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Justice considerations in climate research

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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 from¹.

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 databases²⁻⁴ 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.

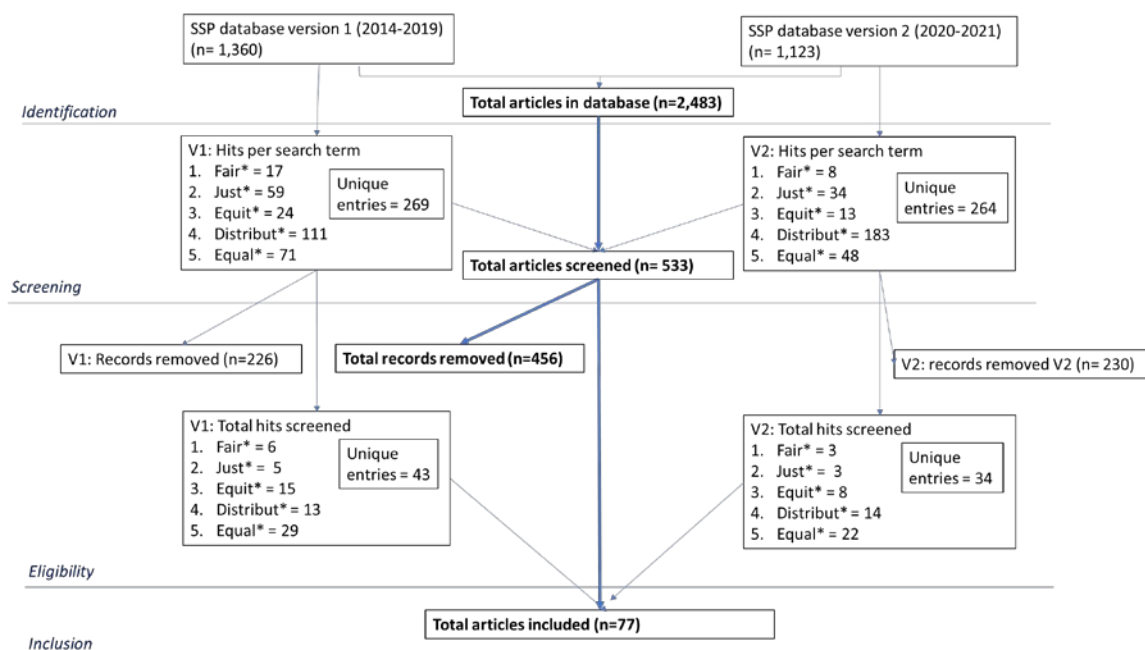


Figure S1. Literature Review. Unique entries, some appeared in several searches.

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

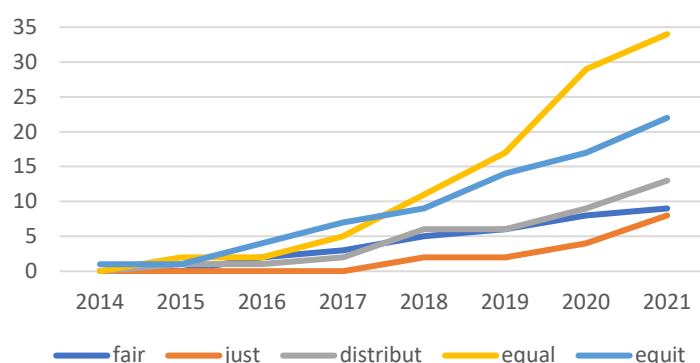


Figure S2. Hits per search term of included articles over the timeframe 2014-2019 (database version 1) and 2020-2021 (database version 2) from the two literature databases²⁻⁴ on the Shared Socioeconomic Pathways. Search terms: *fair, *just**, *distribut**, *equit**, *equal**.**

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

	GHG emissions	GDP	Energy	Food	Health	
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

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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2. Green, C. *et al.* *Shared Socioeconomic Pathways (SSPs) Literature Database, v1, 2014-2019*. (NASA Socioeconomic Data and Applications Center (SEDAC), 2021).
3. O'Neill, B. C. *et al.* Achievements and Needs for the Climate Change Scenario Framework. *Nature Climate Change* 1074–1084 (2020).
4. Green, C. *et al.* *Shared Socioeconomic Pathways (SSPs) Literature Database, Version 2, 2020-2021 (Preliminary Release)*. (NASA Socioeconomic Data and Applications Center (SEDAC), 2022).
5. Meyer, L. H. & Roser, D. Climate justice and historical emissions. *Critical Review of International Social and Political Philosophy* **13**, 229–253 (2010).
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Table S4. Literature included.

No	Author	DOI	Year	Which justice term?	DISTRIBUTIONAL JUSTICE											PROCEDURAL AND RECOGNITIONAL JUSTICE	
					Food 1	Energy 2	Health 3	Economy 4	GHG 6	Utilitarian/ Prioritarian 1	Sufficientarian 2a	Limitarian 2b	Egalitarian 3	MIX 4	Implementation Approach 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.elsevier.2019.102017	2020	fair distribution					6	1				3		2	
2	Pyson et al.	https://doi.org/10.1038/s41558-020-0887-2	2020	equity					6	1				3		2	
3	Pozo et al.	https://www.nature.com/articles/s41558-020-0805-4	2020	equity					6	1				3		2	
4	Pachauri et al.	https://www.nature.com/articles/s41558-021-00911-2	2021	equity			2				2a					3	
5	Kolster et al.	https://iopscience.iop.org/article/10.1088/1748-9326/ac1c77/meta	2021	equity	1		2		4		2a					3	
6	Allen et al.	https://doi.org/10.1017/etp.2021.14	2021	just (operating space)	1		2		6			2b				1	
7	Chen et al.	https://doi.org/10.1016/j.elsevier.2021.121034	2021	just distribution of burdens			2		6	1				3		1	
8	Lenz	https://doi.org/10.1080/14493508.2021.1985348	2021	justice			2		4	6		12a				4	
9	Robiou du Pont et al.	https://doi.org/10.1088/1748-9326/11/5/054006	2016	equity			2		4	6	12a			3		3	
10	Chaturvedi et al.	https://www.sciencedirect.com/science/article/pii/S0950423019324024	2021	equity					4	6	12a			3		3	
11	Bauer et al.	https://www.nature.com/articles/s41558-020-0887-2	2020	equity/fairness					4	6						1	
12	Pye et al.	https://doi.org/10.1038/s41467-020-17678-3	2021	equity			2				1			3	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/10.1088/00300909	2019	equity					4		1					4	
15	Hasagawa et al.	https://doi.org/10.1038/s41591-019-0571-6	2019	equity		1					2a					3	1 indigenous consultation
16	Ota et al.	https://www.sciencedirect.com/science/article/pii/S0950423020302020	2019	equity			1	2	3	4						4	
17	David, Marinella	http://dspace.univr.it/handle/10579/14063	2018	equity, SDGs					6					4		3	
18	Hasagawa et al.	https://doi.org/10.1088/1748-9326/10/1/014010	2015	equity		1									4	3	
19	Emerling J.	https://doi.org/10.1017/S1358770x17000046	2017	equity					4		1					4	
20	Lenz, D.	https://doi.org/10.1017/etp.2021.14	2019	ethical concerns, justice					6							4	
21	Nicole J. van den Berg, He	https://link.springer.com/article/10.1007/s10584-019-07368-y	2019	Fairness					6		2a			3		4	
22	Kunshang Pan, Jie Tao & H	https://www.tandfonline.com/doi/full/10.1080/10943857.2019.1510079?hpid=hp	2018	Fairness					6		12a			3	4	2	
23	Kunshang Pan, Michel der	https://doi.org/10.1016/j.elsevier.2017.04.030	2017	equity, fairness					6		12a			3	4	2	
24	David, P. Vasco	https://deliverpool.scribd.com/delivery.php?d=3302705711206090700813	2016	Fairness, equity					6							4	
25	Hof, Maja, Den Elzen, AM	https://link.springer.com/article/10.1007/s10704-018-9317-x	2018	Fairness					6					3	4	2	
26	Heinrichauten, Yi Du Pont	https://www.sciencedirect.com/science/article/pii/S0950423019324024	2019	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/nclimate3386	2017	equity					6		12a			3		2	
29	Pogge et al.	https://www.nature.com/articles/s41558-019-1541-4	2019	equity					6							4	
30	Emmerling et al.	https://iopscience.iop.org/article/10.1088/1748-9326/aabc9d/meta	2019	intergenerational equity					4	6				3		4	
31	Mehandovic et al.	https://doi.org/10.1088/1748-9326/aabc9d/meta	2019	equity				3		6				3		4	
32	Koenigberg et al.	https://link.springer.com/article/10.1007/s10584-013-0908-3	2014	equity					4	6	1					2	
33	Leimbach & Giannousakis	https://link.springer.com/article/10.1007/s10584-019-02469-9	2019	equity					4	6	1			3		2	
34	Sun et al.	https://doi.org/10.3390/en14071879	2019	equity			2		4	6	1					3	
35	Frangos	https://doi.org/10.3390/en14071879	2021	distribution					1	6	1					3	
36	Campagnolo and De Cian	https://doi.org/10.1016/j.elsevier.2021.106020	2021	distribution			2				2a					1	
37	Trefler et al.	https://doi.org/10.1088/1748-9326/ac9111	2021	Fairness					6		1			3		2	
38	Kartha et al.	https://cdn.ssi.org/wp-content/uploads/2020/09/assess-report-carbon-ineq	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.elsevier.2021.126437	2021	distribution				2		4						1	
41	Wei et al.	https://www.nature.com/articles/s41467-020-15453-2?hpid=hp%2F93112	2020	distribution					6		12a			3	4	2	
42	Huang and Tian	https://doi.org/10.1016/j.elsevier.2020.119043	2021	inequality					6			2a				2	
43	Poblete-Cazenave et al.	https://www.nature.com/articles/s41560-021-00871-0	2021	inequality			2					2a				1	
44	Molotok et al.	https://online.library.wiley.com/doi/full/10.1002/feq3.264	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/s10584-019-02469-9	2020	inequality					4	6	1			3		5	
47	van Meijl et al.	https://www.sciencedirect.com/science/article/pii/S0950423020302020	2020	inequality		1				1		2b		3	4	1	1 workshops/process
48	Andrijevic et al.	https://www.nature.com/articles/s41467-020-19856-4	2020	inequality					4					3		5	
49	Kuiper et al.	https://doi.org/10.1016/j.elsevier.2019.100338	2020	inequality		1			4		2a					1	
50	Chen, Liu, Cheng	https://doi.org/10.1016/j.elsevier.2019.134950	2020	inequality						1						2	
51	Brell et al.	https://www.klimaat.be/2021/01/etp-ssc-ssc-2/products/etp-ssc-reports/te-2-3	2018	procedural and distributive justice												4	1 discussion with case studies on ways of making decisions more procedurally just
52	Tang et al.	https://doi.org/10.1016/j.elsevier.2021.07.029	2021	"purely economic" + Pareto optimal					6	1						2	
53	Riahi et al.	http://dx.doi.org/10.1016/j.elsevier.2016.05.009	2017	inequality		2		4					3			1	
54	Rao et al.	https://doi.org/10.1016/j.futures.2018.07.004	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/10.1029/2018JG007340	2018	inequality					6					3	n.a.		
57	Calvin et al.	https://doi.org/10.1016/j.elsevier.2016.06.002	2017	inequality			2		4					3	n.a.		
58	Bjers et al.	https://doi.org/10.1088/1748-9326/aab7d5	2018	inequality					4		2a					1	
59	Bjij et al.	https://doi.org/10.1016/j.elsevier.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/s11675-019-0780-y	2020	inequality and distribution												1	1 national level (Japan) SSPs + workshops
62	Witter et al.	https://www.sciencedirect.com/science/article/pii/S0950423020302020	2020	not really mentioned - but procedural justice												1	1 EU Agric SSPs, stakeholder process
63	Harris et al.	https://doi.org/10.3390/en11235147	2020	inequality - procedural justice												1	1 stakeholder workshops
64	Andrijevic et al.	https://iopscience.iop.org/article/10.1088/1748-9326/ac1195/meta	2021	inequality			2	3	4		2a					5	
65	Pavanelli et al.	https://www.nature.com/articles/s41467-021-26592-3	2021	inequality			2	3	4		2a					5	
66	Harding et al.	https://www.nature.com/articles/s41467-019-13957-4	2020	inequality					4					3		5	
67	Huang et al.	https://doi.org/10.1016/j.elsevier.2019.119828	2020	inequality					4							1	
68	Jeckerdt et al.	https://www.sciencedirect.com/science/article/pii/S0950423020302020	2019	inequality aversion, discount rates					4		1					2	
69	Glanemann, Willner	https://doi.org/10.1038/s41467-019-13963-3	2020	inequality aversion, discount rates					4		1					2	
70	Kurmiawan and Managi	https://doi.org/10.1002/eq.1723	2018	inequality, poverty, wellbeing												5	
71	Benveniste et al.	https://iopscience.iop.org/article/10.1088/1748-9326/aab7d5	2018	inequalities/distribution					6					3		5	
72	Crespo Cuenca et al.																