/articles/s41467-020-15453-z?ftag=YHFa5b931b	2020	distribution					6	1	2a		3	4	2		
42	Huang and Tian	https://doi.org/10.1016/j.apenergy.2020.116043	2021	inequality					6				3		2		
43	Poblete-Cazenave et al.	https://www.nature.com/articles/s41560-021-00871-0	2021	inequality		2					2a				1		
44	Molotoks et al.	https://onlinelibrary.wiley.com/doi/full/10.1002/fes3.261	2020	inequality	1							2b	3		5		
45	Gazzotti et al	https://www.nature.com/articles/s41467-021-23613-y	2021	inequality				4	6	1					5		
46	Taconet et al	https://link.springer.com/article/10.1007/s10584-019-02637-w	2020	inequality				4	6	1			3		5		
47	van Meijl et al	https://www.sciencedirect.com/science/article/pii/S2211912420300110	2020	inequality	1					1		2b	3	4	1	1	workshops/process
48	Andrijevic et al	https://www.nature.com/articles/s41467-020-19856-w	2020	inequality				4							5		
49	Kuiper et al.	https://doi.org/10.1016/j.gfs.2019.100328	2020	inequality	1			4			2a				1		
50	Chen, Liu, Cheng	https://doi.org/10.1016/j.scitotenv.2019.134950	2020	inequality						1					2		
51	Breil et al.	https://www.eionet.europa.eu/etcs/etc-cca/products/etc-cca-reports/tp_1-2	2018	procedural and distributive justice											4	1	discussion with case studies on ways of making decisions more procedurally just
52	Yang et al.	https://doi.org/10.1016/j.oneear.2021.07.005	2021	purely economic[2] - Pareto optimal					6	1					2		
53	Riahi et al.	http://dx.doi.org/10.1016/j.gloenvcha.2016.05.009	2017	inequality		2		4					3		1		
54	Rao et al.	https://doi.org/10.1016/j.futures.2018.07.001	2019	inequality				4					3		5		
55	Rao and Min	https://doi.org/10.1002/wcc.513	2018	inequality		2		4					3		4		
56	King and Harrington	https://doi.org/10.1029/2018GL078430	2018	inequality					6				3		n.a.		
57	Calvin et al.	https://doi.org/10.1016/j.gloenvcha.2016.06.010	2017	inequality		2		4					3		n.a.		
58	Byers et al.	https://doi.org/10.1088/1748-9326/aabf45	2018	inequality				4			2a				1		
59	Bijl et al.	https://doi.org/10.1016/j.gloenvcha.2017.04.003	2017	inequality	1						2a				n.a.		
60	Soergel et al	https://doi.org/10.1038/s41467-021-22315-9	2021	distribution, poverty				4		1			3		2		
61	Chen et al.	https://link.springer.com/article/10.1007/s11625-019-00780-y	2020	inequality and distribution											1	1	national level (Japan) SSPs - workshops
62	Mitter et al	https://www.sciencedirect.com/science/article/pii/S0959378020307421	2020	not really mentioned - but procedural justice											1	1	EU Agric SSPS, stakeholder process
63	Harris et al	https://doi.org/10.3390/su12135417	2020	inequality - procedural justice											1	1	stakeholder workhops
64	Andrijevic et al.	https://iopscience.iop.org/article/10.1088/1748-9326/ac2195/meta	2021	inequality		2	3	4			2a				5		
65	Pavanello et al	https://www.nature.com/articles/s41467-021-26592-7	2021	inequality		2	3	4			2a				5		
66	Harding et al	https://www.nature.com/articles/s41467-019-13957-y	2020	inequality				4					3		5		
67	Huang et al	https://doi.org/10.1016/j.jclepro.2019.119626	2020	inequality				4					3		1		
68	Ueckerdt et al.	https://esd.copernicus.org/articles/10/741/2019/	2019	inequality aversion, discount rates				4		1					2		
69	Glanemann, Willner	https://doi.org/10.1038/s41467-019-13961-1	2020	inequality aversion, discount rates				4		1					2		
70	Kurniawan and Managi	https://doi.org/10.1002/sd.1722	2018	inequality, poverty, wellbeing						Special - non-declining sustainability					5		
71	Benveniste et al.	https://iopscience.iop.org/article/10.1088/1748-9326/aaa0b9	2018	inequalities/distribution					6				3		5		
72	Crespo Cuaresma et al.	https://www.nature.com/articles/s41599-018-0083-y	2018	income distribution, SDG attainment, poverty				4			2a				5		
73	Hallegatte &Rozenberg	https://doi.org/10.1038/nclimate3253	2017	inclusive development, distributional implications, poverty					6		2a				5		
74	Havlik et al.	https://openknowledge.worldbank.org/bitstream/handle/10986/23441/Clima	2015	inequalities, redistribution, food security	1			4							1		
75	Ricke et al.	https://doi.org/10.1038/s41558-018-0282-y	2018	inequalities/distribution											n.a.		
76	van Soest et al.	doi.org/10.1016/j.efi.2019.10.004	2019	inequality, SDGs				4					3		n.a.		
77	Campagnolo and Davide	https://doi.org/10.1016/j.worlddev.2019.05.015	2019	inequality/SDGs				4			2a		3		n.a.	1	expert panel and stakeholder integration