Supplementary Information

Representation gap for transition factors from social sciences in energy and emissions modeling

Authors: Sanni Kunnas[1]* and Evelina Trutnevyte[1]

[1] Renewable Energy Systems, Section of Earth and Environmental Sciences, Institute for Environmental Sciences (ISE), University of Geneva, Boulevard Carl Vogt 66, CH-1211 Geneva 4, Switzerland

*corresponding author (sanni.kunnas@unige.ch)

Table of Contents

A1. Transition factors from social science theories

A1.1 Theory review

We reviewed a total of 43 theories, frameworks, and models from social sciences to identify relevant transition factors for the literature review. The full list is presented in Table A1. The selection was based on two criteria: First, the theory had to originate from or be extensively applied in a major (sub)discipline of social sciences. Second, the theory had to offer a causal explanation for some form of observable outcome, action, or behavior, thus showcasing a certain level of explanatory and logical power, testability, and generalizability of its key claims. Theories from philosophy, history, and religion, and other humanities were largely excluded, because of their strong descriptive, normative, or interpretative character that focuses more on values and meanings rather than causal outcomes. The practical search for theories was initiated by consulting multi- and interdisciplinary (hand)books that target the bridging of social with natural sciences[1,2]. The search was complemented by several theory reviews, such as on the linking of models with socio-technical transition theories by Hirt et al. (2020)[3], on integrating behavioral drivers into energy system models by Galster et al. (2025)[4], as well as the meta-theoretical framework on energy transitions by Cherp et al. (2018)[5], and on human behavior by Eyster et al. (2022)[6], and many more[7–9]. The decision to stop the search was made based on a subjective judgment, when the authors deemed that the resulting list of transition factors was complete and balanced between the different disciplines.

Table A1: List of theories selected from social sciences, including their disciplinary origins and a summary of the core principles that explains change, behavior, or outcomes.

Theory	Discipline	Summary of core principle
Advocacy coalition framework	Political science	Incremental change happens through policy learning within or across subsystems (cognitive process), whereas radical change necessitates an external event that reframes beliefs and normative views (non-cognitive process)[10].
Affective intelligence theory	Political science; psychology	Preferences and routine behavior are reinforced when outcomes align with expectations (enthusiasm), whereas perceived threat triggers deliberative thinking (anxiety) and may lead to new behaviors[11].
Bounded rationality	Economics; Psychology	Individual decision-making takes place within cognitive and situational constraints, resulting in outcomes that deviate from rational utility-maximization[12,13].
Cognitive dissonance theory	Psychology	Inconsistency between beliefs and behaviors lead to psychological discomfort which individuals want to resolve by changing behaviors or rationalizing contrary facts[14].
Collective action theory	Political science; Economics	Normative, social and institutional pressure enable rational individuals to overcome free-riding and to cooperate collectively[15].
Comparative political economy theory	Political science	Political and economic institutions impact how markets perform and how states decide to regulate markets. These domestic variations influence economic growth, societal performance and policy choices[16].
Constructivism	Political science	State interest and identity are not fixed, but socially and dynamically constructed by collective beliefs, institutions and perceptions about reality[17].
Critical mass theory	Sociology	The uptake of new behaviors and opinions spread rapidly via social movements and network effects, once certain thresholds are reached[18].
Cultural cognition theory	Political science; Psychology	Information is processed, accepted and dismissed based on their alignment and consistency with group identity[19].
Cultural theory of risk	Anthropology; Political science	Cultural assumptions towards authority, responsibility, risk, and social organization (hierarchical, egalitarian, communitarian, individualist) impact institutional behavior and perceptions of appropriate institutional action[20].

Deterrence theory	Economics; Political science; Criminology	Anticipated consequences of non-compliance and the possibility of punishment steer individual behavior[21].
Diffusion of innovations theory	Sociology ; interdisciplinary transition studies	Perceived attributes of technologies (relative advantage, compatibility, ease of understanding, trialability, observability of results) and communication channels of adopters impact how new innovations diffuse[22].
Discourse theory	Political science; Sociology	Discursive power and framing by political actors and media influence how the public perceives the credibility, legitimacy and desirability of policy issues[23].
Dual-process theory	Psychology	Individual information processing and decision-making are guided by heuristics and biases (fast cognitive system) and by analytical thinking (slow cognitive system)[24].
Evolutionary economics	Economics	Economic outcomes are the results of path-dependent and adaptive systems that retain successful practices similar to natural selection rather than governed by strictly rational or pre-determined processes[25].
Game theory	Economics; Political science; Sociology	Individual decision-making is impacted by own intentions and the anticipated decisions of others which impacts expected payoffs[26].
Habit discontinuity theory	Psychology	Behavioral changes in routines occur when strong intentions to change coincide with external disruptions that allow a reassessment of personal behavior[27].
Institutional economics	Economics; Political science	Institutional constraints and capacities shape economic behavior by reducing transaction costs and providing certainty that encourage cooperation[28].
Institutional liberalism	Political science	Mutual benefits, shared norms and institutions can help states cooperate in international politics by mitigation information asymmetry and reducing transaction costs[29].
Institutional trust theory	Sociology; political science; Psychology	Institutional trust or whether governments are deemed trustworthy develops dynamically and influences the perceived legitimacy and acceptance of decision-making[30].
Justice theory	Political science; Sociology	Perceived distributional, procedural, and recognitional justice in decision-making processes impacts the legitimacy, the acceptance of and compliance with outcomes[31].

Multi-level perspective theories (incl. strategic niche management)	Interdisciplinary transition studies; Sociology	System transitions are triggered by landscape pressures and competitive niches that destabilize regimes and over time lead to change on the macro level[32,33]
Multiple streams framework	Political science	Policy change occurs when problem definitions, proposed solutions and public convictions align and open up a window of opportunity for new agenda-setting[34].
Neo-institutional theory	Sociology; Political science	Coercive, mimetic and normative pressure and the desire to meet external expectations shape the behavior of organizations, which can lead to isomorphism and symbolic compliance[35]
Organizational learning theory	Sociology; Psychology; Economics	A change in external circumstances can push organizations from incremental learning with fixed objectives (single-loop) to a radical re-evaluation of goals and principles (double-loop)[36].
Path dependency & historical institutionalism	Political science; Sociology; Economics	Early policy choices shape future trajectories by creating self-reinforcing feedback mechanisms, which lead to institutional lock-in. Change only occurs at periods of disruption (critical junctures) that open windows of opportunity[37,38].
Principal-agent theory	Economics; Political science	Incentives, sanctions and contracts prevent self-interested "Agents" to deviate from the interests of "Principals" by mitigating information asymmetry and monitoring actions[39].
Prospect theory	Psychology	Individual decision-making is more sensitive towards potential losses than potential gains, with individuals being more risk-averse in securing benefits and more risk-seeking in avoiding sure losses[40].
Public choice theory	Economics; Political science	Political rent-seeking makes self-interested decision-makers susceptible to powerful third-party interests and hence often fail to serve public interests[41].
Punctuated equilibrium theory	Political science; Sociology	Punctuations of stability triggered by external shocks or reframing of issues lead to deeper change in otherwise inert political and institutional systems[42].
Rational choice theory	Economics; Political science; Sociology	Individuals are rational and have perfect information to take decisions according to what optimizes or maximizes their utility and self-interest[43].
Realism	Political science	National self-interest and relative power gains are the key drivers of how states act in international politics[44]. High information asymmetry and the absence of a global authority make cross-border cooperation difficult.

Risk perception theory	Psychology	Risk-perception is driven by subjective and affective factors (trust, familiarity, controllability) rather than purely by analytical evaluation (statistical)[45].
Social capital theory	Sociology	Interpersonal interactions create norms of reciprocity, trust, and shared values which promote social capital that help advance individual and collective goals[46].
Social identity theory	Psychology; Sociology	Individual behavior is shaped by "in-group" and "out-group" identities that help simplify social complexities and interpret reality in order to ensure alignment in values, behaviors, and norms with other group members[47].
Social movement theory	Sociology; Political science	The construction of shared identities, values and grievances, and the ability to mobilize resources build bottom-up collective actions for policy change at moments of political opportunity[48].
Social network theory	Sociology	The intensity (weak vs. strong) and network position (centrality, bridging) of social relationships and peer pressure determine group behavior and opportunities of influence[49].
Social practice theory	Sociology; Anthropology	Individual behavioral change arises from sustained practices that shift materials (technology), competences (skills), and meanings (norms) of habits and routines[50].
State capacity theory	Political science	States' capacity to influence society and markets at large is defined by its administrative, political and fiscal powers[51].
Technological innovation systems theory	Interdisciplinary transition studies	Knowledge development, market formation and resource mobilization impact how technologies diffuse within systems[52].
Technology acceptance model	Psychology	Perceived usefulness and ease of use positively influence willingness to adopt, use and accept new technologies[53].
Theory of planned behavior (incl. theory of reasoned action)	Psychology	Attitudes, subjective norms, and perceived behavioral control impact an individual's intention to change behavior and the ultimate behavioral change[54].
Value-belief-norm theory (incl. norm-activation-theory)	Psychology	Values, beliefs, norms, awareness of consequences and the ascription of personal responsibility to consequences impact pro-environmental behavior[55,56].

A1.2. Definition of transition factors

Transition factors are defined as cause-effect mechanisms from social science theories that explain intentional behavior of an actor (e.g., individual purchase of electric vehicle) or unintentional outcomes from the interaction between systems, actors, and external factors (e.g., technological lock-in). Transition factors were distinguished based on their explanatory logic ("why") rather than the outcome they predict ("what") to account for theoretical overlaps across social sciences (e.g., rational choice as the core logic for explaining individual or institutional behavior). After an initial screening round of all theories, transition factors with large similarities in their explanatory logic and analytical scope were merged to avoid duplicates, even if they originated from different theories. The final 24 transition factors are listed in Table A2. Their assigned type is defined and showed in Table A3.

Table A2: List of 24 transition factors in alphabetical order, including their definition and theory support.

Transition factor	Definition	Theory support
Attitudes, perceptions, preferences	Attitudes, perceptions and preferences shape intentions and behavior, because they act as subjective filters and evaluative judgments (e.g., good/bad) for whether outcomes are seen as desirable, accepted, or supported[53,54].	*Psychology* (Theory of planned behavior; Technology acceptance model; Justice theories) *Transition studies* (Diffusion of innovation) *Political science* (Affective intelligence theory)
Bounded rationality	Bounded rationality shapes preference formation and decision-making, because individuals operate under cognitive, situational, and informational constraints that limit the ability to process information in an analytical-rational way and lead to systematic perception biases, satisficing, and heuristics[12,13].	*Psychology (*Bounded rationality; Prospect theory; Dual-Process theory) *Political science* (Affective intelligence theory)
Critical junctures	External shocks at critical junctures alter the perceptions of problems and solutions, because they disrupt established and stable trajectories and thereby create temporary windows of opportunity to adopt new ideas and behaviors[32,37,42].	*Political science* (Historical institutionalism; Punctuated equilibrium theory; Advocacy coalition framework; Multiple streams framework; Affective intelligence theory) *Sociology* (Social movement theory; Social practice theory; Organizational learning theory) *Transition studies* (Multi-Level-Perspective) *Economics (*Evolutionary economics) *Psychology* (Habit discontinuity theory)
Discursive power	Discursive power shapes public perceptions and attitudes, because it emphasizes or downplays the legitimacy of political and societal issues and guides the interpretation with the help of framing tools[23].	*Sociology* (Discourse theory) *Political science* (Constructivism)
Emotions	Emotions and affect shape individual judgments, decision-making, and willingness to change behavior, because they operate as automatic information signals and act as motivational drivers to resolve internal inconsistencies[11,14,24].	*Psychology (*Dual-Process theory; Risk perception theory; Cognitive dissonance theory) *Political science* (Affective intelligence theory)
Expected costs and benefits	Expected costs and benefits shape the strategic and rational decision-making and behavior of individual and collective actors, because it determines whether actors anticipate gaining more or losing more from a particular action[26,43].	*Economics* (Rational choice theory; Game theory; Deterrence theory)

Geopolitical power	Geopolitical power shapes the willingness to cooperate, because states prioritize relative power gains, national interests, and strategic independence over common goals in an anarchic system without strong global authority[44].	*Political science* (Realism)
Incremental learning	Incremental learning gradually improves decision-making and performance over time, because accumulated experiences from past failures and successes help inform and guide current choices and strategies[10,25,36].	*Sociology (*Organizational learning theory) *Economics (*Evolutionary economics) *Political science (*Advocacy coalition framework)
Institutional quality	The quality of institutional frameworks and governance, including capacities and barriers, shape the ability of states and authorities to coordinate, enforce, and monitor policies effectively because strong institutions limit opportunistic behavior among actors and promote efficiency[51,57].	*Political science* (Comparative political economy; State capacity theory; Collective action theory; Principal-Agent theory) *Economics* (Institutional economics)
Intentions	Intentions shape the likelihood of fulfilling a behavioral change, because they drive the willingness and effortfulness in trying to perform an action or behavior[27,54].	*Psychology* (Theory of planned behavior; Habit discontinuity theory)
Justice and fairness	Perceived procedural, distributional and recognitional justice enhances the acceptance of and compliance with policy outcomes, because it strengthens the perceived legitimacy, credibility, and fairness of decision-making processes[31].	*Sociology* (Institutional trust theory) *Psychology* (Justice theory)
Lobby power	The political and economic influence of interest groups shapes the speed, direction, and level of ambition for public policy, because they divert or delay policy measures by rent-seeking decision-makers[10,41].	*Political science* (Public choice theory; Advocacy coalition framework)
Path-dependency	Path-dependency impacts the speed and direction of political and economic decision-making, because it locks in early decisions that are reinforced through positive feedback and thereby make alternative paths more costly[37,38].	*Political science* (Path-dependency and historical institutionalism; Punctuated equilibrium theory) *Economics* (Evolutionary economics) *Transition studies* (Multi-Level-Perspective)
Political and social cohesion	Political and social cohesion shapes the capacity to implement policy objectives and the collective ability to act, because shared values, identities, and ideologies reduce internal opposition between individuals and groups and stabilize long-term decision-making[46,49,51].	*Political science* (Constructivism; Collective action theory) *Sociology* (Social capital theory; Social identity theory; Social movement theory)

Political economy	The political economy influences the speed and cost-efficiency of policy-making, because it determines the type of preferred instrument, degree of state control, and intervention in markets and production systems[16].	*Political science* (Comparative political economy; State capacity theory) *Economics* (Institutional economics)
Political regime and culture	The political regime and culture shape how policies are adopted and challenged, because they determine how political power is distributed within formal institutions and influence what type of authority and social organization is perceived as legitimate and desirable[20].	*Political science* (Comparative political economy; State capacity theory; Cultural theory of risk)
Risk and loss aversion	Risk preferences and loss aversion impact individual decision-making under uncertainty, because individuals tend to be more risk-seeking in avoiding sure losses and more risk-averse in attaining equivalent gains[40].	*Psychology (*Prospect theory; Dual-Process theory)
Social conformity	Social identity and subjective norms influence preference formation, behavior and compliance with policy, because individual or collective actors create external pressure to conform with the norms, values and expectations of social groups that they identify with or seek approval from[19,28,47].	*Sociology* (Social identity theory; Social network theory) *Political science* (Constructivism; Institutional liberalism; Collective action theory; Neo-institutional theory) *Psychology* (Theory of planned behavior; Cultural cognition theory)
Social movement capacity	The capacity to organize collective action shapes the long-term influence of social movements and the diffusion of innovations and behaviors, because a strong identity around shared values and the ability to mobilize both tangible and intangible resources helps to coordinate, grow, and persist over time[48].	*Sociology* (Social movement theory; Social capital theory) *Transition studies* (Technological innovation systems theory)
Social practices	Social practices impact the individual willingness and ability to adopt new behaviors, because routines and habits are deeply rooted in material infrastructures, social competences and cultural meanings[27,50].	*Sociology* (Social practice theory; Habit discontinuity theory) *Transition studies* (Multi-Level-Perspective theory)
Social resources	Social resources, including networks and social capital, enhance the diffusion of new ideas, behaviors, and innovations, because strong relationships improve the flow of information and strengthen peer influence[46,49].	*Sociology* (Social network theory; Social capital theory; Critical mass theory) *Transition studies* (Diffusion of innovations theory)

Social tipping points	Social tipping points shape the speed and patterns through which new ideas, behaviors, or innovations spread, because the quantitative or qualitative thresholds trigger non-linear responses or self-sustaining growth dynamics once a critical mass has been reached[18,48].	*Sociology* (Social movement theory; Critical mass theory)
Trust	Trust between individual and collective actors enhances the acceptance of and compliance with policy outcomes and the willingness to participate in collective actions, because it strengthens the legitimacy, credibility and perceived fairness of decision-making processes[30,45].	*Sociology (*Institutional trust theory; Social capital theory) *Psychology* (Justice theory; Risk perception theory)
Values, beliefs and norms	Values, beliefs and personal norms guide and motivate individual attitudes and behaviors, because they represent stable and fundamental principles that determine what individuals consider important and expect of themselves (internal pressure)[55,56].	*Psychology* (Theory of planned behavior; Value-Belief-Norm theory; Cognitive dissonance theory)

Table A3: Definition of types and examples of transition factors.

Type	Definition	Transition factors
Cognitive-motivational	Mechanisms related to how information is mentally processed, reasoned and perceived, and that impact the internal motivation and willingness to act[1].	Attitudes, perceptions, preferences; Bounded rationality; Emotions; Intentions; Risk and loss aversion.
Socio-normative	Mechanisms that relate to internal and external pressures of social and normative beliefs, expectations and identities[58].	Justice and fairness; Political and social cohesion; Social conformity; Social movement capacity; Social practices; Social resources; Social tipping points; Trust; Values, beliefs, norms.
Institutional-structural	Mechanisms that relate to formal rules, procedures and enforcement that are objectively embedded in institutional and systemic structures[5]	Critical junctures; Discursive power; Incremental power; Institutional learning; Institutional quality; Path-dependency; Political economy; Political regime and culture.
Strategic-rational	Mechanisms that relate to calculated or rational reasoning in relation to anticipated behavior, costs and benefits[43].	Expected costs and benefits; Geopolitical power; Lobby power.

A1.3 Qualitative coding categories for transition factors

To gain qualitative insights into literature that addressed transition factors, we evaluated the level, main actor, sector, resolution, geographic scope, economy, and research type for each relevant article. This information was collected during the Top100 ASReview and is based on the information available in the abstract, title, and keywords. Articles were only allocated to one tag based on what seemed to be the fit with the available information in the abstract. The exception to this rule were the groups of geographic scope and economy, for which several continents and economy types could be selected. For this reason, Table 3 in the main manuscript only indicates the share (%) of each subcategory against the total amount of mentions. For articles from the modeling literature, we also determined what type of strategy was used to integrate the transition factor into the model-based evidence. Here, we consulted the full text to be able to make a proper judgment, where necessary. The full definitions and examples of the qualitative coding categories can be found in Table A4.

Table A4: Definitions and examples for the qualitatively coding of relevant articles included in the evidence base of each transition factor.

Group	Tags	Definition and examples
Level	Macro	Analysis that captures systemic or structural processes, institutions or macro-economic contexts
	Meso	Analysis that captures intermediary processes between individuals and state, such as social movements or interest groups
	Micro	Analysis that captures individual processes, such as perceptions or preferences by consumers or households
	Other / n.a.	Other or information not available (e.g., purely theoretical)
Main actors	States and institutions	(Inter)national and institutional actors and structures that govern through formally codified rules, such as governments or policy
	System-level agents	Systems without centralized (or intentional) agency, but analyzed as integrated wholes, such as energy systems or technology sectors
	Economic actors	Individual and collective actors and organizations that engage in economic activity, such as companies or energy communities
	Organized groups	Collective actors with a formal or semi-formal character that are linked by a common purpose, such as social movements or media
	Individuals	Individuals with autonomous agency, such as households or citizens
	Other / n.a.	Other or information not available (e.g., purely theoretical)
Sector	Whole energy system	The analysis focuses on more than one sector or on entire energy systems
	Electricity	The analysis focuses on the electricity sector, including production, demand, transmission, and storage
	Transport	The analysis focuses on the transport sector, including personal mobility (cars, trains, aviation etc.) and freight (ships, aviation etc.)
	Buildings	The analysis focuses on the building sector, including heating and cooling services
	Industry & services	The analysis focuses on the industry and service sectors, including raw material processing and the public sector

	Other / n.a.	Other or information not available (e.g., purely theoretical)
Resolution	Global-continental	The analysis focuses on global systems or aggregated national systems across continents, such as the EU-27 or G7
	National	The analysis focuses on national systems and on single countries, such as Switzerland or the USA
	Sub-national	The analysis focuses on systems below the national level, such as federal states, cities or municipalities
	Other / n.a.	Other or information not available (e.g., purely theoretical)
Geography*	Europe and North America	All countries on the European continent, USA and Canada
	Asia and Oceania	All countries on the Asian continent and Oceania
	South and Central America	All countries on the South American and Central American continent
	Africa	All countries on the African continent
	Other / n.a.	Other or information not available (e.g., purely theoretical)
Economy*	High-income	High-income industrial and high-income industrializing economies
	Middle-income	Middle-income industrial and middle-income industrializing economies
	Low-income	Low-income economies
	Other / n.a.	Other or information not available (e.g., purely theoretical)
Research type	Quantitative empirical	The research applies empirical methods that primarily generate quantitative results, such as modelling or statistical analysis
	Qualitative empirical	The research applies empirical methods that primarily generate qualitative results, such as interviews or ethnography
	Conceptual theoretical	The research applies theoretical reasoning that primarily generates conceptual results, such as frameworks or literature reviews
	Other / n.a.	Other or information not available (e.g., purely theoretical)
Integration strategy**	Merging	Full endogenization of transition factors into model structure, e.g., parameterization or creation of new socio-technical models.
	Iterating	Translation of exogenous and qualitative narratives of transition factors into quantitative model assumptions, e.g., scenario analysis.
	Bridging	Post-modeling interpretation of model outcomes based on transition factor, e.g., qualitative discussion or quantitative indicator.
	Other / n.a.	Other or information not available
* Based on country and economy classification of UNIDO[59]. ** Based on classification by Hirt et al.[3] and Trutnevyte et al.[60]		

A2 Evaluation of relevance and technical feasibility

A2.1 Criteria definition

Table A5: Definition of evaluation criteria for relevance and feasibility. The evaluation results can be found in Table A6 and Table A7.

Criteria	Key question	Measurement
Increased model realism	Which model assumptions can potentially be improved by integrating the transition factor?	Descriptive categories based on qualitative judgement: **Technology adoption and use**: Assumptions that impact the individual adoption, use and diffusion of technologies, such as peer effects or social practices. **Socio-political environment**: Assumptions that impact the socio-political feasibility of technologies and policies, such as social acceptance or political support. **Policy implementation:** Assumptions that impact how policy is implemented or enforced, such as delays or cost-efficiency. **Technology cost:** Assumptions that impact the cost of technologies, such as learning curves or trade. **External constraints:** Assumptions that impact external dependencies and constraints, such as trade relations, technology availability or cross-border cooperation.
Policy leverage	Can policymakers influence or steer the transition factor with available policy tools and levers?	Descriptive categories based on qualitative judgement: **Low** = Low possibility to influence transition factor **Medium** = Medium possibility to influence transition factor **High** = High possibility to influence transition factor
Quantitative evidence availability	What is the availability of quantitative research on the transition factor in the social scientific literature?	Share of quantitative research articles from the evidence base (Top100 ASReview) of the social scientific literature: **Low**: 0-25% of quantitative articles in evidence base **Medium**: 26-75% of quantitative articles in evidence base **High** : 76-100% of quantitative articles in evidence base
Data availability	What is the availability of open access databases suitable for integrating the transition factor?	Descriptive categories based on qualitative judgement: **Low**: Data is not or poorly available and must be collected **Medium**: Data is partially available **High**: Data is largely available
Integration strategy	Which integration strategies were found in the modeling literature evidence base?	Integration strategies found in the modeling literature: **Merging:** Transition factor is endogenously modelled or parameterized into the structure of models. **Iterating:** Transition factor is used to exogenously inform quantitative assumptions integrated into models.

		Bridging: Transition factor is used to interpret outcomes post-modeling.

A2.2 Technical feasibility criteria: Empirical research, data availability, and integration examples

Table A6: Description of the empirical research and data availability in the social scientific literature on energy transition and integration examples according to merging, iterating, and bridging strategies in the modeling literature. The description of the empirical research is based on the top 100 results from the ASReview and is not fully representative. Examples of databases were collected from the review and from an independent search.

Transition factor (index score)	Social scientific literature: Empirical research and data availability*	Modeling literature: Integration examples
Emotions (1.0)	**Empirical research:** Emotional and affective responses to technologies[61], policies[62], or disruptive events, such as wars[63] or accidents[64], have been frequently studied, often in the context of social acceptance and public attitudes from the individual's perspective. Data mostly stem from surveys[61], media analysis[65] or sentiment analysis, partly with language models[66]. **Examples of databases**: No examples found. **Data availability:** Low	No empirical examples found.
Social movement capacity (0.99)	Rich literature on collective action initiatives, in particular the role, emergence and operation of energy communities[67] or grassroot movement[68]. The ability to organize is rarely the main angle, but partly addressed by looking into leadership roles, such as mayors[69], or what drives mobilization, such as crowdfunding[70] or collective resistance[71]. Data is primarily of qualitative nature[68,72] and elicited from specific case studies, but with some mixed-method examples using surveys or qualitative comparative analysis[69,73].	No empirical examples found.

	Examples of databases: Global Protest Tracker[74], NAVCO Nonviolent and Violent Campaigns[75], Mass mobilization data project[76]. **Data availability:** Low	
Intentions (0.98)	Large pool of empirical studies on the intention to purchase, invest in, or adopt renewable technologies, such as solar PV[77], electric vehicles[78], or renewable heating systems[79], as well as the intention to use energy-efficient household appliances[80]. Intentions usually studied from a micro level (individuals), and more rarely from the meso/macro perspective, such as project developers[81]. Structural equation modelling frequently applied, in particular when using behavioral frameworks like Theory of Planned Behavior or Acceptance Models[78,82]. Data foremostly comes from surveys[81,83]. **Examples of databases**: No examples found. **Data availability:** Low.	No empirical examples found.
Trust (0.98)	Trust (or the lack thereof) is primarily examined from the perspective of citizens or the public towards governments and official [84]or energy project developers[85]. It is frequently included as a variable in determining technology acceptance, in particular towards emerging technologies[86], or transition policies[87]. Data comes mostly from surveys[87] and frequently used for structural equation modelling as part of different acceptance models and frameworks[88]. Some examples also include more mixed-methods and qualitative data, such as from deliberative workshops[86]. **Examples of databases**: World Values Survey[89], OECD Trust Survey Data in Public Institutions[90],	No empirical examples found.

	(Euro/Asia/Afro/Americas) Barometer[91–94], European Social Survey[95]. **Data availability**: Medium	
Social resources (0.97)	The literature is focused on the effects of social networks, social ties and social capital, such as influence of neighbors and family[96] or word-of-mouth learning among farmers[97] and mostly targets technology uptake[98] or participation in renewable energy communities[99]. Survey data is primarily used to examine quantitative effects, e.g., with regression analysis[96]. Qualitative case studies using interviews, site visits and documentary research also exist, such as comparing the social ties of latecomers[100] or the role of social capital and community in technology adoption[101]. **Examples of databases:** OECD How's Life? (Social connections & Civic Engagement)[102], Eurostat Quality of Life (Social interactions)[103] **Data availability:** Low	**Merging:** The endogenous inclusion of "Public Willingness to Participate" (driven by social capital) into a system dynamics energy-emissions model that amplifies or dampens the diffusion and implementation of policy measures for energy and emission savings[104].
Lobby power (0.97)	The influence of lobby groups and advocacy coalitions on political decision-making and regulation has frequently been examined, including examples where it has acted as a barrier[105] as well as a force of action for the energy transition[106]. The Advocacy Coalition Frameworks is frequently used as conceptual support for interpreting power dynamics[107]. Data mostly comes from case studies that apply comparative or qualitative methods, including interviews[108] or media and policy documents[105]. **Examples of databases:** LobbyFacts.eu[109], Transparency International Integrity Hub[110], BridgeGap database on	**Merging**: The modeling of pro-fossil and pro-renewable lobby influence on policy formation that explores how policy volatility impacts investment (flows) into electricity generation technologies[all records WoS]. **Bridging**: The feasibility of an energy simulation with high shares of PV and seasonal storage in Finland is discussed based on the results of a survey that examines the vested interests and lobby efforts against high shares of renewables[113].

	corruption measures[111], Lobbying Disclosure Act (US-only)[112] **Data availability**: Medium 2/9/26 4:59:00 PM	
Social conformity (0.95)	A lot of empirical studies look into when, how, and why social influence or peer pressure drives the uptake of different technologies, such as solar PV[114] or energy-efficient household appliances[115], and participation in renewable energy communities[116]. Some also look into investors' susceptibility to normative pressure[117]. Data is primarily collected from surveys[118], using frameworks such as Theory of Planned Behavior and structural equation modelling to evaluate effects[119,120]. **Examples of databases:** No examples found. **Data availability:** Low	**Merging**: The inclusion of social influence / social learning on vehicle adoption behavior in global integrated assessment models, based on heterogeneous adopter groups whose likelihood to purchase an alternative fuel vehicle increases with diffusion (modelled as changes in risk premiums)[121,122].
Social tipping points (0.92)	A large part of the literature examines threshold and non-linear effects on macro-level indicators of the energy transition, such as the impact of regulation[123], resource rents[124], geopolitical risks[125] or green finance[126] on renewable energy consumption. Some examples study reinforcing loops and transitional tipping points between technologies, policies, users, finance, and infrastructure[127] but are less common. Studies that focus on tipping points in energy-related behavior are primarily conceptual[128]. Macro-scale panel data used in regression analyses is readily available and frequently used[125,126]. Local case studies rely on qualitative data collection methods[127]. **Examples of databases:** No database available on social tipping points, but macro-scale panel data can be used to study the phenomenon. See literature. **Data availability:** Medium	No empirical examples found.

Institutional quality (0.89)	Research on institutional barriers and capacities look into the moderating or hampering effect of mostly political and financial macro-indicators on driving renewable deployment or consumption, such as corruption levels[129], financial development[130] or regulatory quality[131], often in developing regions[132]. Quantitative and global panel data are readily available, often relying on composite macro indicators[129]. For some national and sub-national case studies, qualitative data is also available[133]. **Examples of databases:** Corruption Perceptions Index[134] re, World Wide Governance Indicators[135], Fragile States Index[136], BridgeGap database on corruption measures (Transparency, Enforcement)[111], Global Financial Development[137], Rule of Law Index[138] **Data availability**: High	**Merging** The modeling of transaction costs and other barriers as indirect costs and including them into the cost optimization of energy models[139]. **Iterating** Emission reductions in models scenarios are limited by the potential of technologies which is determined based on assumptions of the institutional quality in different regions (e.g., expertise, regulatory capacity) to handle the technology development and or associated proliferation risks[140,141]. Scenario analysis with/without regulatory barriers that are implemented in models as availability of transmission capacity and degree of sector coupling and flexibility[142].
Political and social cohesion (0.88)	Existing studies focus on the impact of political stability on innovation[143] and investments in renewable energy[144]. The empirical evidence addresses more often political than social indicators, such as party support[145] and ideological factors[146]. Country-scale panel data or public surveys are frequently used to build regression models and study direct or indirect effects between variables[147], with a few cases using mixed-method analyses[143]. **Examples of databases:** National Elections Across Democracy and Autocracy (NELDA)[148], Democratic Electoral Systems Around the World[149], World Wide Governance Indicators (Political stability)[135], Social Cohesion Radar (Asia)[150] **Data availability:** High 2/9/26 4:59:00 PM	**Merging:** Political instability of energy technology supply chains is included as a function into a multi-objective energy system optimization model[151]. **Iterating:** Construction of different decarbonization scenarios with granular policy mixes that are considered to be politically feasible under different federal political contexts[152]. **Bridging**: An energy supply risk metrics that considers political instability is applied post-modeling to the results of an energy system model to evaluate which sectors are mostly affected by disruption risk[153].

Social practices (0.88)	Social practices and habits have been extensively studied, especially for households and individuals. Examples include laundry[154], indoor heating[155], or cooking[156] and are generally considered rigid and difficult to change. Most studies show a mix of quantitative-qualitative methods and results[156], where surveys are often accompanied with some deliberative element, like living labs[154], ethnographies[157] or interviews[158]. **Examples of databases:** No examples found. **Data availability:** Low	**Merging** Energy demand is shaped and determined by heterogeneous household practices from the adoption of digital technologies in an agent-based model and the least-cost pathway for the energy system is then calculated with a soft-linked energy system model. Similar examples from the transport sector exist too[159]. **Iterating** Scenario analysis that detail how energy services will be provided in the future, based on building and vehicle parameters related to use behavior and habits/practices, such as per-capita floor space[160]. Using energy demand estimations from econometric models or household surveys that considers occupant behavior and habits in energy scenarios[161].
Values, beliefs, norms (0.87)	There is a rich empirical literature that establishes different value bases[162–164], beliefs about climate change, technologies and the economy[165], and pro-environmental personal norms[166] as determinants for the willingness to adopt, buy or deploy renewable energy, often with the help of the Theory of Planned Behavior and Value-Belief-Norm frameworks. Data primarily come from surveys and is used for establishing quantitative relationships between variables, such as in structural equation modeling[162–164]. **Examples of databases:** World Values Survey[89], (Euro/Asia/Afro/Americas)barometer[91–94]. **Data availability:** Medium 2/9/26 4:59:00 PM	**Merging** Integrating agents' beliefs about economic growth, climate sensitivity, cost of climate damages, and technological progress into a climate-economic models linked with agent-based models that complements the optimization module[167]. Inclusion of heterogeneous and quantified attitudes and norms towards solar PV from a household survey into an agent-based model that then calculates the diffusion and adoption of solar PV vs a reference scenario[168]. **Iterating** Boundary constraints in mitigation scenarios were defined and evaluated in terms of feasibility and acceptability by sectoral stakeholders in order to reflect normative considerations and value judgments in model structure and results[167].2/9/26 4:59:00 PM
Risk and loss aversion (0.85)	Prominent applications of risk-related research address financial risk preferences for renewable energy[169], impact	**Merging**

	of risk perceptions on public acceptance and willingness to adopt[170], and the technical modeling of uncertain outcomes in electricity grid or dispatch models with operators that exhibit different risk preferences and risk management strategies[171,172]. Empirical data on risk preferences largely stem from surveys or choice experiments[173], whereas risk modelling is frequently done based on purely theoretical assumptions about risk-averse or risk-seeking strategies[174]. **Examples of databases**: Global Findex Database[175], World Risk Poll[176] **Data availability:** Low	The inclusion of risk aversion and risk preferences in energy system modelling through modelling discounted payback period of renewable heating technologies[177] or specific decision criteria that characterize risk attitudes of a decision-maker towards climate uncertainty[178] or previous technologies[179]. The modelling of risk-averse and risk-tolerant consumers that are differently influenced by other users in their own adoption decision[121]. **Bridging:** Discussion of the potential of linking energy and climate system models with modular agent-based models that represent the investment decisions of power companies with different risk attitudes[180]. The analysis of energy system model results based on a composite indicator for security of supply that considers the risk-averse level of the decision maker[181].
Political regime and culture (0.78)	A considerable number of articles examine the "democracy-climate-energy" nexus, such as the impact of democratic governance on energy consumption[182] and policy[183]. There are also many qualitative case studies that give insights on the role of governance structures and division of political power[184,185]. Readily available data includes global panel data and composite indicators about democracy and governance, often with a focus on the developing world and applied in regression models[186,187]. **Examples of databases:** World Wide Governance Indicators[135], The Polity5 Project[188], Variety of Democracy and Party Identity[189], Freedom in the World[190], Global State of Democracy Index[191].	**Iterating** Scenario analysis that examines the effectiveness of different combinations of national/centralized and subnational/ decentralized policies for electric vehicle adoption[192], emission control[193], and electricity sector[194].

	Data availability: High	
Bounded rationality (0.75)	Literature includes examples that simulate decision-making of heterogeneous actors under bounded rationality or information asymmetry, e.g., in the transport [195], electricity sector[196] or energy markets[197]. Prospect theory and game theory models[198] are frequently used as a frameworks. The empirical data on various cognitive biases and limitations in individuals are collected with surveys, but rather limited[199,200]. **Examples of databases**: No examples found. **Data availability:** Low	**Merging** Applying limited or myopic foresight for the energy system model to reflect the imperfect or partial knowledge of technological and socio-political developments from the perspective of the decision-maker[201,202]. Modelling of near-optimal alternatives to reflect the heterogeneity and partly conflicting interests of decision-makers that deviate from purely rational (cost-optimal) objectives[151,203]. Coupling of optimization models with agent-based models to introduce agents with biased perceptions and decision-making for improving estimations of needed capacity[195,204].
Critical junctures (0.45)	The empirical literature on critical junctures is diverse and contains studies on how financial crises[205] and pandemics[206] have impacted the energy supply and demand[207], technology deployment[208] or energy policies[209]. The implications of wars and conflicts have also been readily studied[210,211]. Some articles also look into the effects of disruptive policies on energy systems[212]. Quantitative data for the analysis of macroeconomic data is readily available[206,207]. Much of the research has a qualitative nature and is based on interviews or comparative and descriptive case studies[213,214]. **Examples of databases**: ACLED Conflict Index[215], Crisis Watch Conflict Tracker[216], International Disaster Database[217], Economic Policy Uncertainty Index[218], World Development Indicators[219] **Data availability**: High	**Merging** Quantification of the supply risk of clean energy technologies and the endogenous minimization of that supply risk based on a multi-objective energy optimization model[151]. Stochastically modelled random shocks to labor productivity, capital, stocks and energy efficiency[220]. The impacts of disruptive events are randomly modelled with the proxy of failed generators and the duration of their removal[221]. **Iterating** The disruptive risk related to the introduction of different policies is analyzed in scenarios with varying degrees of nuclear and biomass[212]. Scenario analysis of the impact of COVID-19 recovery package on the low-carbon transformation of the energy system[222], energy shocks[223], disruptive trade policies[224] , weather-induced disruptions to the electricity system[225]. **Bridging**

		The evaluation of price fluctuations and supply disruption likelihood of clean energy materials based on their raw material cost, geopolitical and market aspects for future inclusion in energy system models[226].
Attitudes, perceptions, preferences (0.43)	Social and public acceptance towards technologies, often emerging and contested ones such as nuclear[227], carbon capture storage[228] and energy policies[229] have been widely examined, with most studies taking the individual or citizen perspective when examining preferences and perceptions. Attitudes, perceptions and preferences are both used to predict acceptance[230], and acceptance is also used as a variable to predict intentions and willingness to pay[231]. The evidence base is heavily dominated by quantitative studies, mostly relying on representative surveys[232], as well as some mixed-methods approaches , including interviews[233] and deliberative workshops[86]. **Examples of databases:** World Values Survey[89], (Euro/Asia/Afro/Americas)barometer[91–94]. **Data availability:** Medium	**Merging** Incorporating heterogeneous preferences of households[234] or social acceptance[235] into cost-optimal energy models. Representing heterogeneous consumer preferences and technology purchase decisions through the inclusion of disutility or disamenity costs[236,237]. The non-financial technology preferences of heterogeneous decision-makers are taken into account by linking agent-based models with energy system models to accurately represent investment decisions in the residential sector[238] or vehicle choices[121,159]. **Iterating** The sectoral energy demand of transport is exogenously calculated based on user preferences in vehicle choice and is then merged with energy system model to calculate cost optimal energy supply infrastructures[239]. Scenario analysis to illustrate the system effects and costs of low social acceptance[240,241]. Evaluation of system costs in scenarios showcasing different spatial distribution strategies of renewable energy as a proxy for public acceptance[242,243] . Scenarios are qualitatively described and designed[244], including the use of Shared Socioeconomic Pathways[245]. **Bridging:** Combining energy system models with multi-criteria assessment that elicit stakeholder/user preferences to examine and rank socially acceptable solutions for local energy systems and decarbonization

		pathways[246,247]. Stakeholders evaluate energy system scenarios post-modeling to explore their own economic and social preferences[248].
Geopolitical power (0.38)	The literature addressing elements of geopolitical risk or international power dynamics frequently view it as a barrier to the energy transition, studying its impacts on renewable energy consumption[249], investments[250] or deployment. The use of indicators such as import dependency[251,252] or other energy security metrics[253] is common. Several contributions also look at the material supply chains of renewable energy technologies, such as lithium dependency[254]. The examined research was primarily of quantitative nature, with global panel data on trade[251], geopolitical risk and threats[255] or natural resources[256] readily available. **Examples of databases:** ACLED Conflict Index[215], Crisis Watch Conflict Tracker[216], SIPRI databases (Military Expenditure Database, Arms Transfers Database etc.)[257], Global Peace Index[258], Global Energy Monitor Trackers[259] **Data availability:** High	**Merging** The analysis of optimal subsidy policy design by stochastically modelling geopolitical conflicts that disrupt energy supply[260]. Future energy markets are examined with an agent-based model that endogenously models investment decisions, including the impact of a 25% trade tariff by China on the US[261]. **Iterating** The design of stylized geopolitical futures, e.g., with the help of democracy indices as a proxy for future conflicts between nations based on their political conviction, and subsequent scenario analysis of how they impact maritime trade and energy demand levels[262]. Scenario analysis of endogenous vs exogenous technological progress to represent a reduction in global cooperation[263], import constraints[224,264] and how wars and conflict impact the energy system, notably the war in Ukraine[265,266]. **Bridging** Model outcomes (e.g., decarbonization scenarios) are evaluated post-modeling based on energy security metrics, such as import dependency[267], resilience metrics[268], supply risk[153] and other[269].
Discursive power (0.36)	Many studies examine the (public) discourse around controversial technologies[270,271] as well as polarized energy transition decisions such as phase-outs/ins[272]. Study experiments also include social acceptance from the	**Iterating** The use of low energy demand scenarios in energy system analysis that focus on energy reduction rather than on technology substitution[279,280] or any other

	perspective of different frames, storylines and narratives[273] such as justice or cost-efficiency[274]. Qualitative studies dominate over quantitative ones in the examined literature, such as media or discourse analysis techniques[275]. Data tends to be tailor-made and collected from specific local or national case studies. **Examples of databases:** Directory of open access books[276], Digital discourse database[277], ParlaMint database on parliamentary corpora[278] **Data availability:** Medium	scenarios or narratives that emphasize certain framings of problems and solutions[281,282]. **Bridging** Discussion of the dominating narratives and portrayal of technologies by analyzing model scenarios that limit global warming to 2 degrees[283,284]. Qualitative discussion of how model results challenge existing narratives around hydrogen deployment[285].
Justice and fairness (0.31)	The energy justice literature comprises of a significant amount of conceptual analyses that speak about distributional, recognition, and procedural fairness and equality[286], also addressing aspects of energy democracy[287] or the role and visions of political and civil agents[288]. Empirical studies focus on distributional impacts, often as an output of energy transitions[289]. Quantitative analyses are mostly grounded on survey data[290] or spatial databases on e.g., energy resources or technology adoption[291], from which distributional aspects and socioeconomic impacts can be studied[292]. **Examples of databases:** World Values Survey[89], (Euro/Asia/Afro/Americas)barometer[91–94], Corruption Perceptions Index[134], Rule of Law Index[138] **Data availability:** Medium	**Merging** Integration of equality considerations into the optimization logic of the energy system model[237]. Using discount rates close to zero for renewable energy investments factors to represent intergenerational equality[293]. **Iterating** Implementations of narratives as a set of theoretical assumptions for energy system modelling to explore how centralized vs decentralized, fossil fuel vs renewable electricity access impact justice issues[294]. Scenario analysis of equitable spatial distribution based on decentral and central planning of renewable generation[242], different justice principles of allocating carbon budgets[295] or emission rights[296] or electrification plans based on various justice principles[297]. **Bridging** Measuring (in)equality in energy system outputs with different justice metrics, including affordability and access[298], the spatial distribution of cost, investment,

		capacity and generation[299] , employment[300], and health impacts[301].
Incremental learning (0.24)	The principle of incremental learning is overwhelmingly found in literature applying technology learning curves[302], i.e., the curve describing falling costs with accumulating deployment over time, where it is often studied as the driving force of technology diffusion in energy systems[303]. Institutional or policy learning is studied more rarely[304,305]. Data is readily available for calculating technology curves and learning rates, mostly relying on installed capacity and cost data[306]. **Examples of databases:** No database available on (social) incremental learning, but technology data readily available. See literature. **Data availability:** Medium (Technology cost & deployment)	**Merging** The use of technological learning curves and learning rates, parameterized into the cost function of energy technologies, and acting as an input variable to the model for calculating energy system impacts, such as cost or diffusion[307,308].
Path-dependency (0.21)	A rich literature on various lock-in effects exist, such as for carbon emissions, or technologies, and how they impact the energy transition or climate change mitigation[309,310]. An important part of the literature also discusses how to break lock-ins[311]. Numerous descriptive case studies exist that rely on qualitative data and comparative case studies[310,312]. In quantitative studies, stranded assets in the energy sector are often taken into account[313], as well as the lifetime of carbon-intensive technologies[314]. **Examples of databases:** Global Energy Monitor (Global Coal Plant Tracker, Global Oil and Gas Plant Tracker, Global Gas Finance Tracker, Global Methane Emission Tracker etc.)[259] Global Power Plant Database[315]	**Merging** Extension of the lifetime of power capacities (years), if the capacity remains economically profitable[235]. The irreversibility of investments are built into the optimization structure as a property of capital stock[316]. Modelling of abatement inertia, which is represented by a penalty on abatement speed to reflect that a rapid abatement would lead to stranded asset and repurposing costs[317]. The modeling of policy volatility with advocacy coalitions and how political lock-in impacts investment (flows) into electricity generation technologies[318]. **Iterating** Scenario analysis of different amounts of coal power plants coming online by different timelines and how

	Data availability: High	that impacts stranded assets[319]. Scenario analysis of policy timing and its effects on generation portfolios, including energy subsidies[320], the deployment on negative emissions technologies[321], the lifetime of coal power plants and their early retirement[322] and early vs late decarbonization efforts[323]. **Bridging** The assessment of technological lock-in effects in scenario results, analyzing with the help of carbon pricing, fuel price uncertainty or technology mixes what can help break the lock-in of fossil energy infrastructure[324,325]. Definition of carbon intensive lock-in based on the share of green energy that the model produces[326] . Quantification or qualitative discussion of stranded assets in different energy and climate scenarios, such as lock-in of coal[327] gas[328], or blue hydrogen[329].
Political economy (0.02)	The literature on political economy frequently examines combinations of policy mixes and their effectiveness, such as the impact of carbon taxes[213], feed-in-tariffs[330], or command and control tools[331]. The influences of neoliberal market reforms have also been studied[332] Many studies take a qualitative approach, presenting descriptive and comparative case studies based on historical and institutional research, interviews or workshops[333]. Quantitative studies also exist, based on typologies of governance systems and renewable energy macro data[334] and policy mix evaluations[335]. **Examples of databases:** Index of Economic Freedom[336], Varieties of Democracies[189], EEA Integrated National Climate and Energy Policies and Measures (PaM) [337], Climate Policy Database[338], Policy Instruments for the Environment (PINE)[339] **Data availability:** High	**Iterating** Scenario impact analysis in energy system models of different policy instruments and mixes to decarbonize energy systems and mitigate climate change, including feed-in-tariffs[340], energy subsidies[341], energy efficiency policies[342], technology or decarbonization targets[343], as well as emission trading schemes[344]. Examined impacts include cost-effectiveness[345], health benefits and regional disparities[346], or renewable energy deployment[347].

Expected costs and benefits (0.00)	Expected costs and benefits as a decision-making logic has been widely examined in the form of cost-optimization exercises, such as with energy system optimization models, and applied to transition technologies, decarbonization pathways and scenarios[348,349]. Contributions are to a large extent quantitative, with technology or aggregated system cost data acting as the pillar for most analyses[348,349]. Qualitative analyses are rare[350]. **Examples of databases:** No database available on expected costs and benefits in terms of individual decision-making, but technology cost data readily available for cost-optimal simulations. See literature. **Data availability:** High (Technology cost data).	**Merging** Cost-optimization applied as a decision logic to models, such as for decarbonizing energy systems and for reaching climate mitigation targets or net-zero[351,352].
Only databases that are open access and with a minimum continental geographic scope and a temporal scope of at least two years are listed. The examples are non-exhaustive and only indicative of the data availability.		

A2.3 Relevance criteria: Increased model realism and policy leverage

Table A7: Evaluation of increased model realism and policy leverage of all transition factors. Evaluations were done subjectively based on available empirical research from the literature review and independent research. Responses indicate general tendencies and are neither fully representative nor exhaustive.

Transition factor (index score)	**Increased model realism** *(=which model assumptions can be improved by integrating the transition factor)*	**Policy leverage** *(=can policymakers influence the transition factor with policy tools and levers)*
Emotions (1.00)	Considering insights from empirical research on emotions (e.g., strongly negative or positive reactions towards technologies or policies) would primarily impact model assumptions on individual **technology adoption and use**[62] and on the **socio-political environment**, such as public acceptance[353].	Low possibility to influence the emotional and affective responses of individuals with policy tools, as emotions are generally considered to be instinctual and formed outside of rational-analytical processes[1].
Social movement capacity (0.99)	Considering insights from empirical research on social movement capacity (e.g., development of grassroot initiatives[68]) would primarily impact model assumptions on collective **technology adoption and use** (e.g., by energy communities[67]) and on the **socio-political environment**, such as collective resistance[71].	Low possibility to influence the driving factors behind social movement capacity with policy tools, in particular those related to intangible resources, such as shared set of grievances, values, and identities. Structural prerequisites for collective action, such as windows of opportunities, are typically also out-of-scope for policy measures[48].
Intentions (0.98)	Considering insights from empirical research on behavioral intentions would primarily impact model assumptions on individual **technology adoption and use** and the **socio-political environment** (e.g., willingness to adopt or support[83,119]).	Low possibility to influence behavioral intentions with policy tools, as they are largely considered to be driven by subjective norms, attitudes, and perceptions[54]. Techniques such as nudging and choice architecture in public policy exist, but effectiveness is controversially debated[354,355].

Trust (0.98)	Considering insights from empirical research on trust-based factors (e.g., trust towards authorities[84] or other individuals) would primarily impact model assumptions on **technology adoption and use** and on the **socio-political environment**, such as public acceptance[87].	Medium possibility to influence interpersonal or -institutional trust with policy tools, such as implementing practices of good governance (e.g., transparency, rule of law, accountability etc.[356,357]).
Social resources (0.97)	Considering insights from empirical research on social resources (e.g., peer effects[96,98]) would primarily impact model assumptions on individual **technology adoption and use,** and on **the socio-political environment,** such as public support.	Low possibility to influence social resources with policy tools, as networks and relations are largely considered to be the result of personal and reciprocal interactions within a social system[49].
Lobby power (0.97)	Considering insights from empirical research on lobby power (e.g., influence of advocacy coalitions[107]) would primarily impact model assumptions on the **socio-political environment**, such as level of political support[358], and on **policy implementation**[105].	High possibility to influence lobby power with policy tools, such as implementing practices of transparency rules (e.g., lobby registers, publication of meeting records etc.).[359]
Social conformity (0.95)	Considering insights from empirical research on social conformity (e.g., normative pressure) would primarily impact model assumption on individual **technology adoption and use**[117] and **the socio-political environment**, such as public support[360].	Low possibility to influence the drivers of social conformity with policy tools, as it is largely considered to arise from shared identities and norms within social networks[47].
Social tipping points (0.92)	Considering insights from empirical research on social tipping points would primarily impact model assumptions on **technology adoption and use** and on **the socio-political environment**, e.g., diffusion patterns of new technologies and ideas[128].	Medium possibility to influence social tipping points with policy tools, in particular by adopting policies that would trigger positive tipping points, e.g., in the adoption of innovations or behaviors[361].
Institutional quality (0.89)	Considering insights from empirical research on institutional quality would primarily impact model assumptions on **policy implementation** (e.g., corruption[129] and **technology cost** (e.g., transaction costs and institutional barriers[133]).	High possibility to influence institutional quality with policy tools, in particular by implementing practices of good governance (e.g., transparency, anti-corruption, rule of law, accountability etc.).[135,362]

Political and social cohesion (0.88)	Considering insights from empirical research on political and social cohesion would primarily impact model assumptions on the **socio-political environment** (e.g. partisan support[145]) and on **policy implementation (**e.g., policy stability[144]).	Low possibility to influence political and social cohesion with policy tools, as this is considered to be born out of shared values, identities, and grievances[15,17].
Social practices (0.88)	Considering insights from empirical research on social practices would primarily impact model assumptions on **technology adoption and use** (e.g., culturally meaningful energy uses[156]).	Low possibility to influence culturally and socially anchored practices with policy tools. Techniques such as nudging and choice architecture in public policy exist, but effectiveness is controversially debated[354,355].
Values, beliefs, norms (0.87)	Considering insights from empirical research on values, beliefs, and norms would primarily impact model assumptions on **technology adoption and use** (e.g., as determinants for willingness to buy or adopt[163]) and on **the socio-political environment** (e.g., related to the support of certain policies[162]).	Low possibility to influence values, beliefs, and norms with policy tools, as these are generally considered to be formed outside of rational-analytical processes[56].
Risk and loss aversion (0.85)	Considering insights from empirical research on risk and loss aversion would primarily impact model assumptions on **technology adoption and use,** such as through various risk preferences for technologies[169], and **the socio-political environment,** such as public support[170].	Low possibility to influence risk behavior with policy tools, as these are generally considered to be formed outside of rational-analytical processes[40]. Techniques such as nudging and choice architecture in public policy exist, but effectiveness is controversially debated[354,355].
Political regime and culture (0.78)	Considering insights from empirical research on political regime and culture would primarily impact model assumptions on **policy implementation,** such as the impact of federal and state power division or of democratic institutions[182,184].	Medium possibility to influence political regime and culture with policy tools, such as with electoral reforms or (de)centralization and democratization of decision-making[363,364].
Bounded rationality (0.75)	Considering insights from the empirical research on bounded rationality would primarily impact model assumptions on **technology adoption and use** and the **socio-political environment,** such as technology preferences or support without full information[196].	Low possibility to influence rationally bounded decision-making. Techniques such as nudging and choice architecture in public policy exist, but effectiveness is controversially debated[354,355].

Critical junctures (0.45)	Considering insights from the empirical research on critical junctures would impact model assumptions on **technology adoption and use** (e.g., disrupted practices[208]**), socio-political environment** (e.g., radical shifts in public perceptions[365]**), technology costs** (e.g., availability of technologies[226]**), and external constraints** (e.g., trade restrictions[211]**).**	Medium possibility to influence critical junctures with policy tools, such as through the implementation of resilience and preparedness (e.g., in the area of infrastructure[366]).
Attitudes, perceptions, preferences (0.43)	Considering insights from the empirical research on attitudes, perceptions, and preferences would primarily impact model assumptions on **technology adoption and use** (e.g., acceptance as determinant of willingness to use[231]), and **the socio-political environment** (e.g., public support[227]).	Low possibility to influence the formation process of attitudes, preferences, and perceptions with policy tools, as these are generally considered to be formed outside of rational-analytical processes[1].
Geopolitical power (0.38)	Considering insights from the empirical research on geopolitical power would primarily impact model assumptions on **technology cost** (e.g., imports dependency[224]) and **external constraints** (e.g., trade[251]).	Medium possibility to influence geopolitical power with policy tools, such as through the implementation of security measures (e.g., energy autarky, diversification strategies etc.[367]).
Discursive power (0.36)	Considering insights from the empirical research on discursive power would primarily impact model assumptions on the **socio-political environment** (e.g., narratives that strongly influence public opinion[234]).	Medium possibility to influence discursive power with policy tools, such as code of practices on disinformation, measures on content control or media literacy in digital environments[368,369].
Justice and fairness (0.31)	Considering insights from the empirical research on justice and fairness would primarily impact model assumptions on the **socio-political environment** (e.g., perceived justice as a determinant for acceptance[290]).	Medium possibility to influence perceptions of justice and fairness with policy tools, in particular through the implementation of good governance (e.g., transparency, rule of law, accountability etc.) and energy justice principles[370,371].

Incremental learning (0.24)	Considering insights from the empirical research on incremental learning would primarily impact model assumptions on **policy implementation** (e.g., through policy learning[304]) and **technology costs** (e.g., technology learning curves[302]).	High possibility to influence incremental learning, in particularly by adopting supportive policies in the area of research & development and technology deployment (e.g., subsidies, investment support[372]). Social learning more difficult to impact, but could be improved with tools such as regulatory scrutiny or better regulation agendas[373].
Path-dependency (0.21)	Considering insights from the empirical research on path-dependency (e.g., policy or infrastructure lock-in[374]) would primarily impact model assumptions on **policy implementation** and **technology cost.**	Medium possibility to influence path-dependency with policy tools, such as with policies that break previous technology lock-ins[375]. Inertia in political and social systems more difficult to change[376].
Political economy (0.02)	Considering insights from the empirical research on political economies would primarily impact model assumptions on **policy implementation** (e.g., through regulatory approach[331]) and **technology cost** (e.g., through type of policy instruments[213]).	High possibility to influence the political economy with policy tools, in particular through choices of policy instruments and mixes that regulate markets[335].
Expected cost and benefits (0.00)	Considering insights from the empirical research on expected costs and benefits (e.g., through the application of cost-optimality[349] in individual or system preferences) would primarily impact model assumptions on **technology adoption and use, the socio-political environment** and **technology cost**.	High possibility to influence expected costs and benefits with policy tools, such as by creating financial incentives for desirable practices (e.g., subsidies) and financial punishments for undesirable practices (e.g., taxes)[377].

A3 Literature review

A3.1 Definition of keywords for the literature bases

Two literature bases were defined in order to contrast how transition factors are represented (Table A8). For the social scientific literature, we used keywords that describe the systemic energy transition in a general and broad manner. Sector-specific (e.g., electricity, buildings, industry etc.) or technology-specific keywords (e.g., PV, wind, nuclear, biomass) were excluded. Keywords were compared to and complemented by the results from other systematic literature reviews on energy transitions[378,379]. The modeling literature was defined with keywords that describe modelling practices for energy and emission projections, complemented by systematic searches from other reviews[4,7]. Keywords specifically targeted energy optimization models, energy simulation model, and integrated assessment models due to their similar structural logic (e.g., focused on systems, tendency of centralized coordination[380]). Keywords targeting electricity, transport, industry, buildings (heating & cooling) sectors were included to capture models with a sector-specific scope (e.g., "energy transport model*"). Abbreviations and sector-specific keywords with no evident relation to energy were included with the Boolean operator "NEAR/25 "energ*" to reduce false positives (e.g., "IAM*" NEAR/25 "energ*").

Table A8: Search query for the literature scope on the social scientific literature on energy transition and modeling literature.

(Social scientific) literature on energy transition		
Keywords: "energy transition*" OR "energy system trans*" OR "energy system decarboni*" OR "energy system moderni*" OR "sustainable energ*" OR "renewable energ*" OR "clean energ*" OR "green energ*" OR "low-carbon energ*" OR "decarboni* energ*" OR "net-zero energ*" OR "climate-neutral energ*" OR "carbon-neutral energ*"	**Search**: Topic (Title, abstract, keyword plus, and author keywords)	**Results (16.07.2025)** N= 198 742
Modeling literature		
Keywords: "energy system* model*" OR "energy system* optimi* model*" OR ("ESOM*" NEAR/50 "energ*") OR "energy optimi* model*" OR "model* energy transition*" OR "energy transition model*" OR "energy decarboni* model*" OR "energy simulation* model*" OR "energy system simulation*" OR "integrated assessment model*" OR ("IAM*" NEAR/50 "energ*") OR "electricity system model*" OR "electricity system optimi*" OR "power system model*" OR "electricity sector model*" OR "power sector model*" OR "transport energy model*" OR ("transport system model*" NEAR/50 "energ*") OR ("transport sector model*" NEAR/50 "energ*") OR "building energy model*" OR "residential energy model*" OR "heat* system model*" OR "cooling system model*" OR "indust* energy model*" OR ("industr* sector model*" NEAR/50"energ*")	**Search**: Topic (Title, abstract, keyword plus, and author keywords)	**Results (16.07.2025)** N= 8 993

A3.2 Definition of keywords for transition factors

A3.2.1 Keywords from social scientific theories

The search strings of transition factors are shown in Table A9. These keywords were primarily identified from the theory review, as a way to directly link when literature has used theories or concepts from social sciences in the context of energy transition research or modeling. Keywords were extended and adapted to include neighboring concepts with a similar meaning (e.g., social acceptance and public support) to account for the non-consistent use of terminology in literature. For very generic words with a double meaning (e.g., value, cost) we included several explanatory words to reduce the number of false positives in the literature records. To avoid duplicates, keywords were assigned exclusively to one transition factor, where possible. The exception to this practice was the use of some theory-specific keywords, such as “value-belief-norm” or “theory of planned behavior, from which several transition factors were derived (e.g., “Values, Beliefs, Norms”, or “Attitudes, Perceptions, and Preferences” and “Intentions”). When transition factors were closely related (e.g., “Critical junctures” and “Geopolitical power”), the author assigned keywords based on a subjective judgement (e.g., “war” and “crisis”).

A3.2.2 Keywords from modeling practices and workshop with modelers

To capture literature that is not theory-based, we also included keywords from current modeling practices that directly or indirectly represent social scientific transition factors. To do this, we evaluated the list of transition factors and tried to identify modeling equivalents (and their keywords) that correspond to the cause-effect mechanism of transition factors. For example, the use of Shared Socioeconomic Pathways[281] or technology-specific scenarios (e.g., negative emission technologies[280]) can be seen to indirectly represent the transition factor of “Discursive power”, as these types of scenarios impose a dominating narrative on models of what constitutes legitimate solutions to societal problems. Technology learning curves can be seen as a representation of the transition factor of “Incremental learning”, whereby models assume a constant improvement in cost reduction as experience in deployment grows[307]. Similarly, considering social acceptance in cost-optimal energy scenarios can be seen to reflect the transition factor of “Attitudes, perceptions, preferences”[235]. While including these types of keywords into the search string extended the scope of relevant literature, it also broadened the definition of what constitutes as a transition factor. Nonetheless, this trade-off was accepted, as otherwise a large part of modeling practices would have been excluded.

To get better insights into such practices, we organized a workshop together with representatives from the modelling community. The aim was to identify new keywords and improve the accuracy of existing one in order to capture recent and relevant literature, where modeling includes insights from social sciences. A total of seven researchers from the University of Geneva with professional experience in energy and emission modelling participated in the interdisciplinary exchange, which took place in July 2025 in Geneva. Participation was on a voluntary basis, and all participants gave their written consent to share the results anonymously after the workshop and for the purpose of this research. The workshop was moderated by the corresponding author and was structured in four sections. In each section, one transition factor type (i.e., cognitive-motivational, socio-normative etc.) was presented and explained with examples. Participants were then asked to share examples of existing cases or ideas of how this type of transition factor could be represented or integrated into energy models. Participants could suggest their own keywords to add or propose changes to existing ones. The final decision on whether to implement the proposed changes to the set of keywords was taken by the corresponding author and are marked bold in Table A9.

Table A9: Search strings for each transition factor used in the literature search on Web of Science. Keywords marked in bold represent those that were added after the workshop with modelers. A justification for including these keywords and why they can be seen as an equivalent of existing modeling practices is given in the right column.

Transition factor	Search string	Modeling practices and keywords
Attitudes, perceptions, preferences	“attitude*” OR “preference*” OR “judgment*” OR “theory of planned behavio*” OR “social acceptance” OR “public acceptance” OR “poli* acceptance” OR “social support” OR “public support” OR “poli* support” OR “social opposition” OR “public opposition” OR “poli* opposition” OR “perception*” OR “subjective interpretation*” OR “perceived benefit*” OR “perceived use*” OR “perceived behavio*” OR “perceived eas*” OR “perceived cost*” OR “perceived effic*” OR "perceived control" OR "perceived behavio*" OR **“disamenit*”** OR **“disutilit*”** OR **“discount*”**	The term of “disamenity” or “disutility” cost is used in modeling to internalize the negative effect that local opposition has on the success rate of energy infrastructure projects, e.g., due to impacts on landscapes or noise[237]. Similar effects can be achieved through the use of discounting rates.
Bounded rationality	“heuristic*” OR “bounded rationality” OR “cogniti*” OR “satisfic*” OR “mental shortcut*” OR "judgment error*" OR “bias*” OR “information asymmetr*” OR “asymmetric information*” “imperfect information*” OR “myopic decision*” OR “access to information*” OR "hurdles*" OR "information availabili*" OR "limited information*" **OR “near* optimal” OR “imperfect foresight*” OR “limited foresight*” OR “myopic planning*” OR “myopic foresight*”**	The use of imperfect, limited or myopic models, i.e., models that solve cost-optimality based on shorter sequences and time periods, are used to reflect policy making under real-world circumstances, whereby policy-makers take short-term decisions based on limited information about the future[248]. Similar logic to the use of near-optimal models[349].
Critical junctures	“critical juncture*” OR “policy punctuation*” OR “policy window*” OR “window* of opportunit*” OR “landscape pressure*” OR “regime destabili*” OR “regime shift*” OR “external shock*” OR “exogenous shock*”OR “price shock*” OR “price crash*” OR “economic cris*” OR “poli* cris*” OR “financial cris*” OR “recession*” OR “extreme event*” OR “shock scenari*” OR “supply shock*” OR “supply cris*” OR “discontinuit*” OR “disrupti*” OR “instabilit*” OR “transient shock*” OR “oil shock” OR “gas shock” OR **“black swan*”**	Historical disruptions to energy supply and demand are sometimes termed “black swans”, i.e., events with low probability and low predictability but highly impactful[381].
Discursive power	“discourse*” OR “discursive” OR “framing*” OR “agenda* setting” OR “media analys*” OR “narrative*”	Models frequently use technology-specific[280] or solution-specific narratives[279] in scenario analyses that reflect certain discourses.

Emotions	“affective” OR “affect-driven” OR “affect-based” OR “affect heuristic*” OR “emotion*” OR “sentiment* analy*” OR "fear*" OR "anxi*" OR "anger" OR "guilt*" OR "happ*" OR "hope*" OR "enthusias*" OR "empower*"	No equivalent modeling practices or keywords found.
Expected costs and benefits	“anticipated behavio*” OR “strategic behavio*” OR “rational*” OR “expected cost*” OR “expected benefit*” OR “cost* benefit” OR “self-gain*” OR "game theory" OR "deterrence theory" OR "rational choice theory" **OR "utility maximi*" OR “benefit maximi*” OR OR “value maximi*” OR “cost optim*” OR “profit maximi*” OR “revenue maximi*” OR "utility optimi*" OR “cost minimi*” OR “least-cost”**	There is a large terminology for describing the various objective functions that models aims to optimize based on the logic of cost-optimal outcomes[382].
Geopolitical power	"geopolitic*" OR “energy security” OR “energy sovereign*” OR “energy autarch*” OR “energy autonom*” OR “energy risk*” OR “import reduction*” OR “import *dependen*” OR “energy *dependenc*” OR “strategic *dependenc*” OR “regional cooperation*” OR “international cooperation*” OR “cross-border cooperation*” OR “international conflict*” OR “international politic*” OR “international relation*” OR “anarch*” OR “antagonist*” OR “trade war*” OR “embargo” OR “tarif* war*” OR “trade tension*” OR “energy trade” OR “threat*” OR “energy *sanction*” OR “trade restriction*” OR “trade dynamic*” OR “conflict*” OR “trade disput*”	No equivalent modeling practices or keywords found.
Incremental learning	“regulatory learning” OR “policy learning” OR "single-loop learning" OR "double-loop learning" OR “learning-by-*” OR “learning effect*” OR “trial-and-error*” OR “incremental learning*” OR “institutional learning*” **OR “experience curve*” OR “learning curve*” OR "learning rate" OR “technolog* learning”**	Models frequently assume a constant cost reduction, as technology deployment increases[307]. Although primarily applied in a techno-economic sense, the principal reflects incremental learning.
Institutional quality	"governance capacit*" OR "governance qualit*" OR “good governance” OR "institutional capacit*" OR "institutional qualit*" OR "administrative capacit*" OR "administrative qualit*" OR "bureaucratic capacit*" OR "bureaucratic qualit*" OR "regulatory qualit*" OR “regulatory capaci*” OR "government capacit*" OR “state capaci*” OR "implementation capacit*" OR "coordination capacit*" OR “enforcement capacit*” OR "state capacity" OR “transaction cost*” OR “institutional barrier*” OR “regulatory barrier*” OR “bureaucratic barrier*” OR “administrative barrier*” OR "hurdles" OR	No equivalent modeling practices or keywords found.

	“negotiat* cost*” OR “enforcement cost*” OR “implementation cost*” OR “coordination cost*” OR “implementation barrier*” OR "corruption*"	
Intentions	“intention*” OR “intended” OR “motivation*” OR “readiness to*” OR "willingness to*" OR “theory of planned behavio*”	No equivalent modeling practices or keywords found.
Justice and fairness	“distribution* fairness” OR “distribution* justice” OR “procedur* justice” OR “procedur* fairness” OR “recognition* fairness” OR “recognition* justice” OR “energy justice” OR “just transition” OR "*equit*" OR "*equalit*" OR “energy povert*” OR “disparit*” OR “distribution* outcome*” OR “affordabili*” OR “justice theor*” OR “intergeneration*” OR “**social discount***”	Social discount rates that are close to zero have been used to represent intergenerational equality in models[293].
Lobby power	“lobb*” OR “advocac*” OR “interest group*” OR “interest representation*” OR “poli* power*” OR “poli* influence” OR “incumbent* interest*” OR “vested interest*”	No equivalent modeling practices or keywords found.
Path-dependency	"lock-in*" OR "path-dependen*"OR “pathdependen*” OR "institutional inertia" OR “poli* inertia” OR “institution* rigid*” OR “historical institutionalism” OR “policy legac*” OR “historical legac*” OR “system* inertia*” OR “stranded asset*” OR “sunk cost*”	Models frequently quantify sunk costs or stranded assets in order to evaluate technological lock-ins or delayed policies that stem from path-dependency or system inertia[383].
Political and social cohesion	“Poli* *stabilit*” OR “govern* *stabilit*” OR “poli* volatilit*” OR “bipartisan” OR “ideolog*” OR “poli* value*” OR “poli* will*” OR “political consensus” OR “poli* cohesion” OR “party cohesion” OR “poli* polari*” OR “poli* *coherence*” OR “social cohesion*” OR “poli* fragment*” OR “social* fragment*” OR "poli* feasib*" OR "social* feasib*"	No equivalent modeling practices or keywords found.
Political economy	"political econom*" OR "varieties of capitalism" OR “market econom*" OR "economic governance*" OR “liberali*” OR “market-based” OR “command-and-control” OR "state intervention*" OR "*regulation*" OR “state control*” OR “feed-in*” OR “phase-out*” OR “technolog* ban*” OR “carbon tax*” OR “carbon pricing” OR “auction*” OR “tender*” OR “subsid*” OR “carbon market*” OR “emission trading system*” OR “cap-and-trade*”.	Models very frequently examine and compare the impacts of policy instruments and mixes, which reflects the different approaches on how to regulate energy markets and negative externalities

Political regime and culture	“political regime*” OR “political system*” OR “political culture*” OR “political governance” OR “participat* democra*” OR “consensus-based” OR "authoritarian*" OR "egalitarian" OR "communitarian" OR "individualist" OR “technocra*” OR “individualist*” OR “fatalist*” OR “hierarchist” OR “cultural theor*” OR “federal*” OR “*centrali*” OR “democra*”	No equivalent modeling practices or keywords found.
Risk and loss aversion	“risk behavio*” OR “perceived risk*” OR “perceived uncertaint*” OR “risk perception*” OR “loss aversion*” OR “risk-averse” OR “risk aversion*” OR “risk-seeking” OR “prospect theory”	No equivalent modeling practices or keywords found.
Social conformity	“social identi*” OR “group identi*” OR “community identi*” OR “collective identi*” OR “conformi*” OR “in-group*” OR “out-group*” OR “normative pressure*” OR “social pressure*” OR “peer pressure*” OR “peer influence*” OR “social influence*” OR “norm internali*” OR “subjective norm*” OR “identity-based”	No equivalent modeling practices or keywords found.
Social movement capacity	“social movement*” OR “resource mobili*” OR “organi* capacit*” OR “fundrais*” OR “social mobili*” OR “poli* mobili*” OR “collective action*”OR "social action*" OR "grassroot*" OR "collective mobili*"	No equivalent modeling practices or keywords found.
Social practices	“social practice*” OR “routine*” OR “domestic practice*” OR “consumption practice*” OR “habit*” OR “practice theory” OR “behavio* practice*” OR “practice-based” OR “practice-centered”	No equivalent modeling practices or keywords found.
Social resources	“social capital*” OR “social network*” OR “social relation*” OR “social* learn*” OR “personal network*” OR “peer effect*” OR "network effect*" OR “spread* of information*” OR “knowledge sharing*” OR “information sharing” OR “knowledge diffusion*” OR “knowledge spillover” OR “behavior* spillover” OR “neighbo*”OR “friend*” OR “family" OR “word of mouth*”	No equivalent modeling practices or keywords found.
Social tipping points	“tipping point*" OR “tipping*" OR "critical mass*" OR "poli* threshold*" OR "social threshold*" OR "adoption threshold*" OR "particip* threshold*" OR “domino effect*” OR “critical threshold*” OR “cascade effect*” OR “change threshold*” OR “non-linear effect*” OR “non-linear dynamic*” OR “threshold effect*”	No equivalent modeling practices or keywords found.

Trust	“*trust*” OR “*legitima*” OR “*credib*”	No equivalent modeling practices or keywords found.
Values, beliefs and norms	“core value*” OR “moral value*” OR “pro-environmental value*” OR “normative value*” OR “social value*” OR “collective value*” OR “common value*” OR “fundamental value*” OR “deep* value*” OR “belief*” OR “normative” OR “norms” OR “worldview*” OR “altruistic” OR “egoistic” OR “eco-centric” OR “anthropocentric” OR “human-centered” OR “value orientation*” OR “value-oriented” OR “value-belief-norm” OR “theory of planned behavio*” OR “personal norm*” OR "personal value*" OR “awareness of consequence*” OR “awareness of impact*” OR “ascription of responsibility” OR “personal responsibility” OR “collective responsibility” OR “common responsibility” OR “sense of obligation” OR “moral obligation” OR “norm activation” OR “value-belief-norm” OR “moral judgment” OR “perceived consequence*” OR “perceived responsibility”	No equivalent modeling practices or keywords found.

A3.3. ASReview

ASReview is an open-source, machine-learning model that has been developed to make systematic reviews and meta-research more efficient and less prone to human errors[384]. It is based on the Researcher-in-the-Loop concept, whereby the algorithm interacts with human expertise to identify and rank articles in large datasets. In a first step, the researcher selects articles that have already been identified as relevant for the review purpose, called prior knowledge. This constitutes the training data from which the algorithm learns to identify relevant articles and draft a relevance ranking order. Next, it suggests articles to the researcher, one-by-one, who labels them as either relevant or not relevant. The model learns from each labeling decision, and thus continuously updates its relevance ranking order and improves its prediction of relevant articles[384]. Importantly, each article is screened and labelled by the researcher, with the algorithm merely suggesting articles based on relevance[385]. The researcher can define stopping rules to determine when the dataset has been exhausted of relevant articles, expressed as a number of consecutively labelled articles as not relevant[386]. ASReview has been applied across multiple fields and has been found to significantly reduce the reviewing time[387,388].

ASReview was integrated into the literature review to facilitate the identification of relevant articles that addressed transition factors from the two large literature bases (Figure A1). First, we uploaded the literature records extracted from Web of Science to ASReview for each transition factor (n=24) and literature base (n=2), giving a total of 48 datasets. From each dataset, we selected a maximum of five articles as prior knowledge (Table A10). Where possible, we made sure that prior knowledge articles equally represented keywords to minimize biases in the machine-learning algorithm. Next, articles were labelled as either relevant or not relevant based on whether articles addressed 1) the conceptual or empirical study of the energy transition / modeling of energy and emission projections, 2) the conceptual or empirical use of transition factors. Because of the very large number of articles from the 48 datasets (in total >110 000 articles), we set a limit of screening a maximum of 100 articles per dataset. We defined our stopping rule at 20 consecutively labelled irrelevant articles. While the use and definition of stopping rules pose a trade-off between resource-intensity and comprehensiveness[386], it was a necessary choice to manage practical time constraints of the review. As a consequence of only reviewing a maximum of 100 articles per transition factor and literature base, we stress that the resulting evidence bases cannot be viewed as fully representative of the entire available literature.

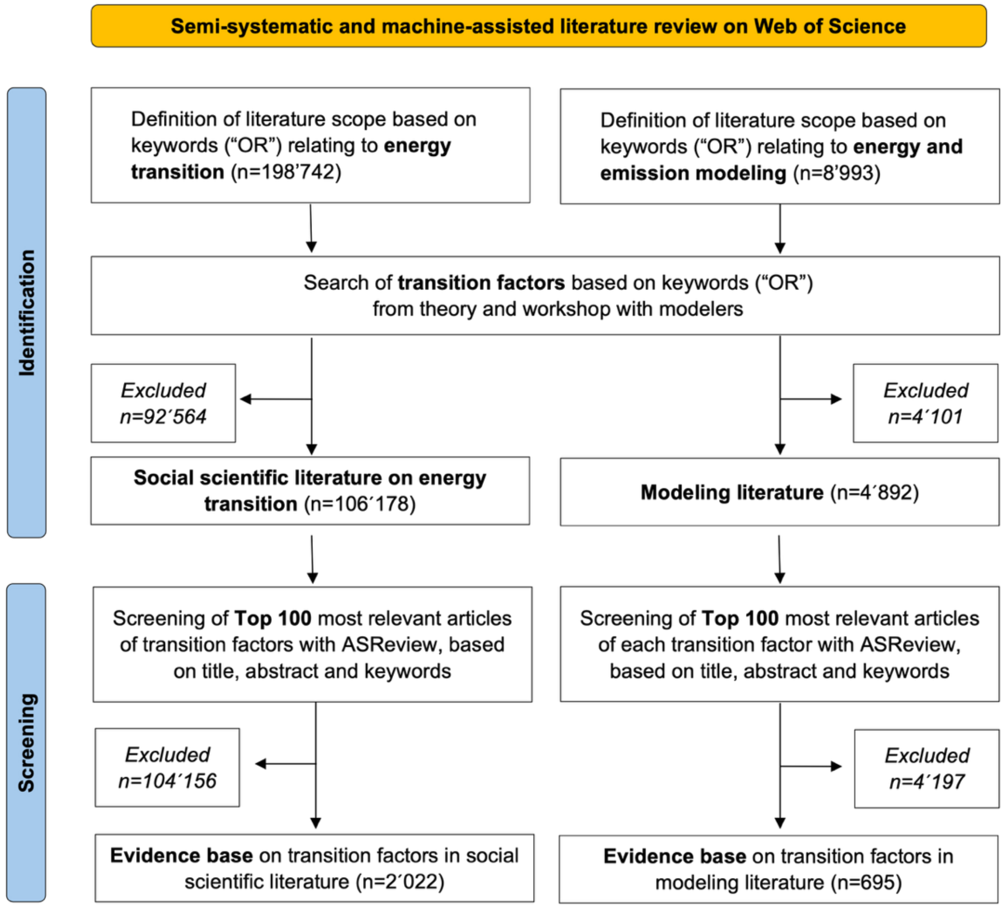

Figure A1: Overview of the semi-systematic and machine-assisted literature review. ASReview was integrated into the screening phase to identify the top 100 most relevant articles for the evidence base.

Table A10: Articles used as prior knowledge in the ASReview screening process for finding relevant articles that included transition factors.

Transition factor	Prior knowledge (max. 5): Social scientific literature	Prior knowledge (max. 5): Modeling literature
Attitudes, perceptions, preferences	1. The Role of Environmental Attitudes in Explaining Public Perceptions of Climate Change and Renewable Energy Technologies in Lithuania 2. Exploring public acceptance of nuclear waste in Taiwan, China: investigating the impact of perceived risks and benefits of nuclear energy 3. Segmenting the South Korean Public According to Their Preferred Direction for Electricity Mix Reform 4. On the Socio-Cultural Determinants of Polish Entrepreneurs' Attitudes towards the Development of Renewable Energy: Business, Climate Skepticism Ideology and Climate Change 5. Public attitudes towards renewable energy technologies in Norway. The role of party preferences	1. Incorporating homeowners' preferences of heating technologies in the UK TIMES model 2. Integration of behavioral effects from vehicle choice models into long-term energy systems optimization models 3. Incorporating social mechanisms in energy decarbonisation modelling 4. Integration of disamenity costs and equality considerations regarding onshore wind power expansion and distribution into energy system optimization models 5. Multi-country evidence on societal factors to include in energy transition modelling
Bounded rationality	1. The impact of heterogeneous market players with bounded-rationality on the electricity sector low-carbon transition 2. Dynamic analysis on decision-making behavior in energy market with renewable energy generation considering the bounded rationality 3. A higher rebound effect under bounded rationality: Interactions between car mobility and electricity generation 4. How cognitive bias and information disclosure affect the willingness of urban residents to pay for green power ? 5. Impact of myopic decision-making and disruptive events in power systems planning	1. Modelling to generate near-Pareto-optimal alternatives (MGPA) for the municipal energy transition 2. Agent-based modeling of urban energy supply systems 3. Evaluation of sector-coupled energy systems using different foresight horizons 4. MUSE: An open-source agent-based integrated assessment modelling framework 5. Fuzzy model of residential energy decision-making considering behavioral economic concepts
Critical junctures	1. Effect of major policy disruptions in energy system transition: Case Finland 2. Multiple dimensions of disruption, energy transitions and industrial policy 3. Effect of the COVID-19 Pandemic on Renewable Energy Firm's Profitability and Capitalization	1. Effect of major policy disruptions in energy system transition: Case Finland 2. Limited impact of COVID-19 recovery packages on near-term CO2 emissions pathways 3. How do energy systems model and scenario studies explicitly represent socio-economic, political and technological disruption and discontinuity? Implications for policy and practitioners

	4. Assessment of autonomous renewable energy system operability under extreme events and disasters 5. Waves of disruption in clean energy transitions: Sociotechnical dimensions of system disruption in Germany and the United Kingdom	4. Green hydrogen in the iron and steel industry increases resilience against shocks in energy prices 5. Raw material risk in clean energy technologies and the power supply system: For which materials should price fluctuations be prioritised?
Discursive power	1. An Array of Deficits: Unpacking NIMBY Discourses in Wind Energy Developers' Conceptualizations of Their Local Opponents 2. The Renewable Energy Transition and the People - Exploring the Intersections of Right-wing Populism and the Renewable Energy Transition in Portuguese Media Discourses 3. Social acceptance of new energy technology in developing countries: A framing experiment in rural India 4. The influence of information format and framing on acceptance of energy storage technologies 5. Framing low-carbon pathways: A discursive analysis of contending storylines surrounding the phase-out of coal-fired power in Ontario	1. When justice narratives meet energy system models: Exploring energy sufficiency, sustainability, and universal access in Sub-Saharan Africa 2. Narrative scenario development based on cross-impact analysis for the evaluation of global-warming mitigation options 3. Fossil Natural Gas Exit - A New Narrative for the European Energy Transformation Towards Decarbonization 4. Evolving Narratives of Low-Carbon Futures in Transportation 5. Linking narratives and energy system modelling in transport scenarios: A participatory perspective from Denmark
Emotions	1. Mixed feelings: A review and research agenda for emotions in sustainability transitions 2. Emotions towards a mandatory adoption of renewable energy innovations: The role of psychological reactance and egoistic and biospheric values 3. Emotional energy communities: Centering emotions and feelings within energy transitions in southern Mexico 4. What's love got to do with it? Understanding local cognitive and affective responses to wind power projects 5. Contrasting Affective responses and the Politics of the Energy Transition: Impact of the War in Ukraine on the Colombian Coal Industry	-

Expected costs and benefits	1. Which wind turbine types are needed in a cost-optimal renewable energy system? 2. The performance of small scale multi-generation technologies in achieving cost-optimal and zero-energy office building solutions 3. Investment appraisal of cost-optimal and near-optimal pathways for the UK electricity sector transition to 2050 4. The United States-China Race for Green Transformation: Institutions, Incentives, and Green Industrial Policies 5. Photovoltaics in Nigeria - Awareness, attitude and expected benefit based on a qualitative survey across regions	1. Coal vs. renewables: Least-cost optimization of the Indonesian power sector 2. Modelling least cost electricity system scenarios for Bangladesh using OSeMOSYS 3. Enhancing policy realism in energy system optimization models: Politically feasible decarbonization pathways for the United States 4. Least-cost options for integrating intermittent renewables in low-carbon power systems 5. Improved representation of investment decisions in the German energy supply sector: An optimization approach using the TIMES model
Geopolitical power	1. The geopolitics of energy system transformation: A review 2. Raw material risk in clean energy technologies and the power supply system: For which materials should price fluctuations be prioritised? 3. What is the causal relationship among geopolitical risk, financial development, and energy transition ? Evidence from 25 OECD countries 4. Geopolitical Risk as a Determinant of Renewable Energy Investments 5. The geopolitics of renewables; exploring the political implications of renewable energy systems	1. Raw material demand and geopolitical risk in carbon-neutral futures 2. Global energy scenarios: A geopolitical reality check 3. Modeling Europe's role in the global LNG market 2040: Balancing decarbonization goals, energy security, and geopolitical tensions 4. Navigating geopolitical crises for energy security: Evaluating optimal subsidy policies via a Markov switching DSGE model 5. The implications of geopolitical, socioeconomic, and regulatory constraints on European bioenergy imports and associated greenhouse gas emissions to 2050
Incremental learning	1. A review on learning effects in prospective technology assessment 2. The impact of technology learning and spillovers between emission-intensive industries on climate policy performance based on an industrial energy system model 3. The role of regulatory learning in energy transition: The case of solar PV in Brazil 4. Policy learning or politics as usual? Explaining the rise and retrenchment of renewable electricity support policies in Europe	1. Importance of technological change and spillovers in long-term climate policy 2. Reviewing the complexity of endogenous technological learning for energy system modeling 3. Hindcasting to inform the development of bottom-up electricity system models: The cases of endogenous demand and technology learning 4. Inclusion of technology diffusion in energy-systems models: some gaps and needs

	5. Boosting solar investment with limited subsidies: Rent management and policy learning in India	5. Applying Endogenous Learning Models in Energy System Optimization
Institutional quality	1. The social efficiency of instruments of promotion of renewable energies: A transaction-cost perspective 2. An expert judgement approach to determine measures to remove institutional barriers and economic non-market failures that restrict photovoltaic self-consumption deployment in Spain 3. Identifying institutional barriers and policy implications for sustainable energy technology adoption among large organizations in California 4. Exploring the impact of institutional quality to South Africa's transition to renewables 5. Political economy of renewable energy: Does institutional quality make a difference in renewable energy consumption?	1. Incorporating indirect costs into energy system optimization models: Application to the Dutch national program Regional Energy Strategies 2. Enhancing the realism of decarbonisation scenarios with practicable regional constraints on CO2 storage capacity 3. The truth about co-benefits: a multidimensional feasibility assessment for thailand and beyond
Intentions	1. An experimental study of consumer attitudes and intentions in electricity markets 2. Understanding the Factors Influencing Consumers' Intention toward Shifting to Solar Energy Technology for Residential Use in Saudi Arabia Using the Technology Acceptance Model 3. Determinants of willingness to pay for smart meters: An empirical analysis of household customers in Germany 4. The effects of behavioral intention on the choice to purchase energy-saving appliances in China: the role of environmental attitude, concern, and perceived psychological benefits in shaping intention 5. The price of actor diversity: Measuring project developers' willingness to accept risks in renewable energy auctions	1. Representing the drivers of lifestyle change in Integrated Assessment Models using theories from environmental psychology: introducing the Motivation, Agency, and Past Behaviour (MAP) framework

Justice and fairness	1. Fair enough? Unraveling justice perspectives on Germany's energy 2. Public participation in decision making, perceived procedural fairness and public acceptability of renewable energy projects 3. Impact assessment framework of just energy transition: based on the justice principles 4. Social equity issues in the distribution of feed-in tariff policy benefits: A cross sectional analysis from England and Wales using spatial census and policy data 5. Quantifying the social equity state of an energy system: environmental and labor market equity of the shale gas boom in Appalachia	1. Can we optimise for justice? Reviewing the inclusion of energy justice in energy system optimisation models 2. Integration of disamenity costs and equality considerations regarding onshore wind power expansion and distribution into energy system optimization models 3. When justice narratives meet energy system models: Exploring energy sufficiency, sustainability, and universal access in Sub-Saharan Africa 4. Social discounting, social costs of carbon, and their use in energy system models 5. Distributional trade-offs between regionally equitable and cost-efficient allocation of renewable electricity generation
Lobby power	1. Incumbent lobbying as a barrier to forward-looking regulation: The case of demand-side response in the GB capacity market for electricity 2. Who drives China's renewable energy policies? Understanding the role of industrial corporations 3. The NRRP and the Italian energy transition. Interest groups in implementation, between structural power, insiderness and new coalitions 4. A struggle for change-The formation of a green-transition advocacy coalition in Finland 5. Energy Lobbying in the Decision-Making Process of the European Union	1. The dynamics of political power: The socio-technical transition of California's electricity system to renewable energy
Path-dependency	1. Locked in transition? Towards a conceptualization of path-dependence lock-ins in the renewable energy landscape 2. Revisiting carbon lock-in in energy systems: Explaining the perpetuation of coal power in Japan 3. The role of lock-in mechanisms in transition processes: The case of energy for road transport 4. Breaking the carbon lock-in: Identifying pathways for Malaysia towards a low-carbon future 5. The key role of historic path-dependency and competitor imitation on the electricity sector low-carbon transition	1. Deliberation Platform for Energy Transition Policies: How to Make Complex Things Simple 2. Emissions Lock-in, Capacity, and Public Opinion: How Insights From Political Science Can Inform Climate Modeling Efforts 3. Implications of accelerated and delayed climate action for Ireland's energy transition under carbon budgets 4. Multi-country evidence on societal factors to include in energy transition modelling

		5. Policy spillovers, technological lock-in, and efficiency gains from regional pollution taxes in the U.S.
Political and social cohesion	1. The effect of policy stability on clean energy investment 2. Political Stability, Economic Risk, and Renewable Energy Technology Innovation: International Evidence 3. In the transformation of energy systems: what is holding Australia back? 4. Contribution of green bonds and green growth in clean energy capacity under the moderating role of political stability 5. How does political stability affect renewable energy finance? International evidence	1. Enhancing policy realism in energy system optimization models: Politically feasible decarbonization pathways for the United States 2. The dynamics of political power: The socio-technical transition of California's electricity system to renewable energy
Political economy	1. Varieties of capitalism and clean energy transitions in the European Union: When renewable energy hits different economic logics 2. The contribution of energy policies to green energy transition in the Asia-Pacific region 3. Political economy of renewable energy transition in rentier states: The case of Oman 4. The political economy of decarbonisation: from green energy race' to green division of labour 5. Political economy of renewable energy: Does institutional quality make a difference in renewable energy consumption	1. Comparing different support schemes for renewable electricity in the scope of an energy systems analysis 2. Modelling Policy Pathways to Maximise Renewable Energy Growth and Investment in the Democratic Republic of the Congo Using OSeMOSYS(Open Source Energy Modelling System) 3. Navigating complexity: integrating political realities into energy system modelling for effective policy in Sub-Saharan Africa 4. Investigating emission regulation policy in the electricity sector: modeling an oligopolistic electricity market under hourly cap-and-trade 5. The decarbonization pathway of power system by high-resolution model under different policy scenarios in China
Political regime and culture	1. The dynamics of advancing climate policy in federal political systems 2. The transition to renewable energies in Tunisia: The asymmetric impacts of technological innovation, government stability, and democracy 3. Determinants of renewable energy consumption: Importance of democratic institutions	1. Enhancing policy realism in energy system optimization models: Politically feasible decarbonization pathways for the United States

	4. Swedish wind power expansion: Conflicting responsibilities between state and municipalities 5. Political power and renewable energy futures: A critical review	
Risk and loss aversion	1. Examining the inter-relationships between procedural fairness, trust in actors, risk expectations, perceived benefits, and attitudes towards power grid expansion projects 2. Energy efficiency and electricity expenditure: An analysis of risk and time preferences on light bulb use in Ghana 3. Risk preferences, bill increases and the future reliability of electricity networks in Australia 4. Comprehensive assessment for battery energy storage systems based on fuzzy-MCDM considering risk preferences 5. Gain and loss of money in a choice experiment. The impact of financial loss aversion and risk preferences on willingness to pay to avoid renewable energy externalities	1. Modelling barriers to low-carbon technologies in energy system analysis: The example of renewable heat in Ireland 2. An investment behavioral modeling framework for advancing power system transformation toward renewable energy integration
Social conformity	1. Using the social identity model of pro-environmental behavior to predict support for the adoption of solar panels 2. Exploring the relationship between group-level autonomy and social acceptance of geo- thermal energy: The role of procedural justice climate, social identity violation, and collec- tive self determined motivation 3. Multiple levels of agency in socio-technical transitions - Mnemonic agents and the constitution of group identities 4. Citizens' self-mobilization, motivational factors, and the group of most engaged citizens: The case of a radioactive waste repository in Denmark 5. The role of peer influence in rooftop solar adoption inequity in the United States	1. Interactions between social learning and technological learning in electric vehicle futures 2. Modelling social influence and cultural variation in global low-carbon vehicle transitions 3. Societal Transformations in Models for Energy and Climate Policy: The Ambitious Next Step
Social movement capacity	1. Citizens' self-mobilization, motivational factors, and the group of most engaged citizens: The case of a radioactive waste repository in Denmark	-

	2. Communities at Risk for Mobilization: Neoliberal Governance and the (un) Contentious Politics of the Dakota Access Pipeline in Rural Illinois 3. How can energy become a community endeavor in Europe? Consortium benchmarking strategies for the mobilization of collective action initiatives 4. Leaders or networkers? The role of mayors in renewable energy transition 5. Citizens' engagement in funding renewable and energy efficiency projects: A fuzzy set analysis	
Social practices	1. A Systematic Literature Review of the Interplay between Renewable Energy Systems and Occupant Practices 2. Influence of social-cultural practices on the adoption of Renewable Energy Technologies (RETs) in Uganda 3. Engaging men and women in energy production in Norway and the United Kingdom: The significance of social practices and gender relations 4. From technical innovations towards social practices and socio-technical transition? Re-thinking the transition to decentralised solar PV electrification in Africa 5. Systems and practices: Reviewing intervention points for transformative socio-technical change	1. Improving the behavioral realism of global integrated assessment models: An application to consumers' vehicle choices 2. The role of digital social practices and technologies in the Swiss energy transition towards net-zero carbon dioxide emissions in 2050
Social resources	1. Engaging Communities in Energy Transitions: A Study on Attitudes Towards Sustainable Heating Technologies and the Role of Peer Effects in Southern Chile 2. Peer effects on photovoltaics (PV) adoption and air quality spillovers in Poland 3. The impacts of observational learning and word-of-mouth learning on farmers' use of biogas in rural Hubei, China: does interpersonal trust play a role? 4. Analysis of smallholder farmers' dynamics of knowledge sharing, skill transfer, and participation in using biogas (application of social network analysis)s	1. The German energy transition: Modeling competition and substitution between nuclear power and Renewable Energy Technologies 2. Interactions between social learning and technological learning in electric vehicle futures 3. Modelling the socio-political feasibility of energy transition with system dynamics

	5. A social network perspective on involvement in community energy initiatives: The role of direct and extended social ties to initiators	
Social tipping points	1. Molehills into mountains: Transitional pressures from household PV-battery adoption under flat retail and feed-in tariffs 2. Policies to bring about social-ecological tipping points in coal and carbon intensive regions 3. Initiating social tipping dynamics in energy transitions: A novel analytical approach for exploring feedback loops and intervention points 4. Social tipping dynamics in the energy system 5. Collapse, social tipping dynamics, and framing climate change	1. Impacts of tidal stream power on energy system security: An Isle of Wight case study 2. Identifying decarbonisation opportunities using marginal abatement cost curves and energy system scenario ensembles 3. Energy policies avoiding a tipping point in the climate system
Trust	1. Trust and community: Exploring the meanings, contexts and dynamics of community renewable energy 2. Trust gaps in energy transitions: Japan's National Deliberative Poll after Fukushima 3. Effects of trust and public participation on acceptability of renewable energy projects in the Netherlands and China 4. Trust and confidence as socio-technical problems in the transformation of energy systems 5. Trust and the transformation of energy systems	-
Values, beliefs and norms	1. Analysis of values-beliefs-norms of decommissioned nuclear power plant reestablishment acceptance in developing countries: a perspective from the Philippines 2. Citizens? willingness to pay for local anaerobic digestion energy: The influence of altruistic value and knowledge 3. The role of value, belief and norm in shaping intentions to use residential rooftop solar for environment sustainability 4. The Impact of Awareness for the Consequences from Adopting Electric Scooters-The Crucial Role of Warm Glow and Extrinsic Appeal	-

	5. Perceived responsibility to address climate change consistently relates to increased pro-environmental attitudes, behaviors and policy support: Evidence across 23 countries	

A3.4: Literature review results

Table A11: Summary table on literature review results. The literature results indicate the total number of articles found from the keyword search on Web of Science in each of the literature bases. The evidence base indicates the relevant articles selected from the screening of 100 articles with ASReview. The representation gap index score is calculated by dividing the evidence base of the modeling literature by that of the social scientific literature and inverting the score.

Transition factor	**Social scientific literature on energy transition**			**Modeling literature**	
	Index score	*Literature results (Web of Science)*	*Evidence base (Top 100 ASReview)*	*Literature results (Web of Science)*	*Evidence base (Top 100 ASReview)*
Emotions	1.00	3’312	85	108	0
Social movement capacity	0.99	514	73	14	1
Intentions	0.98	4’618	96	170	2
Trust	0.98	2’048	86	101	2
Social resources	0.97	13’220	73	383	2
Lobby power	0.97	627	86	16	3
Social conformity	0.95	468	96	15	5
Social tipping points	0.92	468	76	63	6
Institutional quality	0.89	2’208	79	36	9
Political and social cohesion	0.88	1’097	68	63	8
Social practices	0.88	1’868	89	72	11
Values, beliefs, norms	0.87	1’673	93	84	12
Risk and loss aversion	0.85	800	86	39	13
Political regime and culture	0.78	7’295	60	312	13
Bounded rationality	0.75	4’463	76	312	19
Critical junctures	0.45	4’991	76	204	42
Attitudes, perceptions, preferences	0.43	9’088	92	419	52
Geopolitical power	0.38	11’348	91	435	56

Discursive power	0.36	2’163	90	120	58
Justice and fairness	0.31	6’183	95	349	66
Incremental learning	0.24	760	97	101	74
Path-dependency	0.21	1’223	78	100	62
Political economy	0.02	18’547	85	755	83
Expected cost and benefits	0.00	7’196	96	621	96
Total	-	**106’178**	**2’022**	**4’892**	**695**

*Number in brackets indicates the share of quantitative research from the evidence base of the social scientific literature
**Number in brackets indicates examples found in the modeling literature base

References

1. Scholz, R. W. *Environmental Literacy in Science and Society: From Knowledge to Decisions*. (Cambridge University Press, 2011). doi:10.1017/CBO9780511921520.
2. Edler, Jakob & Walz, R. *Systems and Innovation Research in Transition.Research Questions and Trends in Historical Perspective*. (Springer Nature Link, 2024). doi:https://doi.org/10.1007/978-3-031-66100-6.
3. Hirt, L. F., Schell, G., Sahakian, M. & Trutnevyte, E. A review of linking models and socio-technical transitions theories for energy and climate solutions. *Environ. Innov. Soc. Transit.* **35**, 162–179 (2020).
4. Galster, H. S., Van Der Wal, A. J., Batenburg, A. E., Koning, V. & Faaij, A. P. C. A comprehensive review of integrating behavioral drivers of technology adoption and energy service use in energy system models. *Renew. Sustain. Energy Rev.* **214**, 115520 (2025).
5. Cherp, A., Vinichenko, V., Jewell, J., Brutschin, E. & Sovacool, B. Integrating techno-economic, socio-technical and political perspectives on national energy transitions: A meta-theoretical framework. *Energy Res. Soc. Sci.* **37**, 175–190 (2018).
6. Eyster, H. N., Satterfield, T. & Chan, K. M. A. Why People Do What They Do: An Interdisciplinary Synthesis of Human Action Theories. *Annu. Rev. Environ. Resour.* **47**, 725–751 (2022).
7. Krumm, A., Süsser, D. & Blechinger, P. Modelling social aspects of the energy transition: What is the current representation of social factors in energy models? *Energy* **239**, 121706 (2022).
8. Van Valkengoed, A. M., Perlaviciute, G. & Steg, L. Representing the drivers of lifestyle change in Integrated Assessment Models using theories from environmental psychology: introducing the Motivation, Agency, and Past Behaviour (MAP) framework. *Environ. Res. Commun.* **7**, 032001 (2025).
9. Senkpiel, C. *et al.* Integrating Methods and Empirical Findings from Social and Behavioural Sciences into Energy System Models—Motivation and Possible Approaches. *Energies* **13**, 4951 (2020).
10. Sabatier, P. A. An advocacy coalition framework of policy change and the role of policy-oriented learning therein. *Policy Sci.* **21**, 129–168 (1988).
11. Marcus, G. E., MacKuen, M. & Neuman, W. R. Parsimony and Complexity: Developing and Testing Theories of Affective Intelligence. *Polit. Psychol.* **32**, 323–336 (2011).
12. Simon, H. A. Bounded Rationality. in *Utility and Probability* (eds Eatwell, J., Milgate, M. & Newman, P.) 15–18 (Palgrave Macmillan UK, London, 1990). doi:10.1007/978-1-349-20568-4_5.
13. Simon, H. A. Bounded rationality in social science: Today and tomorrow. *Mind Soc.* **1**, 25–39 (2000).

14. Festinger, L. *A Theory of Cognitive Dissonance*. (Stanford University Press, 1957).
15. Olson, M. *The Logic of Collective Action: Public Goods and the Theory of Goups.* (Harvard University Press, Cambridge, MA, 1965).
16. Hall, Peter. A. & Soskice, D. An introduction to varieties of capitalism. in *Debating varieties of capitalism: A reader* 21-.
17. Wendt, A. Anarchy is what States Make of it: The Social Construction of Power Politics. *Int. Organ.* **46**, 391–425 (1992).
18. Granovetter, M. Threshold Models of Collective Behavior. *Am. J. Sociol.* **83**, 1420–1443 (1978).
19. Kahan, D. & Braman, D. Cultural cognition and public policy. *Yale Law Policy Rev.* **24**, 149–172 (2006).
20. Douglas, M. & Wildavsky, A. *Risk and Culture: An Essay on the Selection of Technological and Environmental Dangers*. (University of California Press, 1982).
21. Ehrlich, I. Crime and Punishment. in *The New Palgrave Dictionary of Economics* (eds Durlauf, S. & Blume, L. E.) 1–5 (Palgrave Macmillan UK, London, 1987). doi:10.1057/978-1-349-95121-5_537-1.
22. Rogers, E. M. *Diffusion of Innovations*. (The Free Press, London, 1962).
23. Wetherell, M. Themes in discourse research. The case of Diana. in *Discourse theory and practice. A reader.* 14–28 (The open university press, London, 2001).
24. Kahnemann, Daniel. *Thinking, Fast and Slow*. (Doubleday Canada, 2011).
25. Nelson, R. & Winter, S. *An Evolutionary Theory of Economic Change*. (The Belknap Press of Harvard University Press, Cambridge, 1982).
26. von Neumann, J. & Morgenstern, O. *Theory of Games and Economic Behavior*. (Princeton University Press, Princeton, 1953).
27. Verplanken, B., Walker, I., Davis, A. & Jurasek, M. Context change and travel mode choice: Combining the habit discontinuity and self-activation hypotheses. *J. Environ. Psychol.* **28**, 121–127 (2008).
28. North, D. *Institutions, Institutional Change and Economic Performance*. (Cambridge University Press, Cambridge, 1990).
29. Keohane, R. *After Hegemony. Cooperation and Discord in the World Political Economy.* (Princeton University Press, New Jersey, 1984).
30. Braithwaite, V., Levi, M., Cook, K. & Hardin, R. *Trust and Governance*. (Russell Sage Foundation).
31. Tyler, Tom. R. *Why People Obey the Law*. (Princeton University Press, Princeton and Oxford, 2006).
32. Geels, F. W. Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. *Res. Policy* **31**, 1257–1274 (2002).
33. Kemp, R., Schot, J. & Hoogma, R. Regime shifts to sustainability through processes of niche formation: The approach of strategic niche management. *Technol. Anal. Strateg. Manag.* **10**, 175–198 (1998).

34. Kingdon, J. W. *Agendas, Alternatives and Public Policies*. (Pearson Education Limited, Essex, 2014).
35. DiMaggio, P. & Powell, W. The Iron Cage Revisited: Institutional Isomorphism and Collective Rationality in Organizational Fields. *Am. Sociol. Rev.* **48**, 147–160 (1983).
36. Argyris, Ch. & Schön, D. A. Organizational Learning: A Theory of Action Perspective. *Reis* 345 (1997) doi:10.2307/40183951.
37. Thelen, K. & Steinmo, S. Historical institutionalism in comparative politics. in *Structuring politics. Historical institutionalism in comparative analysis.* (Cambridge University Press, Cambridge, 1992).
38. Thelen, K. Historical institutionalism in comparative politics. *Annu. Rev. Polit. Sci.* **2**, 369–404 (1999).
39. Ross, S. A. The economic theory of agency: The Principal's problem. *Pap. Proc. Eighty-Fifth Annu. Meet. Am. Econ. Assoc.* **63**, 134–139 (1973).
40. Kahneman, D. & Tversky', A. Prospect Theory: An Analysis of Decision under Risk. *Econometrica* **47**, 263–292 (1979).
41. Buchanan, J. & Tullock, G. *The Calculus of Consent: Logical Foundations of Constitutional Democracy*. (Liberty fund, Indianapolis, 1958).
42. True, J., L., Jones, B., D. & Baumgartner, F., R. Punctuated Equilibrium Theory. Explaining stability and change in public policy-making. in *Theories of the policy process* (Routledge, 2007).
43. Becker, G. S. *The Economic Approach to Human Behavior*. (The University of Chicago Press, Chicago and London, 1976).
44. Williams, M. C. Why Ideas Matter in International Relations: Hans Morgenthau, Classical Realism, and the Moral Construction of Power Politics. *Int. Organ.* **58**, (2004).
45. Slovic, P. Perceived Risk, Trust, and Democracy. *Risk Anal.* **13**, 675–682 (1993).
46. Bourdieu, P. The forms of capital. in *Handbook of theory and research for the sociology of education* (New York, 1986).
47. Tajfel, H. & Turner, J. C. The social identity theory of integroup behavior. in *Political psychology* (Psychology Press, New York, 2004).
48. McAdam, D. Social Movement Theory and the Prospects for Climate Change Activism in the United States. *Annu. Rev. Polit. Sci.* **20**, 189–208 (2017).
49. Granovetter, M. The Strength of Weak Ties: A Network Theory Revisited. *Sociol. Theory* **1**, 201 (1983).
50. Reckwitz, A. Toward a Theory of Social Practices: A Development in Culturalist Theorizing. *Eur. J. Soc. Theory* **5**, 243–263 (2002).
51. Skocpol, T. & Finegold, K. State Capacity and Economic Intervention in the Early New Deal. *Polit. Sci. Q.* **97**, 255–278 (1982).
52. Hekkert, M. P., Suurs, R. A. A., Negro, S. O., Kuhlmann, S. & Smits, R. E. H. M. Functions of innovation systems: A new approach for analysing technological change. *Technol. Forecast. Soc. Change* **74**, 413–432 (2007).

53. Davis, F. D. Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. *MIS Q.* **13**, 319 (1989).
54. Ajzen, I. The theory of planned behavior. *Organ. Behav. Hum. Decis. Process.* **50**, 179–211 (1991).
55. Schwartz, S. H. Normative Influences on Altruism. in *Advances in Experimental Social Psychology* vol. 10 221–279 (Elsevier, 1977).
56. Stern, P. C., Dietz, T., Abel, T., Guagnano, G. A. & Kalof, L. A Value-Belief-Norm Theory of Support for Social Movements: The Case of Environmentalism. *Hum. Ecol. Rev.* **6**, (1999).
57. Singh, M. K. What is state capacity and how does it matter for energy transition? *Energy Policy* **183**, 113799 (2023).
58. Cialdini, R., Kallgren, C. & Reno, R. A Focus Theory of Normative Conduct: A Theoretical Refinement and Reevaluation of the Role of Norms in Human Behavior. *Adv. Exp. Soc. Psychol.* **24**, 201–234 (1991).
59. United Nations Industrial Development Organization. *Methodological Document. UNIDO Country Classification. Edition 2025.* https://stat.unido.org/portal/storage/file/publications/country-classif-report-2024.pdf (2024).
60. Trutnevyte, E. *et al.* Societal Transformations in Models for Energy and Climate Policy: The Ambitious Next Step. *One Earth* **1**, 423–433 (2019).
61. Russell, A. & Firestone, J. What's love got to do with it? Understanding local cognitive and affective responses to wind power projects. *Energy Res. Soc. Sci.* **71**, 101833 (2021).
62. Contzen, N., Handreke, A. V., Perlaviciute, G. & Steg, L. Emotions towards a mandatory adoption of renewable energy innovations: The role of psychological reactance and egoistic and biospheric values. *Energy Res. Soc. Sci.* **80**, 102232 (2021).
63. Carmona, S. Contrasting Affective responses and the Politics of the Energy Transition: Impact of the War in Ukraine on the Colombian Coal Industry. *Bull. Lat. Am. Res.* **43**, 335–339 (2024).
64. Park, E. Positive or negative? Public perceptions of nuclear energy in South Korea: Evidence from Big Data. *Nucl. Eng. Technol.* **51**, 626–630 (2019).
65. Dehler-Holland, J., Okoh, M. & Keles, D. Assessing technology legitimacy with topic models and sentiment analysis – The case of wind power in Germany. *Technol. Forecast. Soc. Change* **175**, 121354 (2022).
66. Bucur, C. *et al.* Sentiment analysis of global news on environmental issues: insights into public perception and its impact on low-carbon economy transition. *Front. Environ. Sci.* **12**, 1360304 (2024).
67. Sciullo, A. *et al.* Exploring Institutional and Socio-Economic Settings for the Development of Energy Communities in Europe. *Energies* **15**, 1597 (2022).
68. Blanchet, T. Struggle over energy transition in Berlin: How do grassroots initiatives affect local energy policy-making? *Energy Policy* **78**, 246–254 (2015).
69. Fraser, T., Bancroft, M., Small, A. & Cunningham, L. Leaders or networkers? The role of mayors in renewable energy transition. *Environ. Innov. Soc. Transit.* **42**, 301–316 (2022).

70. De Crescenzo, V., Baratta, R. & Simeoni, F. Citizens' engagement in funding renewable and energy efficiency projects: A fuzzy set analysis. *J. Clean. Prod.* **277**, 124060 (2020).
71. Vogel, K. D., Johnson, M. F. & Sveinsdóttir, A. G. Communities at Risk for Mobilization: Neoliberal Governance and the (un)Contentious Politics of the Dakota Access Pipeline in Rural Illinois. *J. Rural Stud.* **99**, 134–143 (2023).
72. Djinlev, V. & Pearce, B. J. Collective action lessons for the energy transition: learning from social movements of the past. *Sustain. Sci.* **19**, 847–863 (2024).
73. Lyhne, I., Aaen, S. B., Nielsen, H., Kørnøv, L. & Larsen, S. V. Citizens' self-mobilization, motivational factors, and the group of most engaged citizens: The case of a radioactive waste repository in Denmark. *Land Use Policy* **72**, 433–442 (2018).
74. Carnegie Endowment for International Peace. Global Protest Tracker. https://carnegieendowment.org/features/global-protest-tracker (2026).
75. Ash Center for Democratic Governance and Innovation. Harvard Kennedy School. Nonviolent and Violent Campaigns and Outcomes (NAVCO) Data Project. https://ash.harvard.edu/programs/nonviolent-and-violent-campaigns-and-outcomes-data-project/ (2021).
76. Clark, D. Mass Mobilization Protest Data. https://dataverse.harvard.edu/dataverse/MMdata (2021) doi:https://doi.org/10.7910/DVN/HTTWYL.
77. Atulkar, S. Purchase intention of Indian customers: a study on solar PV technology. *Int. J. Energy Sect. Manag.* **16**, 946–964 (2022).
78. Tu, J.-C. & Yang, C. Key Factors Influencing Consumers' Purchase of Electric Vehicles. *Sustainability* **11**, 3863 (2019).
79. Okur, Ö., Fiori, F. & Fouladvand, J. Adoption of renewable heating systems and thermal energy communities in the Netherlands: An empirical study. *Energy Rep.* **11**, 3815–3823 (2024).
80. Waris, I. & Ahmed, W. Empirical evaluation of the antecedents of energy-efficient home appliances: application of extended theory of planned behavior. *Manag. Environ. Qual. Int. J.* **31**, 915–930 (2020).
81. Côté, E., Đukan, M., Pons-Seres De Brauwer, C. & Wüstenhagen, R. The price of actor diversity: Measuring project developers' willingness to accept risks in renewable energy auctions. *Energy Policy* **163**, 112835 (2022).
82. Aslam, W., Farhat, K. & Arif, I. Regular to sustainable products: an account of environmentally concerned consumers in a developing economy. *Int. J. Green Energy* **18**, 243–257 (2021).
83. Liao, X., Shen, S. V. & Shi, X. The effects of behavioral intention on the choice to purchase energy-saving appliances in China: the role of environmental attitude, concern, and perceived psychological benefits in shaping intention. *Energy Effic.* **13**, 33–49 (2020).
84. Palomo-Vélez, G., Perlaviciute, G., Contzen, N. & Steg, L. Trusting the minister or trusting the mayor? Perceived competence and integrity of central and local Dutch institutions governing energy matters. *Environ. Res. Commun.* **6**, 045009 (2024).

85. Liu, L., Bouman, T., Perlaviciute, G. & Steg, L. Effects of trust and public participation on acceptability of renewable energy projects in the Netherlands and China. *Energy Res. Soc. Sci.* **53**, 137–144 (2019).
86. Einsiedel, E. F., Boyd, A. D., Medlock, J. & Ashworth, P. Assessing socio-technical mindsets: Public deliberations on carbon capture and storage in the context of energy sources and climate change. *Energy Policy* **53**, 149–158 (2013).
87. Gordon, J. A., Balta-Ozkan, N., Haq, A. U. & Nabavi, S. A. Fuelling hydrogen futures? A trust-based model of social acceptance. *Sustain. Energy Fuels* **9**, 2510–2555 (2025).
88. Gölz, S. & Wedderhoff, O. Explaining regional acceptance of the German energy transition by including trust in stakeholders and perception of fairness as socio-institutional factors. *Energy Res. Soc. Sci.* **43**, 96–108 (2018).
89. World Value Survey. Integrated Values Surveys (IVS) 1981-2022. https://www.worldvaluessurvey.org/WVSEVStrend.jsp (2022).
90. OECD. OECD Trust Survey Data. https://www.oecd.org/en/data/datasets/oecd-trust-survey-data.html (2023).
91. European Union. Eurobarometer. Public opinion in the European Union. https://europa.eu/eurobarometer/screen/home (2025).
92. AfroBarometer. AfroBarometer merged datasets. https://www.afrobarometer.org/data/merged-data/ (2023).
93. LAPOP Lab. AmericasBarometer surveys. https://www.vanderbilt.edu/lapop/raw-data.php.
94. Hu Fu Center for East Asia Democratic Studies. Asia Barometer Survey. https://asianbarometer.org/datar?page=d10 (2025).
95. European Social Survey. ESS Data Portal. https://ess.sikt.no/en/series/321b06ad-1b98-4b7d-93ad-ca8a24e8788a (2023) doi:https://doi.org/10.6102/zis235.
96. Meng, Z., He, J. & Xu, D. How do peer effects affect the transformation of farmers' willingness and behavior to adopt biogas? *J. Clean. Prod.* **415**, 137857 (2023).
97. Izadi, N., Saadi, H. & Kooshki, L. Analysis of smallholder farmers' dynamics of knowledge sharing, skill transfer, and participation in using biogas (application of social network analysis). *Sustain. Futur.* **8**, 100271 (2024).
98. Sokołowski, J. Peer effects on photovoltaics (PV) adoption and air quality spillovers in Poland. *Energy Econ.* **125**, 106808 (2023).
99. Goedkoop, F., Dijkstra, J. & Flache, A. A social network perspective on involvement in community energy initiatives: The role of direct and extended social ties to initiators. *Energy Policy* **171**, 113260 (2022).
100. Yu, Z. & Gibbs, D. Social ties, homophily and heterophily in urban sustainability transitions: User practices and solar water heater diffusion in China. *Energy Res. Soc. Sci.* **46**, 236–244 (2018).
101. Broska, L. H. It's all about community: On the interplay of social capital, social needs, and environmental concern in sustainable community action. *Energy Res. Soc. Sci.* **79**, 102165 (2021).

102. OECD. How's Life? https://www.oecd.org/en/publications/how-s-life_23089679.html (2024).
103. Eurostat. Quality of life indicators - social interaction. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Quality_of_life_indicators_-_social_interactions (2022).
104. Freeman, R. Modelling the socio-political feasibility of energy transition with system dynamics. *Environ. Innov. Soc. Transit.* **40**, 486–500 (2021).
105. Gomel, D. & Rogge, K. S. Mere deployment of renewables or industry formation, too? Exploring the role of advocacy communities for the Argentinean energy policy mix. *Environ. Innov. Soc. Transit.* **36**, 345–371 (2020).
106. University of Szczecin & Kochanek, E. Energy Lobbying in the Decision-Making Process of the European Union. *Stud. Eur. – Stud. Eur. Aff.* **28**, 51–69 (2024).
107. Nevzorova, T. & Kutcherov, V. The Role of Advocacy Coalitions in Shaping the Technological Innovation Systems: The Case of the Russian Renewable Energy Policy. *Energies* **14**, 6941 (2021).
108. Lizzi, R. & Prontera, A. The NRRP and the Italian energy transition. Interest groups in implementation, between structural power, insiderness and new coalitions. *Contemp. Ital. Polit.* **16**, 54–73 (2024).
109. Corporate Europe Observatory and Lobby Control. LobbyFacts.eu. https://www.lobbyfacts.eu (2026).
110. Transparency International. The Integrity Watch Data Hub. https://data.integritywatch.eu (2025).
111. BridgeGap. BridgeGap Data Hub on Corruption Measures. https://datahub.corruptiondata.eu/downloads/ (2026).
112. US Congress and Senate. Lobbying Disclosure Act (LDA). https://lda.gov/system/public/ (2026).
113. Child, M., Haukkala, T. & Breyer, C. The Role of Solar Photovoltaics and Energy Storage Solutions in a 100% Renewable Energy System for Finland in 2050. *Sustainability* **9**, 1358 (2017).
114. O'Shaughnessy, E., Grayson, A. & Barbose, G. The role of peer influence in rooftop solar adoption inequity in the United States. *Energy Econ.* **127**, 107009 (2023).
115. Hossain, I., Fekete-Farkas, M. & Nekmahmud, Md. Purchase Behavior of Energy-Efficient Appliances Contribute to Sustainable Energy Consumption in Developing Country: Moral Norms Extension of the Theory of Planned Behavior. *Energies* **15**, 4600 (2022).
116. Wang, J., Liu, F., Li, L. & Zhang, J. More than innovativeness: Comparing residents' motivations for participating renewable energy communities in different innovation segments. *Renew. Energy* **197**, 552–563 (2022).
117. Rana, M., Al Mamun, Md. A., Hossain, Md. K., Rekha, R. S. & Alam, S. M. S. Understanding the adoption of renewable energy technologies by households in South Asia: a theory of planned behavior perspective. *Discov. Sustain.* **6**, 477 (2025).

118. Johnson, N. & Reimer, T. Using the social identity model of pro-environmental behavior to predict support for the adoption of solar panels. *J. Environ. Stud. Sci.* **13**, 587–601 (2023).
119. Vu, T. D., Nguyen, T. M. N. & Vu, P. T. Exploring young customers' purchasing intention for solar appliances in an emerging market: evidence from structural equation modeling approach. *Int. J. Energy Sect. Manag.* **19**, 795–819 (2025).
120. Wijaya, D. I. & Kokchang, P. Factors Influencing Generation Z's Pro-Environmental Behavior towards Indonesia's Energy Transition. *Sustainability* **15**, 13485 (2023).
121. Pettifor, H., Wilson, C., McCollum, D. & Edelenbosch, O. Y. Modelling social influence and cultural variation in global low-carbon vehicle transitions. *Glob. Environ. Change* **47**, 76–87 (2017).
122. Edelenbosch, O. Y., McCollum, D. L., Pettifor, H., Wilson, C. & Van Vuuren, D. P. Interactions between social learning and technological learning in electric vehicle futures. *Environ. Res. Lett.* **13**, 124004 (2018).
123. Hou, H., Wu, D., Wang, X. & Kong, D. Foreign direct investment, environmental regulation, and energy transition—An empirical study based on data from 38 OECD countries worldwide. *Manag. Decis. Econ.* **46**, 573–589 (2025).
124. Li, R., Yang, Z. & Wang, Q. Does renewable energy reduce energy intensity? A matter of income inequality. *Humanit. Soc. Sci. Commun.* **12**, 138 (2025).
125. Wang, Q., Zhang, C. & Li, R. Impact of different geopolitical factors on the energy transition: The role of geopolitical threats, geopolitical acts, and geopolitical risks. *J. Environ. Manage.* **352**, 119962 (2024).
126. Deng, M. *et al.* The role of green finance in reshaping end-use energy consumption: insights from regional evidence in China. *Front. Environ. Sci.* **13**, 1539987 (2025).
127. Campfens, J. K. E. K., Duygan, M. & Binder, C. R. Initiating social tipping dynamics in energy transitions: A novel analytical approach for exploring feedback loops and intervention points. *Environ. Innov. Soc. Transit.* **56**, 100973 (2025).
128. Alkemade, F. *et al.* Social tipping dynamics in the energy system. *Earth Syst. Dyn.* **15**, 485–500 (2024).
129. Inglesi-Lotz, R. Exploring the impact of institutional quality to South Africa's transition to renewables. *Energy Sources Part B Econ. Plan. Policy* **19**, 2291433 (2024).
130. Saadaoui, H. The impact of financial development on renewable energy development in the MENA region: the role of institutional and political factors. *Environ. Sci. Pollut. Res.* **29**, 39461–39472 (2022).
131. Saadaoui, H. & Chtourou, N. Do Institutional Quality, Financial Development, and Economic Growth Improve Renewable Energy Transition? Some Evidence from Tunisia. *J. Knowl. Econ.* **14**, 2927–2958 (2023).
132. Adedoyin, F. F., Bekun, F. V., Eluwole, K. K. & Adams, S. Modelling the Nexus between Financial Development, FDI, and CO2 Emission: Does Institutional Quality Matter? *Energies* **15**, 7464 (2022).
133. Rosales-Asensio, E., De Simón-Martín, M., Borge-Diez, D., Pérez-Hoyos, A. & Comenar Santos, A. An expert judgement approach to determine measures to remove institutional

barriers and economic non-market failures that restrict photovoltaic self-consumption deployment in Spain. *Sol. Energy* **180**, 307–323 (2019).
134. Transparency International. Corruption Perception Index. https://www.transparency.org/en/cpi/2024 (2024).
135. World Bank. Worldwide Governance Indicators. https://www.worldbank.org/en/publication/worldwide-governance-indicators (2024).
136. The Fund for Peace. Fragile States Index. https://fragilestatesindex.org/global-data/ (2024).
137. World Bank. Global Financial Development. https://www.worldbank.org/en/publication/gfdr/data/global-financial-development-database (2022).
138. World Justice Project. Rule of Law Index. https://worldjusticeproject.org/rule-of-law-index/ (2025).
139. Wang, N., Verzijlbergh, R. A., Heijnen, P. W. & Herder, P. M. Incorporating indirect costs into energy system optimization models: Application to the Dutch national program Regional Energy Strategies. *Energy* **276**, 127558 (2023).
140. Grant, N., Gambhir, A., Mittal, S., Greig, C. & Köberle, A. C. Enhancing the realism of decarbonisation scenarios with practicable regional constraints on CO2 storage capacity. *Int. J. Greenh. Gas Control* **120**, 103766 (2022).
141. Lehtveer, M. & Hedenus, F. Nuclear power as a climate mitigation strategy – technology and proliferation risk. *J. Risk Res.* **18**, 273–290 (2015).
142. Lund, P. D. *et al.* Pathway Analysis of a Zero-Emission Transition in the Nordic-Baltic Region. *Energies* **12**, 3337 (2019).
143. Cheung, G. & Davies, P. J. In the transformation of energy systems: what is holding Australia back? *Energy Policy* **109**, 96–108 (2017).
144. Wang, Y. & Chang, C.-P. The effect of policy stability on clean energy investment. *Econ. Change Restruct.* **56**, 327–344 (2023).
145. Apergis, N. & Pinar, M. The role of party polarization in renewable energy consumption: Fresh evidence across the EU countries. *Energy Policy* **157**, 112518 (2021).
146. Arslan, E., Koyuncu, C. & Yilmaz, R. The Influence of Government Ideology on Renewable Energy Consumption in the European Union Countries. *Sustainability* **15**, 14870 (2023).
147. Clulow, Z., Ferguson, M., Ashworth, P. & Reiner, D. Comparing public attitudes towards energy technologies in Australia and the UK: The role of political ideology. *Glob. Environ. Change* **70**, 102327 (2021).
148. Hyde, S. & Marinov, N. National Elections Across Democratic and Autocracy (NELDA). https://nelda.co/#access (2020).
149. Bormann, N.-C. & Golder, M. Democratic Electoral Systems around the world, 1946–2020. *Elect. Stud.* **78**, 102487 (2022).
150. Bertelsmann Stiftung. Social Cohesion Radar Asia. https://www.bertelsmann-stiftung.de/en/our-projects/germany-and-asia/social-cohesion-asia (2015).

151. Colucci, G., Finke, J., Bertsch, V., Di Cosmo, V. & Savoldi, L. Combined assessment of material and energy supply risks in the energy transition: A multi-objective energy system optimization approach. *Appl. Energy* **388**, 125647 (2025).
152. Zhu, Q. *et al.* Enhancing policy realism in energy system optimization models: Politically feasible decarbonization pathways for the United States. *Energy Policy* **161**, 112754 (2022).
153. Vai, A., Colucci, G., Nicoli, M. & Savoldi, L. May the availability of critical raw materials affect the security of energy systems? An analysis for risk-aware energy planning with TEMOA-Italy. *Mater. Today Energy* **48**, 101805 (2025).
154. Matschoss, K. *et al.* Challenging practices: experiences from community and individual living lab approaches. *Sustain. Sci. Pract. Policy* **17**, 135–151 (2021).
155. Malatesta, T. & Breadsell, J. K. Identifying Home System of Practices for Energy Use with K-Means Clustering Techniques. *Sustainability* **14**, 9017 (2022).
156. Grabher, H. F., Rau, H., Ledermann, S. T. & Haberl, H. Beyond cooking: An energy services perspective on household energy use in low and middle income countries. *Energy Res. Soc. Sci.* **97**, 102946 (2023).
157. Van Beek, E., Boess, S., Bozzon, A. & Giaccardi, E. Practice reconfigurations around heat pumps in and beyond Dutch households. *Environ. Innov. Soc. Transit.* **53**, 100903 (2024).
158. Grimsby, L. K. *et al.* New perspectives on multiple fuel use: Energy flexibility in household cooking solutions in Tanzania. *Energy Res. Soc. Sci.* **115**, 103636 (2024).
159. Tattini, J. *et al.* Improving the representation of modal choice into bottom-up optimization energy system models – The MoCho-TIMES model. *Appl. Energy* **212**, 265–282 (2018).
160. Fishman, T. *et al.* A comprehensive set of global scenarios of housing, mobility, and material efficiency for material cycles and energy systems modeling. *J. Ind. Ecol.* **25**, 305–320 (2021).
161. Piselli, C., Pisello, A. L. & Sovacool, B. K. From social science surveys to building energy modeling: Investigating user-building interaction for low-carbon heating solutions in Europe. *Energy Rep.* **8**, 7188–7199 (2022).
162. Tolentino, L. M. V., Ong, A. K. S. & German, J. D. Analysis of values-beliefs-norms of decommissioned nuclear power plant reestablishment acceptance in developing countries: a perspective from the Philippines. *Nucl. Eng. Technol.* **56**, 3224–3235 (2024).
163. Farm, M. Y., Vafaei-Zadeh, A., Hanifah, H. & Nikbin, D. The role of value, belief and norm in shaping intentions to use residential rooftop solar for environment sustainability. *Energy Policy* **194**, 114334 (2024).
164. Wall, W. P., Khalid, B., Urbański, M. & Kot, M. Factors Influencing Consumer's Adoption of Renewable Energy. *Energies* **14**, 5420 (2021).
165. Mueller, J. T. & Tickamyer, A. R. Climate change beliefs and support for development: Testing a cognitive hierarchy of support for natural resource-related economic development in rural Pennsylvania. *J. Rural Stud.* **80**, 553–566 (2020).

166. Wolske, K. S., Stern, P. C. & Dietz, T. Explaining interest in adopting residential solar photovoltaic systems in the United States: Toward an integration of behavioral theories. *Energy Res. Soc. Sci.* **25**, 134–151 (2017).
167. Schmid, E. & Knopf, B. Ambitious mitigation scenarios for Germany: A participatory approach. *Energy Policy* **51**, 662–672 (2012).
168. Davidson, M. R., Filatova, T., Peng, W., Verbeek, L. & Kucuksayacigil, F. Simulating institutional heterogeneity in sustainability science. *Proc. Natl. Acad. Sci.* **121**, e2215674121 (2024).
169. Bartczak, A., Chilton, S., Czajkowski, M. & Meyerhoff, J. Gain and loss of money in a choice experiment. The impact of financial loss aversion and risk preferences on willingness to pay to avoid renewable energy externalities. *Energy Econ.* **65**, 326–334 (2017).
170. Mueller, C. E. Examining the inter-relationships between procedural fairness, trust in actors, risk expectations, perceived benefits, and attitudes towards power grid expansion projects. *Energy Policy* **141**, 111465 (2020).
171. Ghazvini, A., Olamaie, J. & Sedighizadeh, M. Economic-environmental operation of an unbalanced microgrid including energy storage systems via semidefinite relaxation. *Renew. Energy Focus* **42**, 129–145 (2022).
172. Seyedeh-Barhagh, S., Abapour, M., Mohammadi-Ivatloo, B., Shafie-Khah, M. & Laaksonen, H. Optimal scheduling of a microgrid based on renewable resources and demand response program using stochastic and IGDT-based approach. *J. Energy Storage* **86**, 111306 (2024).
173. Fleiß, E., Hatzl, S. & Rauscher, J. Smart energy technology: A survey of adoption by individuals and the enabling potential of the technologies. *Technol. Soc.* **76**, 102409 (2024).
174. Soroudi, A., Rabiee, A. & Keane, A. Information gap decision theory approach to deal with wind power uncertainty in unit commitment. *Electr. Power Syst. Res.* **145**, 137–148 (2017).
175. World Bank. The Global Findex Database. https://www.worldbank.org/en/publication/globalfindex/download-data (2025).
176. Lloyd's Register Foundation / Gallup World Poll. World Risk Poll. https://www.lrfoundation.org.uk/wrp/world-risk-poll-data (2023).
177. Zhu, T., Curtis, J. & Clancy, M. Modelling barriers to low-carbon technologies in energy system analysis: The example of renewable heat in Ireland. *Appl. Energy* **330**, 120314 (2023).
178. Giudici, F., Garofalo, E., Bozzi, S. & Castelletti, A. Climate uncertainty and technological innovation shape investments in renewable energy for small off-grid islands. *Renew. Sustain. Energy Transit.* **2**, 100036 (2022).
179. Knobloch, F., Huijbregts, M. A. J. & Mercure, J.-F. Modelling the effectiveness of climate policies: How important is loss aversion by consumers? *Renew. Sustain. Energy Rev.* **116**, 109419 (2019).

180. Hung, F., Ghaffari, A., Yang, Y. C. E. & Dillingham, G. An investment behavioral modeling framework for advancing power system transformation toward renewable energy integration. *Energy Clim. Change* **5**, 100127 (2024).
181. Badea, A. C., Rocco S., C. M., Tarantola, S. & Bolado, R. Composite indicators for security of energy supply using ordered weighted averaging. *Reliab. Eng. Syst. Saf.* **96**, 651–662 (2011).
182. Chen, C., Pinar, M. & Stengos, T. Determinants of renewable energy consumption: Importance of democratic institutions. *Renew. Energy* **179**, 75–83 (2021).
183. Yang, S. & Park, S. The effects of renewable energy financial incentive policy and democratic governance on renewable energy aid effectiveness. *Energy Policy* **145**, 111682 (2020).
184. Jordaan, S. M., Davidson, A., Nazari, J. A. & Herremans, I. M. The dynamics of advancing climate policy in federal political systems. *Environ. Policy Gov.* **29**, 220–234 (2019).
185. Niskanen, J., Haikola, S., Magnusson, D. & Anshelm, J. Swedish wind power expansion: Conflicting responsibilities between state and municipalities. *Renew. Sustain. Energy Rev.* **206**, 114881 (2024).
186. Ahlborg, H., Boräng, F., Jagers, S. C. & Söderholm, P. Provision of electricity to African households: The importance of democracy and institutional quality. *Energy Policy* **87**, 125–135 (2015).
187. Ergun, S. J., Owusu, P. A. & Rivas, M. F. Determinants of renewable energy consumption in Africa. *Environ. Sci. Pollut. Res.* **26**, 15390–15405 (2019).
188. Center for Systematic Peace. Polity5 Project. https://www.systemicpeace.org/polityproject.html (2021).
189. V-Dem Institute. Varieties of Democracy and Varieties of Party Identity. https://www.v-dem.net/data/ (2025).
190. Freedom House. Freedom in the World (2013-2025). https://freedomhouse.org/report/freedom-world (2025).
191. International IDEA. Global State of Democracy Indices. https://www.idea.int/democracytracker/gsod-indices (2026).
192. Pan, W. & Shittu, E. Assessment of mobility decarbonization with carbon tax policies and electric vehicle incentives in the U.S. *Appl. Energy* **379**, 124838 (2025).
193. Peng, W. *et al.* The surprisingly inexpensive cost of state-driven emission control strategies. *Nat. Clim. Change* **11**, 738–745 (2021).
194. Shu, D. Y. *et al.* Overcoming the central planner approach – Bilevel optimization of the European energy transition. *iScience* **27**, 110168 (2024).
195. Safarzyńska, K. & Van Den Bergh, J. C. J. M. A higher rebound effect under bounded rationality: Interactions between car mobility and electricity generation. *Energy Econ.* **74**, 179–196 (2018).
196. Barazza, E. & Strachan, N. The impact of heterogeneous market players with bounded-rationality on the electricity sector low-carbon transition. *Energy Policy* **138**, 111274 (2020).

197. Li, Y., Han, H., Gao, B. & Liu, X. Dynamic analysis on decision-making behavior in energy market with renewable energy generation considering the bounded rationality. *Electr. Power Syst. Res.* **241**, 111306 (2025).
198. Guo, H., Chen, Q., Shahidehpour, M., Xia, Q. & Kang, C. Bidding behaviors of GENCOs under bounded rationality with renewable energy. *Energy* **250**, 123793 (2022).
199. Reise, C., Musshoff, O., Granoszewski, K. & Spiller, A. Which factors influence the expansion of bioenergy? An empirical study of the investment behaviours of German farmers. *Ecol. Econ.* **73**, 133–141 (2012).
200. Zhou, Y., Chen, H., Xu, S. & Wu, L. How cognitive bias and information disclosure affect the willingness of urban residents to pay for green power ? *J. Clean. Prod.* **189**, 552–562 (2018).
201. Maier, R. *et al.* Impact of foresight horizons on energy system decarbonization pathways. *Adv. Appl. Energy* **18**, 100217 (2025).
202. Lambert, J., Hanel, A., Fendt, S. & Spliethoff, H. Evaluation of sector-coupled energy systems using different foresight horizons. *Renew. Sustain. Energy Rev.* **184**, 113562 (2023).
203. Esser, K., Finke, J., Bertsch, V. & Löschel, A. Participatory modelling to generate alternatives to support decision-makers with near-optimal decarbonisation options. *Appl. Energy* **395**, 126184 (2025).
204. Sarfarazi, S., Sasanpour, S. & Cao, K.-K. Improving energy system design with optimization models by quantifying the economic granularity gap: The case of prosumer self-consumption in Germany. *Energy Rep.* **9**, 1859–1874 (2023).
205. Wang, C.-H., Padmanabhan, P. & Huang, C.-H. The impacts of the 1997 Asian financial crisis and the 2008 global financial crisis on renewable energy consumption and carbon dioxide emissions for developed and developing countries. *Heliyon* **8**, e08931 (2022).
206. Tsipas, F., Elrashidy, Z. & Sandretto, D. Green bonds efficiency and renewable energy: Insights from the Covid-19 pandemic. *J. Environ. Manage.* **371**, 123090 (2024).
207. Ghenai, C. & Bettayeb, M. Data analysis of the electricity generation mix for clean energy transition during COVID-19 lockdowns. *Energy Sources Part Recovery Util. Environ. Eff.* **47**, 4845–4864 (2025).
208. Olatunji, O. O. *et al.* Reimagine renewable energy exploration in post-COVID-19 Africa. *Energy Sources Part Recovery Util. Environ. Eff.* **44**, 4275–4295 (2022).
209. Bersalli, G., Tröndle, T., Heckmann, L. & Lilliestam, J. Economic crises as critical junctures for policy and structural changes towards decarbonization – the cases of Spain and Germany. *Clim. Policy* **24**, 410–427 (2024).
210. Zakeri, B. *et al.* Pandemic, War, and Global Energy Transitions. *Energies* **15**, 6114 (2022).
211. Rokicki, T., Bórawski, P. & Szeberényi, A. The Impact of the 2020–2022 Crises on EU Countries' Independence from Energy Imports, Particularly from Russia. *Energies* **16**, 6629 (2023).
212. Pilpola, S. & Lund, P. D. Effect of major policy disruptions in energy system transition: Case Finland. *Energy Policy* **116**, 323–336 (2018).

213. Scordato, L., Klitkou, A., Tartiu, V. E. & Coenen, L. Policy mixes for the sustainability transition of the pulp and paper industry in Sweden. *J. Clean. Prod.* **183**, 1216–1227 (2018).
214. Leipprand, A. & Flachsland, C. Regime destabilization in energy transitions: The German debate on the future of coal. *Energy Res. Soc. Sci.* **40**, 190–204 (2018).
215. Armed Conflict Location and Event Data Project. ACLED Conflict Index. https://acleddata.com/series/acled-conflict-index (2024).
216. International Crisis Group. Crisis Watch Conflict Tracker. https://www.crisisgroup.org/crisiswatch/database (2026).
217. Center for Research on the Epidemiology of Disasters. The International Disaster Database (EM-DAT). https://www.emdat.be (2026).
218. Economic Policy Uncertainty. Economic Policy Uncertainty Index. https://www.policyuncertainty.com (2026).
219. World Bank. World Development Indicators. https://datatopics.worldbank.org/world-development-indicators/ (2026).
220. Lamperti, F., Dosi, G., Napoletano, M., Roventini, A. & Sapio, A. Faraway, So Close: Coupled Climate and Economic Dynamics in an Agent-based Integrated Assessment Model. *Ecol. Econ.* **150**, 315–339 (2018).
221. Wigger, H. *et al.* Quantitative Assessment of Sector Coupling Battery Energy Storage Systems and Their Contribution to the Resilience of the Power System. *Int. J. Energy Res.* **2024**, 8812115 (2024).
222. Gaucher, Y., Tanaka, K., Ciais, P. & Boucher, O. Limited impact of COVID-19 recovery packages on near-term CO_2 emissions pathways. *Environ. Res. Commun.* **4**, 101006 (2022).
223. Leuratti, N., Marangoni, G., Drouet, L., Kamp, L. M. & Kwakkel, J. Green hydrogen in the iron and steel industry increases resilience against shocks in energy prices. *Environ. Res. Lett.* **20**, 024021 (2025).
224. Moskalenko, N., Löffler, K., Hainsch, K., Hanto, J. & Herpich, P. Europe’s independence from Russian natural gas — Effects of import restrictions on energy system development. *Energy Rep.* **11**, 2853–2866 (2024).
225. Jasiūnas, J., Lund, P. D., Mikkola, J. & Koskela, L. Linking socio-economic aspects to power system disruption models. *Energy* **222**, 119928 (2021).
226. Schlosser, S. J. & Naegler, T. Raw material risk in clean energy technologies and the power supply system: For which materials should price fluctuations be prioritised? *Energy Rep.* **13**, 4359–4374 (2025).
227. Liang, Y., Ma, B., Wang, Z. & Bian, Q. Exploring public acceptance of nuclear waste in Taiwan, China: investigating the impact of perceived risks and benefits of nuclear energy. *J. Risk Res.* **26**, 1314–1330 (2023).
228. Ladenburg, J., Kim, J., Zuch, M. & Soytas, U. Taking the carbon capture and storage, wind power, PV or other renewable technology path to fight climate change? Exploring the acceptance of climate change mitigation technologies – A Danish national representative study. *Renew. Energy* **220**, 119582 (2024).

229. Roh, S. & Geong, H.-G. Extending the Coverage of the Trust–Acceptability Model: The Negative Effect of Trust in Government on Nuclear Power Acceptance in South Korea under a Nuclear Phase-Out Policy. *Energies* **14**, 3343 (2021).
230. Sonnberger, M. & Ruddat, M. Local and socio-political acceptance of wind farms in Germany. *Technol. Soc.* **51**, 56–65 (2017).
231. Waring, T. & Longo, A. Implementing Carbon Capture and Storage in the United Kingdom: Estimating Willingness to Pay through a Contingent Valuation Survey. *Environ. Manage.* **75**, 1432–1443 (2025).
232. Chung, J.-B. & Kim, E.-S. Public perception of energy transition in Korea: Nuclear power, climate change, and party preference. *Energy Policy* **116**, 137–144 (2018).
233. Yang, L., Zhang, X. & McAlinden, K. J. The effect of trust on people's acceptance of CCS (carbon capture and storage) technologies: Evidence from a survey in the People's Republic of China. *Energy* **96**, 69–79 (2016).
234. Li, P.-H., Keppo, I. & Strachan, N. Incorporating homeowners' preferences of heating technologies in the UK TIMES model. *Energy* **148**, 716–727 (2018).
235. Fisch-Romito, V., Jaxa-Rozen, M., Wen, X. & Trutnevyte, E. Multi-country evidence on societal factors to include in energy transition modelling. *Nat. Energy* **10**, 460–469 (2025).
236. Ramea, K., Bunch, D. S., Yang, C., Yeh, S. & Ogden, J. M. Integration of behavioral effects from vehicle choice models into long-term energy systems optimization models. *Energy Econ.* **74**, 663–676 (2018).
237. Lohr, C. *et al.* Integration of disamenity costs and equality considerations regarding onshore wind power expansion and distribution into energy system optimization models. *Energy Sustain. Soc.* **14**, 58 (2024).
238. Sachs, J., Meng, Y., Giarola, S. & Hawkes, A. An agent-based model for energy investment decisions in the residential sector. *Energy* **172**, 752–768 (2019).
239. Wulff, N. *et al.* Energy system implications of demand scenarios and supply strategies for renewable transportation fuels. *Energy Strategy Rev.* **58**, 101606 (2025).
240. Bolwig, S. *et al.* Climate-friendly but socially rejected energy-transition pathways: The integration of techno-economic and socio-technical approaches in the Nordic-Baltic region. *Energy Res. Soc. Sci.* **67**, 101559 (2020).
241. Panos, E., Kannan, R., Hirschberg, S. & Kober, T. An assessment of energy system transformation pathways to achieve net-zero carbon dioxide emissions in Switzerland. *Commun. Earth Environ.* **4**, 157 (2023).
242. Henni, S., Schäffer, M., Fischer, P., Weinhardt, C. & Staudt, P. Bottom-up system modeling of battery storage requirements for integrated renewable energy systems. *Appl. Energy* **333**, 120531 (2023).
243. Neumann, F. Costs of regional equity and autarky in a renewable European power system. *Energy Strategy Rev.* **35**, 100652 (2021).
244. Senkpiel, C. & Hauser, W. Systemic Evaluation of the Effects of Regional Self-Supply Targets on the German Electricity System Using Consistent Scenarios and System Optimization. *Energies* **13**, 4695 (2020).

245. Bauer, N. *et al.* Shared Socio-Economic Pathways of the Energy Sector – Quantifying the Narratives. *Glob. Environ. Change* **42**, 316–330 (2017).
246. Valenzuela-Venegas, G. *et al.* A renewable and socially accepted energy system for astronomical telescopes. *Nat. Sustain.* **7**, 1642–1650 (2024).
247. Naegler, T. *et al.* Integrated Multidimensional Sustainability Assessment of Energy System Transformation Pathways. *Sustainability* **13**, 5217 (2021).
248. Henke, H. T. J. *et al.* Exploring European decarbonisation pathways in the Power Decisions Game. *Energy Sustain. Soc.* **14**, 41 (2024).
249. Alsagr, N. & Van Hemmen, S. The impact of financial development and geopolitical risk on renewable energy consumption: evidence from emerging markets. *Environ. Sci. Pollut. Res.* **28**, 25906–25919 (2021).
250. Flouros, F., Pistikou, V. & Plakandaras, V. Geopolitical Risk as a Determinant of Renewable Energy Investments. *Energies* **15**, 1498 (2022).
251. Hille, E. Europe's energy crisis: Are geopolitical risks in source countries of fossil fuels accelerating the transition to renewable energy? *Energy Econ.* **127**, 107061 (2023).
252. Muhammad, S., Hoffmann, C. & Müsgens, F. Assessing energy security risks: Implications for household electricity prices in the EU. *Energy* **327**, 136201 (2025).
253. Lin, K. *et al.* Heterogenous impact of energy security and environmental regulations on energy transition: Exploring the disparity between high-income and middle-income countries. *Renew. Energy* **237**, 121610 (2024).
254. Zhang, Z., Zhao, M., Zhang, X., Huang, Z. & Feng, Y. What is the causal relationship among geopolitical risk, financial development, and energy transition ? Evidence from 25 OECD countries. *Int. Rev. Financ. Anal.* **104**, 104288 (2025).
255. Bakhsh, S., Zhang, W., Ali, K. & Anas, M. Energy transition and environmental stability prospects for OECD economies: The prominence role of environmental governance, and economic complexity: Does the geopolitical risk matter? *J. Environ. Manage.* **354**, 120358 (2024).
256. Chen, Z., He, M. & Ali, M. Natural Resources and Geopolitical Risk Impact on Energy Security Risk: The Role of Renewable Energy Consumption and Foreign Direct Investment. *Nat. Resour. Forum* 1477-8947.70006 (2025) doi:10.1111/1477-8947.70006.
257. Stockholm International Peace Research Institute. SIPRI Databases. https://www.sipri.org/databases (2025).
258. Vision of Humanity. Global Peace Index. https://www.visionofhumanity.org/maps/#/ (2025).
259. Global Energy Monitor. Global Energy Monitor Trackers. https://globalenergymonitor.org (2026).
260. Chan, Y. T., Punzi, M. T. & Zhao, H. Navigating geopolitical crises for energy security: Evaluating optimal subsidy policies via a Markov switching DSGE model. *J. Environ. Manage.* **349**, 119619 (2024).
261. Guo, Y. & Hawkes, A. The impact of demand uncertainties and China-US natural gas tariff on global gas trade. *Energy* **175**, 205–217 (2019).

262. Franz, S. *et al.* Implications of an antagonist age for maritime trade and its impacts on energy demand. *One Earth* **7**, 2175–2188 (2024).
263. Wu, L. *et al.* Global carbon reduction and economic growth under autonomous economies. *J. Clean. Prod.* **224**, 719–728 (2019).
264. Mandley, S. J., Wicke, B., Junginger, M., Van Vuuren, D. P. & Daioglou, V. The implications of geopolitical, socioeconomic, and regulatory constraints on European bioenergy imports and associated greenhouse gas emissions to 2050. *Biofuels Bioprod. Biorefining* **16**, 1551–1567 (2022).
265. Harmsen, M. *et al.* How the Russian–Ukrainian war reshapes the climate policy context. *Environ. Res. Lett.* **19**, 124088 (2024).
266. Hartvig, Á. D. *et al.* The economic and energy security implications of the Russian energy weapon. *Energy* **294**, 130972 (2024).
267. Abrahamsen, F. E., Ruud, S. G. & Gebremedhin, A. Moving Toward a Sustainable Energy System: A Case Study of Viken County of Norway. *Energies* **13**, 5912 (2020).
268. Galinis, A. *et al.* Implications of carbon price paths on energy security in four Baltic region countries. *Energy Strategy Rev.* **30**, 100509 (2020).
269. Hanto, J. *et al.* Assessing the implications of hydrogen blending on the European energy system towards 2050. *Adv. Appl. Energy* **13**, 100161 (2024).
270. Isoaho, K. & Markard, J. The Politics of Technology Decline: Discursive Struggles over Coal Phase-Out in the UK. *Rev. Policy Res.* **37**, 342–368 (2020).
271. Selje, T. Comparing the German exit of nuclear and coal: Assessing historical pathways and energy phase-out dimensions. *Energy Res. Soc. Sci.* **94**, 102883 (2022).
272. Biddau, F., Rizzoli, V. & Sarrica, M. Phasing-out 'coal tradition' in favour of 'renewable colonialism': how the press contributes to the discursive (de)legitimization of coal and renewables in a coal region in transition. *Sustain. Sci.* **19**, 381–402 (2024).
273. Zumofen, G., Stadelmann-Steffen, I. & Sträter, R. The influence of information format and framing on acceptance of energy storage technologies. *Renew. Sustain. Energy Rev.* **210**, 115209 (2025).
274. Aklin, M., Cheng, C.-Y. & Urpelainen, J. Social acceptance of new energy technology in developing countries: A framing experiment in rural India. *Energy Policy* **113**, 466–477 (2018).
275. Valquaresma, A., Batel, S., Afonso, A. I., Guerra, R. & Silva, L. The Renewable Energy Transition and "the People" – Exploring the Intersections of Right-wing Populism and the Renewable Energy Transition in Portuguese Media Discourses. *Environ. Commun.* **18**, 847–861 (2024).
276. DOAB Foundation. Directory of Open Access Books. https://www.doabooks.org (2026).
277. University of Bern. Digital Discourse Database. https://digitaldiscoursedatabase.org (2018).
278. CLARIN. ParlaMint - Comparable and Interoperable Parliamentary Corpora. https://www.clarin.eu/parlamint (2022).

279. Gaur, A., Balyk, O., Glynn, J., Curtis, J. & Daly, H. Low energy demand scenario for feasible deep decarbonisation: Whole energy systems modelling for Ireland. *Renew. Sustain. Energy Transit.* **2**, 100024 (2022).
280. Grubler, A. *et al.* A low energy demand scenario for meeting the 1.5 °C target and sustainable development goals without negative emission technologies. *Nat. Energy* **3**, 515–527 (2018).
281. Leimbach, M., Marcolino, M. & Koch, J. Structural change scenarios within the SSP framework. *Futures* **150**, 103156 (2023).
282. Franz, S., Rottoli, M. & Bertram, C. The wide range of possible aviation demand futures after the COVID-19 pandemic. *Environ. Res. Lett.* **17**, 064009 (2022).
283. Haikola, S., Anshelm, J. & Hansson, A. Limits to climate action - Narratives of bioenergy with carbon capture and storage. *Polit. Geogr.* **88**, 102416 (2021).
284. Hansson, A., Anshelm, J., Fridahl, M. & Haikola, S. Boundary Work and Interpretations in the IPCC Review Process of the Role of Bioenergy With Carbon Capture and Storage (BECCS) in Limiting Global Warming to 1.5°C. *Front. Clim.* **3**, 643224 (2021).
285. Abuzayed, A., Liebensteiner, M. & Hartmann, N. Hydrogen-ready power plants: Optimizing pathways to a decarbonized energy system in Germany. *Appl. Energy* **395**, 126228 (2025).
286. Shangguan, C., Shangguan, Z. & Sun, W. Impact assessment framework of just energy transition: based on the justice principles. *Front. Environ. Sci.* **12**, 1491946 (2024).
287. Droubi, S., Heffron, R. J. & McCauley, D. A critical review of energy democracy: A failure to deliver justice? *Energy Res. Soc. Sci.* **86**, 102444 (2022).
288. Tarasova, E. Multiple just transitions? A study of how a just transition is envisioned in Poland. *Energy Policy* **194**, 114322 (2024).
289. Healy, N. & Barry, J. Politicizing energy justice and energy system transitions: Fossil fuel divestment and a "just transition". *Energy Policy* **108**, 451–459 (2017).
290. Liu, L., Bouman, T., Perlaviciute, G. & Steg, L. Public participation in decision making, perceived procedural fairness and public acceptability of renewable energy projects. *Energy Clim. Change* **1**, 100013 (2020).
291. Grover, D. & Daniels, B. Social equity issues in the distribution of feed-in tariff policy benefits: A cross sectional analysis from England and Wales using spatial census and policy data. *Energy Policy* **106**, 255–265 (2017).
292. Lacey-Barnacle, M., Robison, R. & Foulds, C. Energy justice in the developing world: a review of theoretical frameworks, key research themes and policy implications. *Energy Sustain. Dev.* **55**, 122–138 (2020).
293. Löffler, K. Social discounting, social costs of carbon, and their use in energy system models. *Environ. Res. Lett.* **16**, 104005 (2021).
294. Gladkykh, G., Davíðsdóttir, B. & Diemer, A. When justice narratives meet energy system models: Exploring energy sufficiency, sustainability, and universal access in Sub-Saharan Africa. *Energy Res. Soc. Sci.* **79**, 102075 (2021).

295. Chen, X. *et al.* Regional emission pathways, energy transition paths and cost analysis under various effort-sharing approaches for meeting Paris Agreement goals. *Energy* **232**, 121024 (2021).
296. Pedersen, T. T., Andersen, M. S., Victoria, M. & Andresen, G. B. Using Modeling All Alternatives to explore 55% decarbonization scenarios of the European electricity sector. *iScience* **26**, 106677 (2023).
297. Menghwani, V. *et al.* Planning with justice: Using spatial modelling to incorporate justice in electricity pricing – The case of Tanzania. *Appl. Energy* **264**, 114749 (2020).
298. Calcaterra, M. *et al.* Reducing the cost of capital to finance the energy transition in developing countries. *Nat. Energy* **9**, 1241–1251 (2024).
299. Sasse, J.-P. & Trutnevyte, E. Distributional trade-offs between regionally equitable and cost-efficient allocation of renewable electricity generation. *Appl. Energy* **254**, 113724 (2019).
300. Altieri, K. E. *et al.* Achieving development and mitigation objectives through a decarbonization development pathway in South Africa. *Clim. Policy* **16**, S78–S91 (2016).
301. Pehle, H., Sasse, J.-P. & Trutnevyte, E. Regional inequalities in air quality and health co-benefits due to climate change mitigation in the European electricity sector. *Clim. Change* **178**, 27 (2025).
302. Thomassen, G., Van Passel, S. & Dewulf, J. A review on learning effects in prospective technology assessment. *Renew. Sustain. Energy Rev.* **130**, 109937 (2020).
303. Usui, T., Furubayashi, T. & Nakata, T. Induced technological change and the timing of public R&D investment in the Japanese electricity sector considering a two-factor learning curve. *Clean Technol. Environ. Policy* **19**, 1347–1360 (2017).
304. McGowan, F. Policy learning or politics as usual? Explaining the rise and retrenchment of renewable electricity support policies in Europe. *Environ. Polit.* **29**, 589–608 (2020).
305. Altenburg, T. & Engelmeier, T. Boosting solar investment with limited subsidies: Rent management and policy learning in India. *Energy Policy* **59**, 866–874 (2013).
306. Rocha Aponte, F., Wiebe, K. S. & Luttikhuis, N. The role of sustainability characteristics in the diffusion of renewable energy technologies. *Sustain. Energy Technol. Assess.* **57**, 103226 (2023).
307. Leibowicz, B. D., Krey, V. & Grubler, A. Representing spatial technology diffusion in an energy system optimization model. *Technol. Forecast. Soc. Change* **103**, 350–363 (2016).
308. Huang, W., Chen, W. & Anandarajah, G. The role of technology diffusion in a decarbonizing world to limit global warming to well below 2 °C: An assessment with application of Global TIMES model. *Appl. Energy* **208**, 291–301 (2017).
309. Barazza, E. & Strachan, N. The key role of historic path-dependency and competitor imitation on the electricity sector low-carbon transition. *Energy Strategy Rev.* **33**, 100588 (2021).
310. Klitkou, A., Bolwig, S., Hansen, T. & Wessberg, N. The role of lock-in mechanisms in transition processes: The case of energy for road transport. *Environ. Innov. Soc. Transit.* **16**, 22–37 (2015).

311. Schuch, E. *et al.* Breaking the carbon lock-in: Identifying pathways for Malaysia towards a low-carbon future. *Technol. Forecast. Soc. Change* **202**, 123331 (2024).
312. Trencher, G., Rinscheid, A., Duygan, M., Truong, N. & Asuka, J. Revisiting carbon lock-in in energy systems: Explaining the perpetuation of coal power in Japan. *Energy Res. Soc. Sci.* **69**, 101770 (2020).
313. Backe, S. *et al.* Exploring the link between the EU emissions trading system and net-zero emission neighbourhoods. *Energy Build.* **281**, 112731 (2023).
314. Chen, X. & Mauzerall, D. L. The Expanding Coal Power Fleet in Southeast Asia: Implications for Future CO_2 Emissions and Electricity Generation. *Earths Future* **9**, e2021EF002257 (2021).
315. World Resource Institute. Global Power Plant Database. https://datasets.wri.org/datasets/global-power-plant-database?map=eyJhY3RpdmVMYXllckdyb3VwcyI6W3siZGF0YXNldElkIjoiNTM2MjNkZmQtM2RmNi00ZjE1LWEwOTEtNjc0NTdjZGI1NzFmIiwibGF5ZXJzIjpbIjJhNjk0Mjg5LWZlYzktNGJmZS1hNmQyLTU2YzM4NjRlYzM0OSJdfV0sImJhc2VtYXAiOiJsaWdodCIsImJvdW5kYXJpZXMiOmZhbHNlLCJib3VuZHMiOnsiYmJveCI6bnVsbCwib3B0aW9ucyI6e319LCJsYWJlbHMiOiJkYXJrIiwibGF5ZXJzUGFyc2VkIjpbWyIyYTY5NDI4OS1mZWM5LTRiZmUtYTZkMi01NmMzODY0ZWMzNDkiLHsiYWN0aXZlIjp0cnVlLCJsYXllclNvdXJjZSI6bnVsbCwib3BhY2l0eSI6MSwidmlzaWJpbGl0eSI6dHJ1ZSwiekluZGV4IjoxMX1dXSwidmlld1N0YXRlIjp7ImxhdGl0dWRlIjoxMi40NjM1MTc5OTcxMzk4NDYsImxvbmdpdHVkZSI6LTIwLjM1NzM1MjQzNTYzNTMwNiwiem9vbSI6NC4yNDg2Mjk1NDQ1MjI3NTZ9fQ%3D%3D (2025).
316. Baldwin, E., Cai, Y. & Kuralbayeva, K. To build or not to build? Capital stocks and climate policy∗. *J. Environ. Econ. Manag.* **100**, 102235 (2020).
317. Coppens, L. & Venmans, F. The welfare properties of climate targets. *Ecol. Econ.* **228**, 108424 (2025).
318. Gottschamer, L. & Zhang, Q. The dynamics of political power: The socio-technical transition of California's electricity system to renewable energy. *Energy Res. Soc. Sci.* **70**, 101618 (2020).
319. Edwards, M. R. *et al.* Modeling direct air carbon capture and storage in a 1.5 °C climate future using historical analogs. *Proc. Natl. Acad. Sci.* **121**, e2215679121 (2024).
320. Roth, M. B., Adams, P. J., Jaramillo, P. & Muller, N. Z. Policy spillovers, technological lock-in, and efficiency gains from regional pollution taxes in the U.S. *Energy Clim. Change* **3**, 100077 (2022).
321. Pradhan, S. *et al.* Effects of Direct Air Capture Technology Availability on Stranded Assets and Committed Emissions in the Power Sector. *Front. Clim.* **3**, 660787 (2021).
322. Flora, M. & Tankov, P. Green investment and asset stranding under transition scenario uncertainty. *Energy Econ.* **124**, 106773 (2023).
323. Aryanpur, V. *et al.* Implications of accelerated and delayed climate action for Ireland's energy transition under carbon budgets. *Npj Clim. Action* **3**, 97 (2024).

324. Mercure, J.-F. *et al.* The dynamics of technology diffusion and the impacts of climate policy instruments in the decarbonisation of the global electricity sector. *Energy Policy* **73**, 686–700 (2014).
325. Usher, W. & Strachan, N. Critical mid-term uncertainties in long-term decarbonisation pathways. *Energy Policy* **41**, 433–444 (2012).
326. Lamperti, F., Dosi, G., Napoletano, M., Roventini, A. & Sapio, A. Climate change and green transitions in an agent-based integrated assessment model. *Technol. Forecast. Soc. Change* **153**, 119806 (2020).
327. Sudharmma Vishwanathan, S., Fragkos, P., Fragkiadakis, K. & Garg, A. Assessing enhanced NDC and climate compatible development pathways for India. *Energy Strategy Rev.* **49**, 101152 (2023).
328. Kleanthis, N., Stavrakas, V. & Flamos, A. Bidirectional soft-linking of a Capacity Expansion Model with a Production Cost Model to evaluate the feasibility of transition pathways towards carbon neutrality in the power sector. *Appl. Energy* **378**, 124843 (2025).
329. Kountouris, I. *et al.* A unified European hydrogen infrastructure planning to support the rapid scale-up of hydrogen production. *Nat. Commun.* **15**, 5517 (2024).
330. Zha, D., Jiang, P., Zhang, C., Xia, D. & Cao, Y. Positive synergy or negative synergy: An assessment of the carbon emission reduction effect of renewable energy policy mixes on China's power sector. *Energy Policy* **183**, 113782 (2023).
331. Lamperti, F., Napoletano, M. & Roventini, A. GREEN TRANSITIONS AND THE PREVENTION OF ENVIRONMENTAL DISASTERS: MARKET-BASED VS. COMMAND-AND-CONTROL POLICIES. *Macroecon. Dyn.* **24**, 1861–1880 (2020).
332. Newell, P. & Phillips, J. Neoliberal energy transitions in the South: Kenyan experiences. *Geoforum* **74**, 39–48 (2016).
333. Ćetković, S. & Buzogány, A. Varieties of capitalism and clean energy transitions in the European Union: When renewable energy hits different economic logics. *Clim. Policy* **16**, 642–657 (2016).
334. Benney, T. M. Varieties of capitalism and renewable energy in emerging and developing economies. *J. Econ. Policy Reform* **24**, 413–438 (2021).
335. Jiang, P., Zha, D., Yang, G. & Xia, D. Which decarbonization policy mixes are better for China's power sector? A simulation balancing aggregate abatement effects and economic impacts. *Energy Econ.* **139**, 107900 (2024).
336. Heritage Foundation. Index of Economic Freedom. https://www.heritage.org/index/pages/about (2025).
337. European Environmental Agency. Integrated National Climate and Energy Policies and Measures (PaM). https://www.eea.europa.eu/en/datahub/datahubitem-view/6f1efaf1-ae32-48cb-b962-0891f84b1f5f (2025).
338. NewClimate Institute. Climate Policy Database. https://climatepolicydatabase.org/policies (2024).

339. OECD. Policy Instruments for the Environment (PINE) Database. https://www.oecd.org/en/data/datasets/policy-instruments-for-the-environment-pine-database.html (2025).
340. Fais, B., Blesl, M., Fahl, U. & Voß, A. Analysing the interaction between emission trading and renewable electricity support in TIMES. *Clim. Policy* **15**, 355–373 (2015).
341. Aryanpur, V. *et al.* How energy subsidy reform can drive the Iranian power sector towards a low-carbon future. *Energy Policy* **169**, 113190 (2022).
342. Günther, C., Pahle, M., Govorukha, K., Osorio, S. & Fotiou, T. Carbon prices on the rise? Shedding light on the emerging second EU Emissions Trading System (EU ETS 2). *Clim. Policy* 1–12 (2025) doi:10.1080/14693062.2025.2485196.
343. Daly, H. E. & Ó Gallachóir, B. P. Future energy and emissions policy scenarios in Ireland for private car transport. *Energy Policy* **51**, 172–183 (2012).
344. Pietzcker, R. C., Osorio, S. & Rodrigues, R. Tightening EU ETS targets in line with the European Green Deal: Impacts on the decarbonization of the EU power sector. *Appl. Energy* **293**, 116914 (2021).
345. Wu, Y.-H. & Lee, T.-C. Designing a cost-effective policy mix for transition toward net-zero emissions: a case study of the mid-term plan by 2035 of Taiwan. *Carbon Manag.* **15**, 2379545 (2024).
346. Jordan, K. H., Dennin, L. R., Adams, P. J., Jaramillo, P. & Muller, N. Z. Climate Policy Reduces Racial Disparities in Air Pollution from Transportation and Power Generation. *Environ. Sci. Technol.* **58**, 21510–21522 (2024).
347. Fais, B., Blesl, M., Fahl, U. & Voß, A. Comparing different support schemes for renewable electricity in the scope of an energy systems analysis. *Appl. Energy* **131**, 479–489 (2014).
348. Garðarsdóttir, S. Ó., Göransson, L., Normann, F. & Johnsson, F. Improving the flexibility of coal-fired power generators: Impact on the composition of a cost-optimal electricity system. *Appl. Energy* **209**, 277–289 (2018).
349. Li, F. G. N. & Trutnevyte, E. Investment appraisal of cost-optimal and near-optimal pathways for the UK electricity sector transition to 2050. *Appl. Energy* **189**, 89–109 (2017).
350. Chen, G. C. The United States–China Race for Green Transformation: Institutions, Incentives, and Green Industrial Policies. *J. Chin. Polit. Sci.* **29**, 461–482 (2024).
351. Price, J., Keppo, I. & Dodds, P. E. The role of new nuclear power in the UK's net-zero emissions energy system. *Energy* **262**, 125450 (2023).
352. Otti, M. & Zwickl-Bernhard, S. Net-zero emissions in the energy-intensive industrial sector by 2040: Insights from a country with ambitious national renewable policies. *Energy Strategy Rev.* **60**, 101748 (2025).
353. Cousse, J., Wüstenhagen, R. & Schneider, N. Mixed feelings on wind energy: Affective imagery and local concern driving social acceptance in Switzerland. *Energy Res. Soc. Sci.* **70**, 101676 (2020).
354. Chater, N. & Loewenstein, G. The i-frame and the s-frame: How focusing on individual-level solutions has led behavioral public policy astray. *Behav. Brain Sci.* **46**, e147 (2023).

355. Lehner, M., Mont, O. & Heiskanen, E. Nudging – A promising tool for sustainable consumption behaviour? *J. Clean. Prod.* **134**, 166–177 (2016).
356. Ripamonti, J. P. Does being informed about government transparency boost trust? Exploring an overlooked mechanism. *Gov. Inf. Q.* **41**, 101960 (2024).
357. Grimmelikhuijsen, S. *et al.* Can decision transparency increase citizen trust in regulatory agencies? Evidence from a representative survey experiment. *Regul. Gov.* **15**, 17–31 (2021).
358. Vesa, J., Gronow, A. & Ylä-Anttila, T. The quiet opposition: How the pro-economy lobby influences climate policy. *Glob. Environ. Change* **63**, 102117 (2020).
359. Laboutková, Š., Šimral, V. & Vymětal, P. Beyond lobbying regulation: the advantages of a broader approach to implementing and evaluating transparent lobbying rules. *Interest Groups Advocacy* **14**, 194–218 (2025).
360. Johnson, N. & Reimer, T. Using the social identity model of pro-environmental behavior to predict support for the adoption of solar panels. *J. Environ. Stud. Sci.* **13**, 587–601 (2023).
361. Todor, A., Țăranu, A., Udrea, R., Dănilă, M. & Helepciuc, F.-E. Policies to bring about social-ecological tipping points in coal and carbon intensive regions. *Glob. Environ. Change* **90**, 102952 (2025).
362. Mahmood, S., Iqbal, A., Alhussan, A. A. & El-kenawy, E.-S. M. Political stability and good governance as catalysts for achieving sustainable cities, clean energy, and responsible consumption: evidence from an emerging economy. *Humanit. Soc. Sci. Commun.* **12**, 1823 (2025).
363. Stoyan, A. T. Ambitious Reform Via Constituent Assemblies: Determinants of Success in Contemporary Latin America. *Stud. Comp. Int. Dev.* **55**, 99–121 (2020).
364. Yesilkagit, K., Bauer, M., Peters, B. G. & Pierre, J. The Guardian State: Strengthening the public service against democratic backsliding. *Public Adm. Rev.* **84**, 414–425 (2024).
365. Latré, E., Perko, T. & Thijssen, P. Public opinion change after the Fukushima nuclear accident: The role of national context revisited. *Energy Policy* **104**, 124–133 (2017).
366. Rubino, G. *et al.* Spatial strategies for siting variable renewable energy sources to ensure weather resilience in Switzerland. *Renew. Energy* **249**, 123237 (2025).
367. Kim, J., Jaumotte, F., Panton, A. J. & Schwerhoff, G. Energy security and the green transition. *Energy Policy* **198**, 114409 (2025).
368. D'Andrea, A., Fusacchia, G. & D'Ulizia, A. Policy Review: Countering Disinformation in the Digital Age - Policies and Initiatives to Safeguard Democracy in Europe. *Inf. Polity* **30**, 82–91 (2025).
369. Flonk, D., Jachtenfuchs, M. & Obendiek, A. Controlling internet content in the EU: towards digital sovereignty. *J. Eur. Public Policy* **31**, 2316–2342 (2024).
370. Van Der Kooij, P. Putting the three-tenets energy justice framework into policy practice: A case study in the Netherlands. *Energy Res. Soc. Sci.* **127**, 104300 (2025).
371. Heeter, J. & Reames, T. Incorporating energy justice into utility-scale photovoltaic deployment: A policy framework. *Renew. Energy Focus* **42**, 1–7 (2022).

372. Ding, H., Zhou, D. Q., Liu, G. Q. & Zhou, P. Cost reduction or electricity penetration: Government R&D-induced PV development and future policy schemes. *Renew. Sustain. Energy Rev.* **124**, 109752 (2020).
373. Senninger, R. & Blom-Hansen, J. Meet the critics: Analyzing the EU Commission's Regulatory Scrutiny Board through quantitative text analysis. *Regul. Gov.* **15**, 1436–1453 (2021).
374. Tong, D. *et al.* Committed emissions from existing energy infrastructure jeopardize 1.5 °C climate target. *Nature* **572**, 373–377 (2019).
375. Wang, X., Wang, B. & Wang, S. Policy-driven pathways to decouple China's hydrogen expansion from carbon lock-in. *Energy* **344**, 139924 (2026).
376. Zantvoort, B. Political inertia and social acceleration. *Philos. Soc. Crit.* **43**, 707–723 (2017).
377. Tchorzewska, K. B., Rio, P. D., Garcia-Quevedo, J. & Martinez-Ros, E. Carrot first, stick second? Environmental policy-mix sequencing and green technologies. *Technol. Forecast. Soc. Change* **210**, 123835 (2025).
378. Cellini, M. *et al.* Exploring the nexus of gender and energy transitions: A systematic literature review. *Energy Res. Soc. Sci.* **119**, 103887 (2025).
379. Zhang, W., Li, B., Xue, R., Wang, C. & Cao, W. A systematic bibliometric review of clean energy transition: Implications for low-carbon development. *PLOS ONE* **16**, e0261091 (2021).
380. Fodstad, M. *et al.* Next frontiers in energy system modelling: A review on challenges and the state of the art. *Renew. Sustain. Energy Rev.* **160**, 112246 (2022).
381. Krupa, J. & Jones, C. Black Swan Theory: Applications to energy market histories and technologies. *Energy Strategy Rev.* **1**, 286–290 (2013).
382. Plazas-Niño, F. A., Ortiz-Pimiento, N. R. & Montes-Páez, E. G. National energy system optimization modelling for decarbonization pathways analysis: A systematic literature review. *Renew. Sustain. Energy Rev.* **162**, 112406 (2022).
383. Löffler, K., Burandt, T., Hainsch, K. & Oei, P.-Y. Modeling the low-carbon transition of the European energy system - A quantitative assessment of the stranded assets problem. *Energy Strategy Rev.* **26**, 100422 (2019).
384. Van de Schoot, R. & De Bruin, J. Researcher-in-the-loop for systematic reviewing of text databases. Preprint at https://doi.org/10.5281/ZENODO.4013206 (2020).
385. Quan, Y., Tytko, T. & Hui, B. Utilizing ASReview in screening primary studies for meta-research in SLA: A step-by-step tutorial. *Res. Methods Appl. Linguist.* **3**, 100101 (2024).
386. Boetje, J. & Van De Schoot, R. The SAFE procedure: a practical stopping heuristic for active learning-based screening in systematic reviews and meta-analyses. *Syst. Rev.* **13**, 81 (2024).
387. Kempeneer, S., Pirannejad, A. & Wolswinkel, J. Open government data from a legal perspective: An AI-driven systematic literature review. *Gov. Inf. Q.* **40**, 101823 (2023).

388. Gómez-Llobell, M., Peleteiro Raíndo, A., Climent Medina, J., Gómez Centurión, I. & Mosquera Orgueira, A. Immune Checkpoint Inhibitors in Acute Myeloid Leukemia: A Meta-Analysis. *Front. Oncol.* **12**, 882531 (2022).