JUST TRANSITION AND INDUSTRIAL DECARBONIZATION

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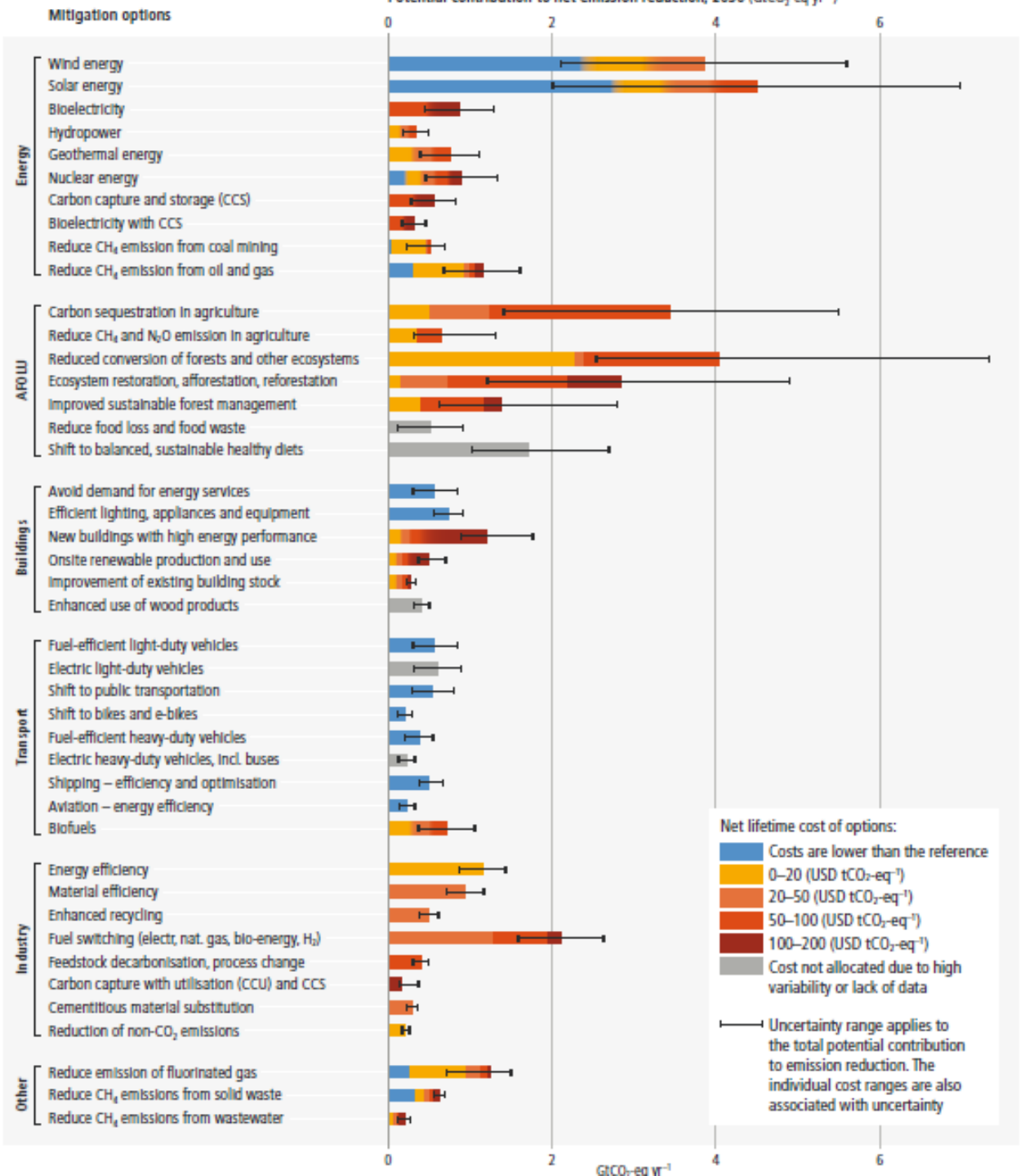
BOSTON UNIVERSITY

WE HAVE A FRUITFUL ARRAY OF POSSIBLE TECHNICAL OPTIONS TO LOW-CARBON TRANSITIONS



Source: IPCC. Climate Change 2022: Mitigation of Climate Change. Geneva, Intergovernmental Panel on Climate Change.

BUT THESE HAVE A HOST OF EQUITY AND JUSTICE IMPACTS

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Review

Who are the victims of low-carbon transitions? Towards a political ecology of climate change mitigation

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ABSTRACT

This study critically examines 20 years of geography and political ecology literature on the energy justice implications of climate change mitigation. Grounded in an expert guided literature review of 198 studies and their corresponding 332 case studies, it assesses the linkages between low carbon transitions—including renewable electricity, biofuel, nuclear power, smart grids, electric vehicles, and land use management—with degradation, dispossession and destruction. It draws on a framework that envisions the political ecology of low-carbon transitions as consisting of four distinct processes: enclosure (capture of land or resources), exclusion (unfair planning), encroachment (destruction of the environment), or entrenchment (worsening of inequality or vulnerability). The study vigorously interrogates how these elements play out by country and across countries, by type of mitigation option, by type of victim or affected group, by process, and by severity, e.g. from modern slavery to organized crime, from violence, murder and torture to the exacerbation of child prostitution or the destruction of pristine ecosystems. It also closely examines the locations, disciplinary affiliations, methods and spatial units of analysis employed by this corpus of research, with clear and compelling insights for future work in the space of geography, climate change, and energy transitions. It suggest five critical avenues for future research: greater inclusivity and diversity, rigor and comparative analysis, focus on mundane technologies and non-Western case studies, multi-scalar analysis, and focus on policy and recommendations. At times, low-carbon transitions and climate action can promote squalor over sustainability and leave angry communities, disgruntled workers, scorned business partners, and degraded landscapes in their wake. Nevertheless, ample opportunities exist to make a future low-carbon world more pluralistic, democratic, and just.

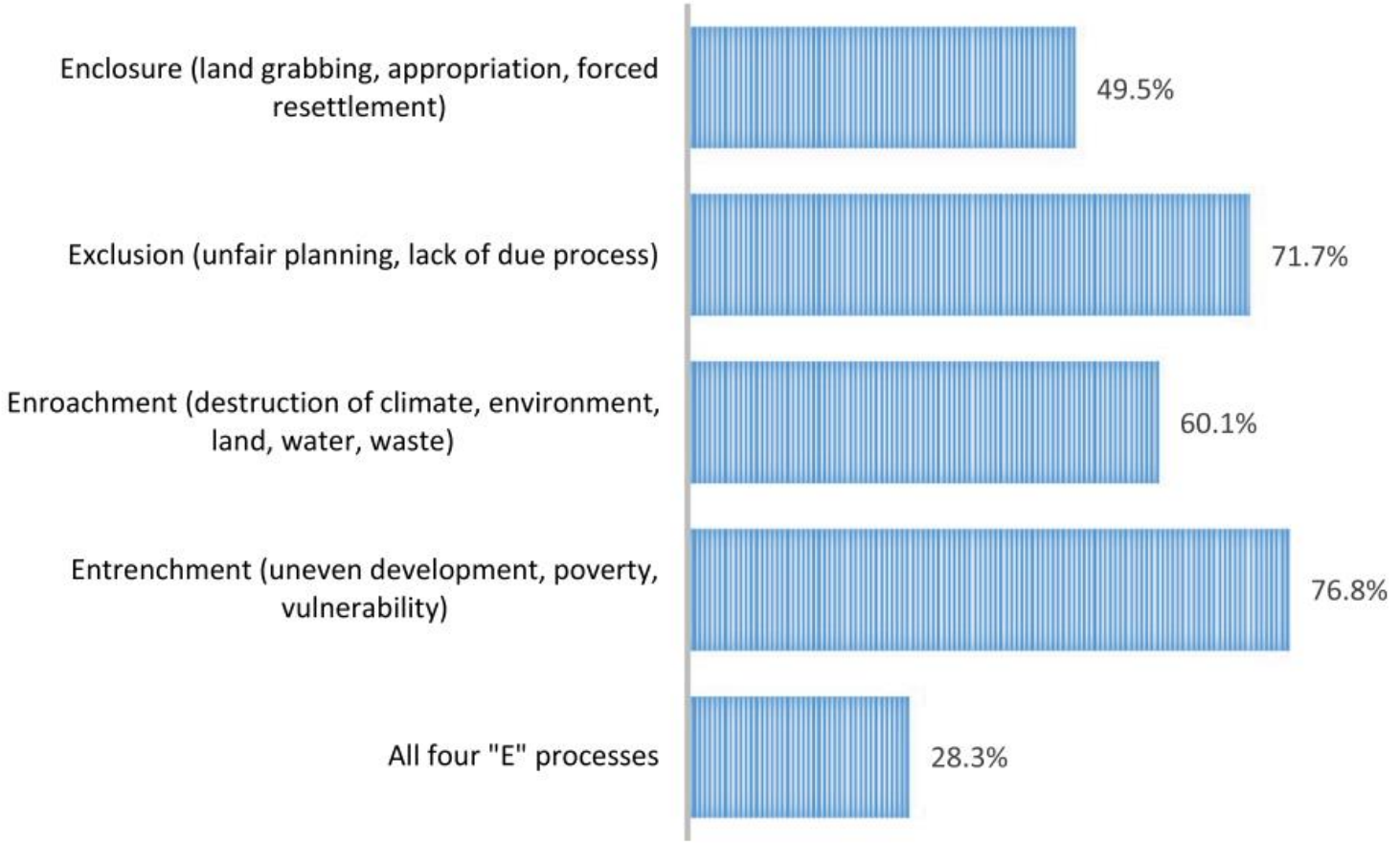
Table 3
Vulnerable groups mentioned in academic research on political ecology and climate mitigation (n = 198 studies).

Vulnerable group	No. of articles	% of articles
Non-human species	153	77.3%
Local communities, host communities, adopters or households	152	76.8%
Farmers, agriculturalists, or pastoralists	74	37.4%
Rural poor	73	36.9%
Occupational workers, wage laborers, or their unions	72	36.4%
Indigenous/aboriginal groups, ethnic/racial minorities, or members of a lower caste	71	35.9%
Future generations (e.g., nuclear waste)	71	35.9%
Fishers and water resource users	51	25.8%
Environmental groups, civil society, wildlife reservists, land managers or nature conservationists	38	19.2%
Urban poor	36	18.2%
Women (including gender roles)	27	13.6%
Recreationists, campers, hikers, forest users	27	13.6%
Banks, financiers, investors (including fossil fuel incumbents)	27	13.6%
Elderly	13	6.6%
Students	13	6.6%
Disabled individuals	12	6.1%
Forced labor or modern slaves	10	5.1%
Coastal homeowners (e.g. offshore wind energy)	10	5.1%
Prostitutes	10	5.1%
Children or youth (including health impacts)	5	2.5%
Local businesses (including tourism)	5	2.5%
Refugees (including displaced persons and forced migrants)	3	1.5%
Alcoholics	3	1.5%
Affluent suburban homeowners	1	0.5%

META-ANALYSIS OF 198 ARTICLE AND 332 DISTINCT CASE STUDIES

Case study technology for academic research on political ecology and climate mitigation (n = 198 studies).

Technology	No. of articles	% articles	% cases
Wind (including onshore, offshore)	97	49.0%	28.9%
Solar (including solar PV, CSP, solar thermal)	75	37.9%	22.3%
Hydro (including big dams, small and micro hydropower)	40	20.2%	11.9%
Bioenergy & waste (including refuse, biomass, residues, wood, crops)	20	10.1%	6.0%
Nuclear (including uranium mining and processing)	19	9.6%	5.7%
Biofuel (including ethanol, biodiesel, Jatropha, palm oil)	17	8.6%	5.1%
Land (including biochar, forest management, soil, smart agriculture, mining)	17	8.6%	5.1%
Housing (including energy efficiency, heating, retrofits)	15	7.6%	4.5%
Electric mobility (including EVs and PHEVs)	12	6.1%	3.6%
Smart grids (including smart meters and homes)	8	4.0%	2.4%
Geothermal (including conventional and advanced)	6	3.0%	1.8%
Mundane (e.g., bikes, cookstoves, light bulbs)	4	2.0%	1.2%
Hydrogen (including fuel cells)	2	1.0%	0.6%
Energy transport nodes (including T&D for electricity, biofuel pipelines)	2	1.0%	0.6%
Clean coal (including CCS and CCUS)	1	0.5%	0.3%
Mobility (including congestion charging, ridesharing, MaaS)	1	0.5%	0.3%



Sovacool, BK. “Who are the victims of low-carbon transitions? Towards a political ecology of climate change mitigation,” *Energy Research & Social Science* 73 (March, 2021), 101916, pp. 1-16.

Table 4
Indigenous peoples and ethnic communities marginalized or displaced by climate mitigation efforts.

Reference(s)	Technology/ies	Particular group(s) negatively effected
Avila [98], Lawrence [124]	Wind energy	Sami herding community in Sweden
Avila [98]	Wind energy	Zapoteco and Huave coastal and agricultural communities in Mexico
Avila [98]	Wind energy	Traditional fisheries and pastoralists in India
Avila [98]	Wind energy	Adivasis forestland users in India
Avila [98], Rignall [125]	Wind energy, solar energy	Saharaui contested territories and other indigenous groups in Morocco
Avila [98]	Wind energy	Lenca communities in Honduras
Avila [98], Calzadilla and Mauger [92]	Wind energy	Turkana, Randile and Borana communities in Kenya, especially ranchers and cattle stewards
Avila [98]	Wind energy	Traditional fisheries in Brazil
Avila [98]	Wind energy	Quilombola communities in Brazil
Avila [98],Carruthers and Rodriguez [86], Gerber [88], Kelly [126], Sánchez De Jaegher [127]	Wind energy, hydropower, forestry, tree plantations	Mapuche communities and Mapuche-Williche indigenous leaders in Chile
Avila [98]	Wind energy	Wayuu communities in Colombia
Avila [98]	Wind energy	Koyna Sanctuary traditional pastoralists in India
Avila-Calero [128], Calzadilla and Mauger [92],Dunlap [129], Dunlap [130], Dunlap [131], Howe and Boyer [132], Siamanta and Dunlap [133], Sovacool et al. [17], Zárate-Toledo et al. [134]	Wind energy	Indigenous peoples of the Isthmus of Tehuantepec in Mexico
Barandiarán [135], Revette [136]	Electric vehicles, smart grids, renewable energy storage (lithium for batteries)	Indigenous communities living near lithium mines and salt flats in Bolivia's Uyuni
Barandiarán [135]	Electric vehicles, smart grids, renewable energy storage (lithium for batteries)	Indigenous communities living near lithium mines and salt flats in Chile's Atacama
Bednar et al. [137], Reames [138], Reames et al. [139]	Energy efficiency, heating, lighting	African Americans in urban Michigan
Bednar et al. [137], Reames [138]	Energy efficiency, heating	Hisdpanics in urban Michigan
Bonds and Downey [105], Sovacool and Bulan [84]	Biofuel (palm oil), hydropower	Erosion of land tenure of the Penan, Kayan, Kenyah, Kajang, and Ukit groups in Malaysia
Bonds and Downey [105],	Biofuel (palm oil)	5 million indigenous people displaced by palm oil development in Indonesia
Borras and Franco [83]	Climate smart agriculture	Indigenous peoples and ethnic minorities in Myanmar
Borras and Franco [83], Poffenberger [140]	Climate smart agriculture, forestry, land use	Indigenous peoples and forest dependent minorities in Cambodia
Borras et al. [141], Fortin and Richardson [142], Leach et al. [143], Lohmann [91]	Biofuel (ethanol), land use (biochar)	Dispossessed indigenous peoples in the Amazon
Brady and Monani [121], Mulvaney [144], Powell [145]	Wind energy, solar energy	American Indian tribal lands and Native American tribes
Brannstrom et al. [146]	Wind energy	Territories of indigenous peoples and traditional communities in Brazil
Cram [147],Cram [148]	Nuclear power (waste)	Yakama Nation, the Nez Perce Tribe, and the Confederated Tribes of the Umatilla Indian Reservation in the United States

Table 4 (*continued*)

Reference(s)	Technology/ies	Particular group(s) negatively effected
Dolter and Boucher [151]	Solar energy	First Nations and Indigenous Peoples in Saskatchewan Canada
Dunlap [85], Dunlap [107], Dunlap [152], Pasqualetti [153], Sovacool et al. [30], Sovacool et al. [17]	Wind energy	Indigenous peoples of Juchitán de Zaragoza in Oaxaca Mexico
Dunlap [154], Dunlap [155]	Wind energy	Zapotec Indigenous community in Mexico
Fairhead et al. [80], German et al. [78], Leach et al. [143], Lohmann [91],Mirumachi et al. [26], Newell and Bumpus [156], Sikor and Lund [157], Stock and Birkenholtz [158]	Biofuel, climate smart agriculture, forestry, land use (biochar), carbon funds, solar energy (solar parks)	Global indigenous communities and ethnic groups affected by land grabbing or appropriation of resources
Finley-Brook and Thomas [159]	Hydropower	Naso and Ngobe indigenous territories in western Panama
Furnaro [160]	Renewable energy (broadly)	Indigenous communities in Chile
Gerber [88]	Bioenergy (tree plantations)	Dayak communities in Borneo
Gerber [88]	Bioenergy (tree plantations)	Tupinikim, Guarani and Pataxó communities in Brazil
Gerber [88]	Bioenergy (tree plantations)	Maisin communities in Papua New Guinea
Graetz [161], Marsh and Green [162]	Nuclear power (uranium mining, nuclear waste)	Aboriginal Australians and Torres Strait Islander "First Peoples" in Australia
Hommes et al. [163]	Hydropower	Ethnic minorities and indigenous peoples in Turkey
Islar et al. [164]	Solar energy, wind energy, hydropower	Dalits (often viewed as the lowest social caste) and indigenous people in Nepal
Martínez and Castillo [165]	Hydropower	Peasant, indigenous, and Afro-Colombian rural communities
Newell and Mulvaney [166]	Solar energy, wind energy, smart grids, electric vehicles	Trade unions and indigenous peoples movements
Richards and Lyons [167]	Bioenergy, land use, forestry (plantation forests)	Indigenous and subsistence farmers in Uganda
Scott and Smith [168]	Wind energy, solar energy	Six Nations communities in Canada
Siciliano et al. [108], Sovacool and Bulan [84]	Hydropower	Orang Ulu peoples and indigenous peoples from the upper Balui River, including some semi-nomads in Sarawak, Malaysia
Sovacool et al. [30]	Biofuel	Indigenous communities such as the Dene, Cree, and Metis in Canada

Table 4 (*continued*)

Reference(s)	Technology/ies	Particular group(s) negatively effected
	(waste streams)	in Ghana
Sovacool et al. [94]	Electric vehicles, smart grids, renewable energy storage (cobalt for batteries)	Discrimination against ethnic minorities in Democratic Republic of the Congo
Stock and Birkenholtz [158], Yenneti and Day [169], Yenneti and Day [170], Yenneti et al. [171]	Solar energy (solar parks)	Indigenous minorities or those of a lower caste in Gujarat India
Sunter et al. [172]	Solar energy (rooftop PV)	African Americans neighborhoods in the United States
Sunter et al. [172]	Solar energy (rooftop PV)	Hispanic neighborhoods in the United States
Temper [173]	Tree plantations (pine and eucalyptus), biofuel (sugarcane plantations)	Farmers and indigenous groups in Uganda
Temper [173]	Biofuel (Jatropha)	Indigenous groups and pastoralists in Ghana
Temper [173]	Biofuel (ethanol)	Indigenous groups and traditional communities in Senegal
Temper [173]	Biofuel, forestry, land use	Mukaya Diaspora in Juba in South Sudan
Temper [173]	Biofuel (ethanol)	Indigenous groups, traditional communities, and landless peasants in Mozambique
Temper [173]	Biofuel (palm oil)	Indigenous groups in southwest Cameroon
Temper [173]	Forestry, land use	Indigenous groups in Rio Negro Argentina
Temper [173]	Forestry, land use	Indigenous groups and communities in San Martin Peru
Velasco [174]	Hydropower	Emberá Katıo indigenous community
Walker et al. [175]	Hydropower	Munduruku people in the Tapajo's River Valley

EQUITY AND JUST TRANSITION IN THE IPCC

- **Just Transition. "**A set of principles, processes and practices that aim to ensure that no people, workers, places, sectors, countries or regions are left behind in the transition from a high-carbon to a low-carbon economy."
- "It stresses the need for targeted and proactive measures from governments, agencies, and authorities to ensure that any negative social, environmental or economic impacts of economy-wide transitions are minimised, whilst benefits are maximised for those disproportionally affected."
- "Key principles of just transitions include: respect and dignity for vulnerable groups; fairness in energy access and use, social dialogue and democratic consultation with relevant stakeholders; the creation of decent jobs; social protection; and rights at work."
- "Just transitions could include fairness in energy, land use and climate planning and decision-making processes; economic diversification based on low-carbon investments; realistic training/retraining programs that lead to decent work; gender specific policies that promote equitable outcomes; the fostering of international cooperation and coordinated multilateral actions; and the eradication of poverty."
- "Lastly, just transitions may embody the redressing of past harms and perceived injustices."

Pathak, M, R. Slade, P.R. Shukla, J. Skea, R. Pichs-Madruga, D. Ürge-Vorsatz, BK Sovacool et al. "Technical Summary." In: Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [P.R. Shukla, J. Skea, R. Slade, A. Al Khourdajie, R. van Diemen, D. McCollum, M. Pathak, S. Some, P. Vyas, R. Fradera, M. Belkacemi, A. Hasija, G. Lisboa, S. Luz, J. Malley, (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA. doi: 10.1017/9781009157926.002

JUST TRANSITIONS FRAMEWORKS

Table 1
Summary of three literatures on socially just or equitable sociotechnical transitions.

Literature	Disciplinary groundings	Predominant focus	Common unit of analysis	Key concepts	Illustrative studies
Energy and environmental justice	Philosophy, law, ethics, moral studies, environmental studies	What is morally just or right	Tenets of justice or principles	Procedure, recognition, distribution, cosmopolitanism	[19,21, 35–39]
Equity and sustainability transitions	Transition studies, innovation studies, business and management, evolutionary economics, science and technology studies	Who wins and who loses from transitions processes or outcomes	Sociotechnical system	Niches, regimes, and landscapes, transitions pathways	[40–42]
Participation and energy democracy	Energy studies, climate studies, sociology, political science	Ownership of and engagement in energy supply	Ownership share, production share, decision-making rights	Governance and participation processes	[43–51]

Source: Authors

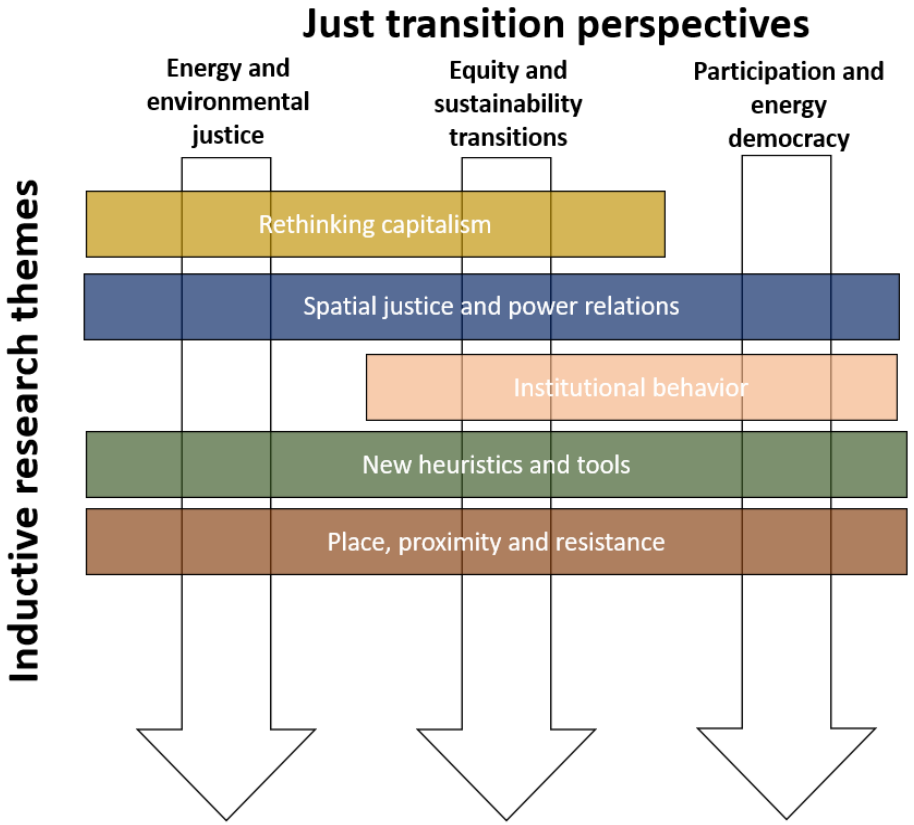
Table 2
Fits and misfits in three perspectives on just transitions.

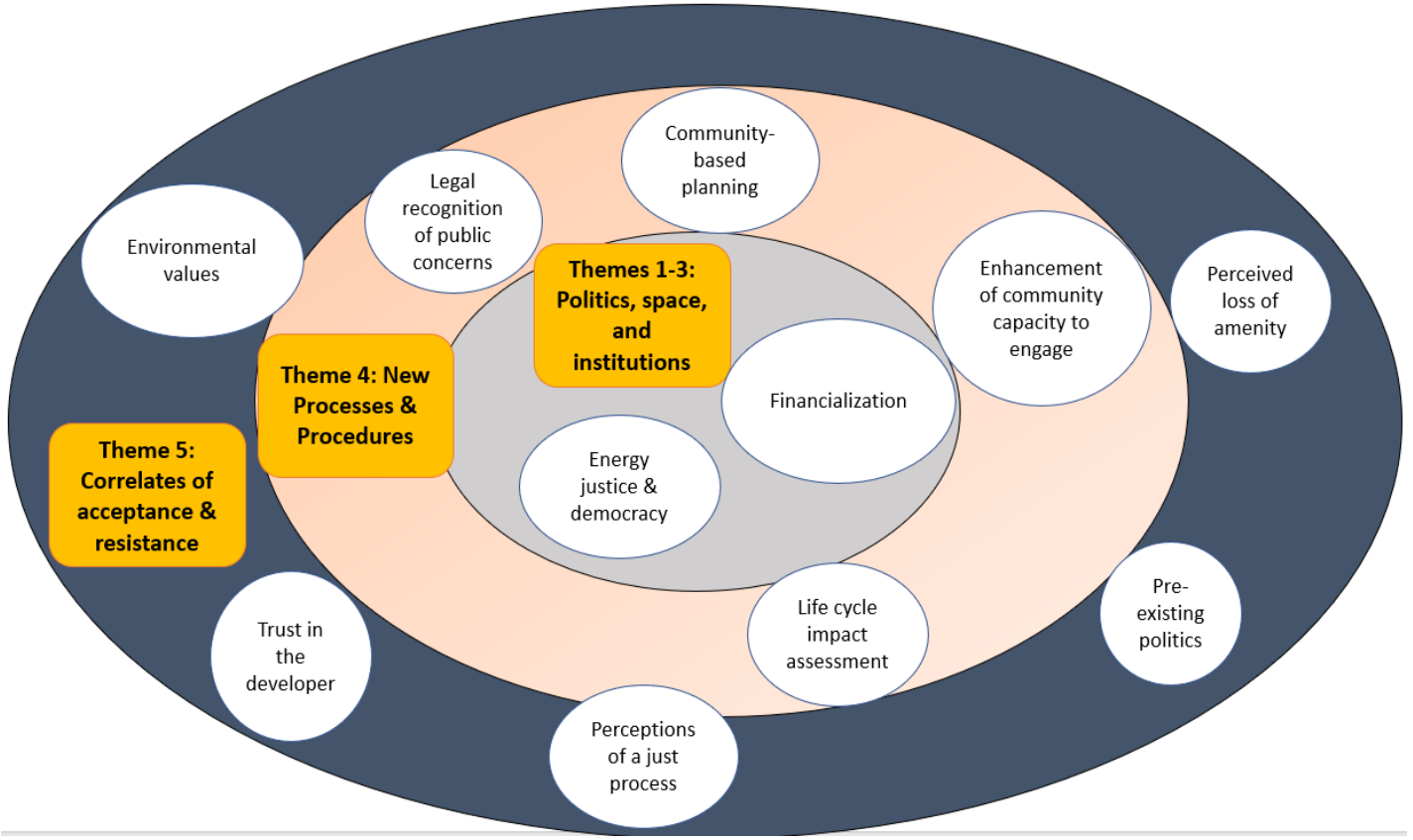
Community	In focus	Out of focus	Fits (strong explanatory power)	Misfits (weak explanatory power)
Energy and environmental justice	Disruption of ethical values, culture, or health	Early patterns of innovation and design	Impacts on communities or the environment, mobilizations in support of energy justice goals	Less visible impacts that "embodied" or "hidden" in practices, design, or waste flows
Equity and sustainability transitions	Distributional consequences of sociotechnical change	Processes of sociotechnical embedding	Social acceptance and objection of technology	Long term technological trajectories
Participation and energy democracy	Engagement and ownership processes	Large scale sociotechnical processes	Social acceptance and objection of energy infrastructure	Wider dynamics of sociotechnical change

Source: Authors, based on their collective insights drawn from the review process Each of the "fits" and "misfits" are drawn from the theoretical strengths and weaknesses elaborated on in Sections 3 and 4.

Source: Upham, P, BK Sovacool, and B Ghosh. "Just transitions for industrial decarbonization: A framework for innovation, participation, and justice," *Renewable & Sustainable Energy Reviews* 167 (October, 2022), 112699, pp. 1-16.

JUST TRANSITIONS FRAMEWORKS





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JUST TRANSITIONS FRAMEWORKS

UK Parliament POST

POSTnote 706

By Henry Grub,
Jonathan Wentworth
16 October 2023

What is a just transition for environmental targets?

Table 2: Different scales of just transitions

LARGEST SCALE	
International	"Common but differentiated responsibilities" between richer vs poorer nations, or compensation to undertake climate adaptation[60–63]
National	Inequalities between a country's regions, how a country's Nationally Determined Contribution (NDC) to reducing carbon emissions may affect some parts of the country more than others[64,65]
Regions & Cities	Exacerbation of inequalities within areas, phasing away from major regional industries or consequences of major changes for rural and urban areas (such as heavy industry or agriculture)[14,64]
Communities	Consideration of whether transitions increase deprivation, or how communities, or socio-economic groups, can benefit[66]
Individuals & Households	Job security, household income and household dependents, value for consumers or human rights
SMALLEST SCALE	

Table 1: Types of transition-related justice

What? – the factors of society	
Environmental justice	Fair distribution of environmental risks and hazards between societal groups[30], such as flood (PN 647) or wildfire risk (PN 603), sewage discharge hazards or exposure to air pollution (PN 691)
Climate justice	Fair compensation and help for countries that have contributed least to climate change, but will suffer greater consequences[31]
Social justice	Broad concept relating to fair distribution of opportunities and privileges within a society (local, national or global)
How? – the functioning of society	
Procedural justice	Fair and transparent decision-making institutions and processes, enabling people to fairly participate and raise objections or protestations[32,33]
Substantive/distributional justice	Fair allocation of specific costs and benefits, and fairly sharing rights, resources and responsibilities between societal groups[25,34]
Retributive or corrective justice	Those causing harm to the environment are punished (for example, fined) and/or compensate for (environmental or climate) harm done[19]
Recognition justice	Fairly accounting for the views and knowledge of marginalised groups (such as women or indigenous peoples)[35,36] or recognising where there is unfairness or harm done[37,38]
Epistemic justice	Ensuring marginalised groups that are affected by change do not have their knowledge and perspectives ignored, blocked or undermined[32,39]
Who? – the relationships between societies[d]	
Intergenerational justice	Ensuring resources and the environment are not degraded, so future generations are not unfairly disadvantaged[19,40,41]
Intragenerational justice	Ensuring fairness between present-day people in communities, groups, and internationally[42,43]
Interspecies justice	Considers a fair relationship between humans and nature, and the right of nature to exist for itself, not for humans, whilst respecting the contribution of nature to society's functioning[44–46]

“JUST TRANSITION” CAN ALSO BE INDICATED BY ACTIONS AND POLICIES

(a) Just Transition commissions, task forces and dialogues

Australia: La Trobe Valley Authority

Canada: Task Force on Just Transition for Canadian Coal Power Workers

China: Mine closure provisions in the 13th Five Year Plan for Coal Industry Development, 2016–2020

Costa Rica: National Decarbonisation Plan 2018–2050

Czech Republic: Czech Coal Commission

Finland: Working group to ensure a fair and just transition and acceptability of climate measures

France: 2018 Ecological Transition Contracts programme

Germany: German Commission on Growth, Structural Change and Employment (German Coal Commission)

Ghana: The National Dialogue on Decent Work and 'Just Transition' to a Sustainable Economy and Society

Greece: National Just Transition Fund for Lignite areas

New Zealand: 'Just Transitions Unit' within the ministry of Business, Innovation and Employment (MBIE)

Poland: The 1998 Mining Social Package and Special Privileges for the mining communes

Scotland: Scottish Just Transition Commission

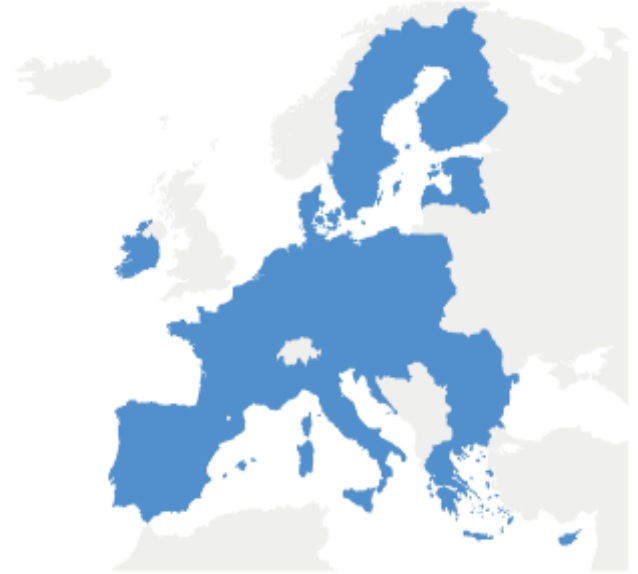
Slovakia: Transformation Action Plan of coal region Upper Nitra

South Africa: National Planning Just Transition Dialogue + the One Million Climate Jobs Campaign

Spain: Framework Agreement for a Just Transition on Coal Mining and Sustainable Development

United States: Partnership for Opportunity and Workforce and Economic Revitalisation Plan (POWER+)

(b) European Green Deal – Just Transitions Fund



(c) Platform for coal regions in transition

Lecocq, F., H. Winkler, J.P. Daka, S. Fu, J.S. Gerber, S. Kartha, V. Krey, H. Lofgren, T. Masui, R. Mathur, J. Portugal-Pereira, B. K. Sovacool, M. V. Vilariño, N. Zhou. “Mitigation and development pathways in the near- to mid-term. In Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [P.R. Shukla, J. Skea, R. Slade, A. Al Khourdajie, R. van Diemen, D. McCollum, M. Pathak, S. Some, P. Vyas, R. Fradera, M. Belkacemi, A. Hasija, G. Lisboa, S. Luz, J. Malley, (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA. doi: 10.1017/9781009157926.006

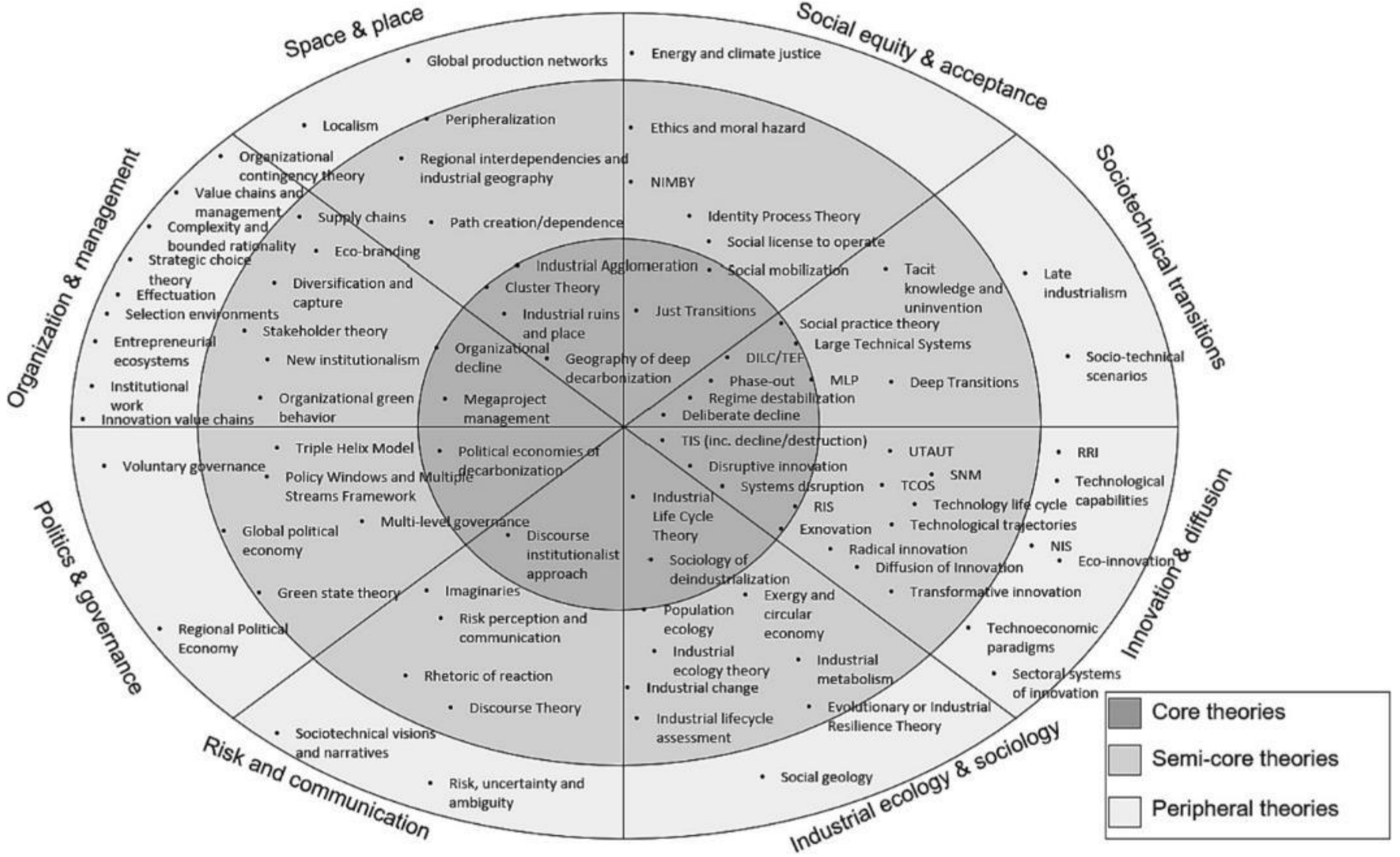
“JUST TRANSITION” CAN ALSO BE INDICATED BY SOCIAL MOVEMENTS

Box 4.6 | Selected Organisations and Movements Supporting a Just Transition

- 350.org (global)
- Asian Pacific Forum on Women, Law and Development (Asia Pacific)
- Blue Green Alliance (USA)
- Beyond Coal campaign (USA)
- Central Única dos Trabalhadores (Brazil)
- Climate Action Network (global)
- Climate Justice Alliance (USA)
- Cooperation Jackson (USA)
- Dejusticia (Colombia)
- Deutscher Gewerkschaftsbund (German Trade Union Confederation, Germany)
- DiEM25 (pan-European)
- European Union
- European Trade Union Confederation (EU)
- Grassroots Global Justice (USA)
- IndustriALL Global Union (global)
- Indigenous Environmental Network (USA)
- International Labor Organization (global)
- ITUC-affiliated Just Transition Centre (global)
- ITUC-affiliated Just Transition Centre (Americas)
- Just Transition Alliance (USA)
- Just Transition Centre (global)
- Just Transition Fund (USA)
- Kentuckians for the Commonwealth (USA)
- Labor Network for Sustainability (USA)
- Latrobe Valley Authority (Australia)
- Movement Generation (USA)
- NAACP (USA)
- National Union of Mineworkers of South Africa (South Africa)
- Pan African Climate Justice Alliance (Africa)
- Post Petroleum Transitions Roundtable (Mesa de Transición Post Petrolera) (Argentina)
- Powering Past Coal Alliance (global)
- Right to the city alliance (USA)
- Sierra Club (USA)
- Sunrise Movement (USA)
- The Leap Manifesto (Canada)
- The Trade Unions for Energy Democracy Initiative (global)
- Trade Union Confederation of the Americas (TUCA)
- Transition Towns Movement (UK)
- Women’s Environment and Development Organization (global)

Lecocq, F., H. Winkler, J.P. Daka, S. Fu, J.S. Gerber, S. Kartha, V. Krey, H. Lofgren, T. Masui, R. Mathur, J. Portugal-Pereira, B. K. Sovacool, M. V. Vilariño, N. Zhou. “Mitigation and development pathways in the near- to mid-term. In Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [P.R. Shukla, J. Skea, R. Slade, A. Al Khourdajie, R. van Diemen, D. McCollum, M. Pathak, S. Some, P. Vyas, R. Fradera, M. Belkacemi, A. Hasija, G. Lisboa, S. Luz, J. Malley, (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA. doi: 10.1017/9781009157926.006

And Just Transitions is only one of 88 (!) theories to ID



Sovacool, BK, M Iskandarova, and JF Hall. "Industrializing theories: Conceptual frameworks and typologies for industrial sociotechnical change in a low-carbon future," *Energy Research & Social Science* 97 (March, 2023), 102954, pp. 1-36.

And each of these theories sees ID as something different:

Sovacool, BK, M Iskandarova, and JF Hall. "Industrializing theories: Conceptual frameworks and typologies for industrial sociotechnical change in a low-carbon future," *Energy Research & Social Science* 97 (March, 2023), 102954, pp. 1-36.

Family of perspectives	Core theories	Common elements or focus	How industrial decarbonization is defined	What or who shapes it?	To what effect?
Theories of sociotechnical transitions	Triple Embeddedness Framework, Deliberate Decline, Regime Destabilization Framework, Technology Phase Out, Multi-Level Perspective on Transitions, Social Practice Theory, Large Technical Systems	Sociotechnical system, path dependence, lock-in	A process of disruption, decline, or phase-out to established unsustainable sectors or technologies, and the emergence of new alternatives	A coevolutionary competition between new entrants (or niches) and incumbents (or regimes)	To transform or reorient sociotechnical systems towards carbon-neutral platforms
Theories of innovation and diffusion	Technological Innovation Systems, Disruptive Innovation, Systems Disruption, Regional Innovation Systems, Exnovation	Technology, processes or products	A contest between old innovations and new ones, embedded in innovation systems	Inventors, entrepreneurs, innovators and firms, policymakers, consumers	Incorporation of new technology, to develop and sustain more sustainable and lower-carbon industries
Theories of social equity and acceptance	Just Transition, Social Mobilization	Social protection, justice	A socioeconomic phenomenon that threatens to harm communities hosting industrial clusters or infrastructure	Social attitudes, legitimacy, resistance	To ensure a fairer, more accountable, more equitable low-carbon future
Theories of space place and geography	Geographies of Deep Decarbonization, Industrial ruins and place attachment, Cluster Theory, Industrial Agglomeration	Territorial embeddedness, marginal and peripheral spaces	A relational and multi-scalar effort to generate new low-carbon regimes across different places, spaces, and scales	Structural spatial, economic, and political patterns	To promote less uneven development within and across countries
Theories of organizational behavior and management	Megaproject Management, Organizational Decline	Projects, organizations, business models	A strategic and tactical challenge facing managers and firms	Corporate managers, employees, innovators, stakeholder networks	To manage tensions and take advantage of opportunities
Theories of politics and governance	Political Economies of Decarbonization	Collective action dilemmas, leakage	A political act that affects the market power of incumbents	Transnational elites, state and non-state institutions	To better account for winners and losers within decarbonization pathways
Theories of risk and communication	Discourse Institutionalist Approach	Construction of risk, rhetoric, ideas formation	A risk and opportunity facing particular communities	Institutionalization, disruption of power systems and ideologies, competing discourses	Successful challenging of dominant climate imaginary and the value system behind it
Theories of industrial ecology and sociology	Industry Life Cycle Theory, Sociology of Deindustrialization, Population Ecology Theory	Communities of place, organization	An evolutionary struggle for fitness among a population of organizations and various selection pressures	Organizational strategy and industrial metabolism	To achieve a dominant design or thrive in a low-carbon society

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Leading the post-industrial revolution? Policy windows, issue linkage and decarbonization dynamics in the UK's net-zero strategy (2010–2022)

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Table 2. Key industrial decarbonization policies in the UK by category

Policy category	Name	Description	Year implemented or revised
Climate change	Climate Change Act	Commits the UK government by law to reducing greenhouse gas emissions by at least 100% of 1990 levels (net zero) by 2050	2008, updated in 2019
Carbon pricing	UK Emissions Trading Scheme	Came into force on January 1, 2021 to replace the UK's participation in the EU ETS, which was established in 2005.	2021
	Climate Change Levy	An environmental tax charged on the energy that businesses use, intended to encourage businesses to be more energy efficient in how they operate, as well as helping to reduce their overall emissions	2016, but updated annually
Competitiveness support	UK ETS Free Allowances	Provides £1.05 billion in allowances to targeted industrial clusters	2019
	Financial relief for energy-intensive industries	Gives £470 million per year in reduced electricity costs	2012–2021
	Climate Change Agreements	A voluntary scheme that encourages businesses in a wide range of industrial sectors with energy-intensive processes, such as chemicals, paper and ceramics to agricultural businesses such as intensive pig and poultry farming to invest in energy efficiency measures	2015–2021
Demonstration Funding	Energy Innovation Program	Offers £505 million in support that aims to accelerate the commercialization of innovative clean energy technologies and processes	2016
	Net Zero Innovation Program	Provides £1 billion in support for low-carbon technology such as offshore wind, nuclear advanced modular reactors (supported through the aligned Advanced Nuclear Fund), energy storage and flexibility, bioenergy, hydrogen, direct air capture and greenhouse gas removal, industrial fuel switching, and CCUS	2021
	Transforming Foundation Industries	Disburses £66 million to the cement, metals, glass, paper, ceramics, and chemicals industries to make them more internationally competitive	2020
	Industrial Energy Transformation Fund	Budgets £315 million to help businesses with high energy use to cut their energy bills and carbon emissions through investing in energy efficiency and low carbon technologies	2019
	Industrial Decarbonization Challenge	Offers £170 million to the six largest industrial clusters in their mission to decarbonize at scale, laying the foundation for developing at least one low-carbon industrial cluster by 2030 and the world's first net-zero industrial cluster by 2040	2019
Deployment Funding	CCUS/Hydrogen Business Models	Provides revenue support to hydrogen producers and CCUS facilities, making up the operating cost gap between low-carbon and higher-carbon fuels via 15 year contracts	2022
	Renewable Heat Incentive	A scheme that provides £684 million per year aiming to encourage uptake of renewable heat technologies amongst householders, communities and businesses through financial incentives, and increase heating coming from renewable sources	2014 (closing in 2022)
	Net Zero Hydrogen Fund	Provides up to £240 million to support the development and deployment of new low carbon hydrogen production to de-risk investment and reduce lifetime costs	2022
	Clean Steel Fund	Pledges £250 million to support the UK steel sector to transition to lower carbon iron and steel production	2019
	Industrial Heat Recovery Support	Offers £18 million to encourage and support investment in heat recovery technologies	2018 (closing in 2022)
Infrastructure	CCUS Infrastructure Fund	Allocates £1 billion for CCUS transport and storage networks, coupling to bioenergy via BECCS, and capital expenditure for CCUS-enabled "blue" hydrogen projects	2020
	Heat Network Improvement Program	Provides £320 million to increase the number of heat networks being built, deliver carbon savings, and create the conditions necessary for a sustainable heat network market	2018
Demand-side and behavior	First Demand-Side Policy Introduced	Supports demand-side measures such as the introduction of product standards, labelling schemes or procurement policies	2021

Source: Authors, modified from HM Government (2021a). CCUS = carbon capture utilization and storage. BECCS = bioenergy with carbon capture and storage. UK = United Kingdom. ETS = emissions trading scheme.

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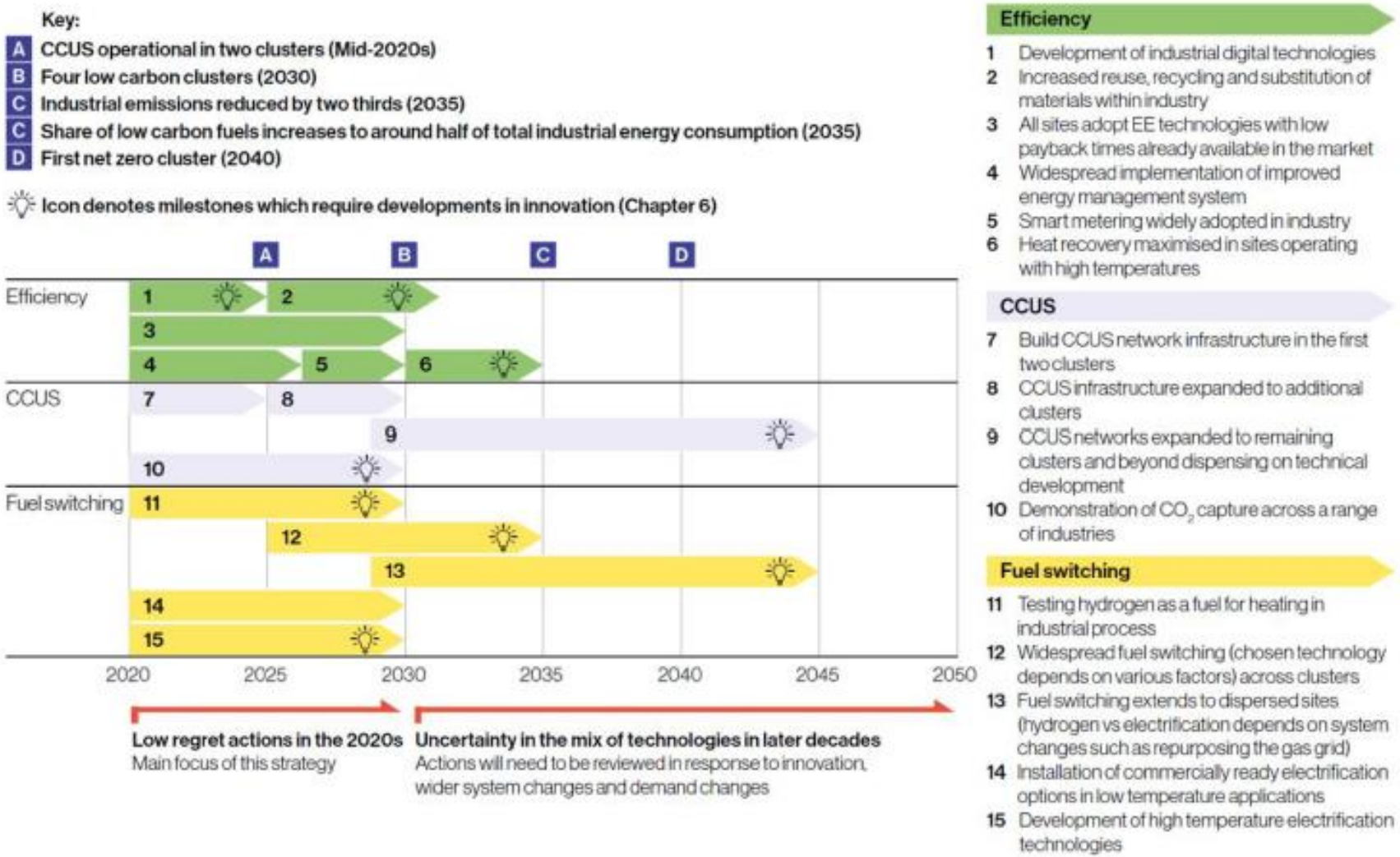

Figure 4. An overview of industrial decarbonization technology pathways in the UK, 2020–2050. *Source*: HM Government (2021a). Note CCUS = carbon capture utilization and storage. EE = energy efficiency.