Table S2 - Summary of Methodological Characteristics of Composite Sustainability Indices in the Electricity and Energy Sector

Author(Year)	Category / Focus	Geography	Scope	Method	Weighting / Normalization	Key Indicators Used	Key Limitations
Prokhorova, Budanov & Budanov (2024)	Generalized integrated indicator for energy safety (ZNPP case)	Ukraine	Industrial power-generation enterprise	Indicative analysis + AHP + expert estimation + automated monitoring	Expert weighting; normalization through analytic hierarchy consistency checks	Energy security, reliability, operational risk, staff competency, equipment condition	Limited external data validation; sample restricted to one enterprise (ZNPP); heavy reliance on expert scoring for weight calibration
Cavallaro (2015)	Fuzzy Environmental Pressure Index (FEPI) for electricity generation	Italy	Energy technology–specific	Mamdani-type Fuzzy Inference System	Linguistic rules; membership-based fuzzification; centroid defuzzification	Air pollution, radiation, water/soil contamination, health impact	Uses qualitative membership functions; lacks empirical calibration with real emission data
Qian et al. (2024)	EEBD-3ES model – Energy, Economy, Environment, Social impacts of coal reduction	China	National–provincial level	Hybrid AHP + Entropy Weight + Scenario Simulation	Entropy for data-driven weights; AHP for qualitative adjustment	Economic output, employment, emissions, social welfare, trade	Model complexity and dependence on scenario assumptions; limited sensitivity testing on weight shifts

Neofytou, Nikas & Doukas (2020)	Sustainable Energy Transition Readiness (SETR Index)	Greece & EU	Cross-country (14 EU states)	Hybrid PROMETHEE II + AHP	AHP for weights; preference functions for ranking	Governance, innovation, infrastructure, policy, finance, technology	Temporal limitation (single-year data); expert sample size moderate (n≈15)
Raza, Janajreh & Ghenai (2014)	Sustainability Index for energy storage system selection	Pakistan / UAE	Technology-level comparison (fuel cell vs Li-polymer vs lead-acid)	Weighted Sum MCDA	Expert-assigned weights; range normalization	Technical, economic, environmental, and lifecycle	Limited indicator breadth (3 techs only); subjective weighting without validation
Goldrath, Ayalon & Shechter (2015)	Combined Sustainability Index for electricity efficiency measures	Israel	National energy efficiency policy	MCDA (five sub-index model)	Equal weights; normalized across dimensionless scores	Economic, environmental, technological, social, political	Static dataset (single-year snapshot); equal weights not empirically justified
Liu (2014)	General Sustainability Indicator (conceptual synthesis + review)	China	Global conceptual framework	Literature synthesis + fuzzy AHP conceptualization	Weighted aggregation (illustrative); discusses AHP/entropy	Environmental, economic, social, institutional, technical	Conceptual—no primary data or model testing; no reproducibility metrics
Wang et al. (2020)	Fuzzy evaluation for transition reliability in Integrated	China	System-level (IES)	Multi-level Fuzzy Comprehensive Evaluation	Combined empowerment (AHP + Entropy)	Reliability, economy, environment, safety	Case-specific data from one IES; no comparative benchmark validation

	Energy Systems (IES)						
Wu et al. (2021)	Low-carbon transition performance assessment	China	Regional / national	Improved TOPSIS + Entropy	Entropy-based objective weights; Euclidean normalization	Carbon intensity, renewable share, GDP, energy efficiency	Uses annual cross-sectional data; no stakeholder verification
Raza et al. (2014, early version)	Preliminary sustainability index for energy storage	UAE	Technological prototype	Weighted Sum MCDA	Equal weighting (pilot model)	Technical, cost, and environmental	Prototype iteration without peer benchmarking; lacks uncertainty treatment
Afgan (2010)Afgan	Conceptual / Framework	Europe (EU energy systems)	Conceptual design of Intelligent Energy Systems using ICT for sustainability assessment	MCDA (Multi-criteria Decision Analysis)with additive weighted index	Weighted arithmetic mean; normalization of multi-dimensional indices; fuzzy set membership functions	Economic (Investment, O&M, Electricity cost), Environmental (CO_2, Air pollution, Particulates), Social (Acceptability, Job creation), Resource (Material use, Recycling)	No empirical data validation; limited stakeholder participation; theoretical model only; assumes perfect data availability

Cucchiella et al. (2017)cucchiella2017	Quantitative / Empirical	28 EU countries	Country-level sustainability benchmarking (Environment + Energy)	AHP + MCDA hybridusing Eurostat datasets	Pairwise comparison matrix normalized (Saaty scale); CR<0.1 ensures consistency	9 indicators: GHG emissions, Government Env. Expenditure, Recycled WEEEs, Recycled ELVs, Recycled MSW, Renewable share (electricity, transport, heating), Primary Energy Efficiency	Limited to environmental and energy pillars (no social/economic); snapshot year (2013); relies on expert survey consistency
Torul Yürek et al. (2024)	Multi-objective optimization of national energy system with battery storage	Turkey	National-level planning (2022–2030)	MOLP + Pythagorean Fuzzy AHP–TOPSISintegrated MCDM	AHP-derived weights for criteria; entropy consistency within fuzzy set; normalization via linear scaling	4 criteria (Economic, Technological, Social, Environmental); Sub-indices: Sustainability Index (SI), Socio-Political Index (SPI), Cost/LCOE, Emission reduction, Job creation, Policy incentives	SI and SPI partially rely on expert judgment from earlier models; limited stakeholder diversity; short-term projection (2022–2030)

Ospina Betancur et al. (2022)	Relationship between economic/social growth and energy development	Colombia	National / macroeconomic	Multivariate statistical analysis(correlation, dispersion matrices, pictorial graphs)	Standardization for variance control; no weighting scheme	Economic (GDP, industry, consumption), Social (employment, education, life quality), Energy (generation, access, consumption)	Purely correlational; lacks predictive modeling or index aggregation; single-year cross-sectional
Mainali & Silveira (2015)MainaliSilveiraUsingaSustainabi…	Sustainability index for rural electrification technologies	India	Techno-socio comparison of 10 systems (2005–2015)	PCA-based ETSI composite index	Z-score standardization + principal components weight	Economic (cost, efficiency), Social (job creation, acceptance), Environmental (emissions)	Static index (no dynamic interactions); expert validation limited
Ordu & Soytaş (2015)ordu2015	Energy commodity–market interaction	Turkey	Pre/post-2008 financial crisis	VAR & Granger causality	Log-normalized returns	Oil, Gas, Electricity prices vs stock indices	No sustainability dimension; short sample period
Sarkodie & Adams (2020)Sarkodie	Electricity access vs HDI and inequality	Sub-Saharan Africa	26 countries (2000–2018)	Driscoll–Kraay panel regression	Cross-country normalization of HDI & access indices	Electricity access, Governance, Inequality, HDI	Limited qualitative stakeholder data
Shah et al. (2019)shah2019	Energy Security + Environmental Sustainability Index (ESESI)	South Asia	8 countries (2006–2017)	Composite MCDA	Min–max normalization + equal weights	Energy imports, RES share, CO_2, efficiency	Equal weight bias; no economic pillar

Yumashev et al. (2020)Yumashev 2020	HDI vs energy consumption and CO_2	Global (UN/OECD dataset)	Cross-country macro study	Econometric regression	PPP adjustment	HDI, GDP, CO_2, energy share	No MCDA or weighting structure
Zieliński & Jonek-Kowalska (2021)Zielinksiii	CSR vs profitability in energy companies	Poland	Firm-level (2009–2019)	Descriptive + comparative financial analysis	Ratio normalization	ROA, ROE, EPS, CSR index membership	CSR definition narrow (only stock index)
Yan et al. (2020)yan2020	Industrial quality capacity index for smart energy meters	China	Sectoral (technical benchmarking)	MCDA + PCA verification	Principal component weights	Standardization, inspection, metrology, R&D	Industrial scope only; no social context
Reyer et al. (2017)Stein 2013	Climate change impact meta-assessment	Latin America & Caribbean	Regional multi-sectoral	Meta-analysis of model outputs	Comparative normalization	GDP loss, temperature, agriculture, water stress	Synthesizes secondary data; not original index
Konara et al. (2021)	Energy transition policy evaluation	Sri Lanka	National contextual study	Indicative framework analysis	Qualitative scoring	Renewable target, policy readiness	Limited quantitative validation

Stein (2013)	Global energy development and sustainability trends	Global	120 countries (1980–2012)	Comparative quantitative trend analysis + macro-indicator correlation	Normalized by GDP and population; no weighting	Energy intensity, CO_2 per capita, renewable share, GDP growth, electricity access	No formal index; lacks normalization across sustainability pillars; limited statistical modeling
Doukas et al. (2012)	EU Energy Policy Index	EU-27	Policy performance of member states	MCDA (AHP + expert scoring)	Expert weights; normalization [0–1]	Efficiency, environment, tech readiness, security	Subjectivity in expert weights; limited temporal data
Ediger et al. (2007)	Fossil Fuel Sustainability Index (FFSI)	Global (62 countries)	Fossil fuel dependency and sustainability	Composite index, PCA weighting	Equal & PCA weights; 0–1 scaling	R/P ratio, P/C ratio, CO_2 intensity	Lacks socio-economic context; only fossil metrics
Falbo et al. (2010)	Electricity Market Index (FAST)	Spain & Germany	Electricity spot price dynamics	Quantitative simulation, Axiomatic Index Theory	Weighted averages vs axiomatic structure	Price volatility, market manipulation risk, hedging efficiency	Not a sustainability index; no environmental dimension
Kılkış (2018)	Urban sustainability benchmarking (SDEWES Index)	South-East Europe (18 cities)	City systems – energy, water, environment	MCDA + Monte Carlo Simulation	Normalized (0–5 scale); equal weights	35 indicators across 7 dimensions (energy, water, waste, air, transport, governance, economy)	Data availability heterogeneity across cities
Neelawela et al. (2019)	Electricity security index	Global (14 countries)	25-year historical analysis	Composite Index Construction	Entropy weight + Normalization (0–1)	Affordability, reliability, efficiency, environmental impact	Small sample of countries limits global representativeness

Neves & Leal (2010)	Local energy sustainability planning	Portugal (EU case)	Municipal energy plans	Indicator framework + pilot testing	Equal weights; normalized scale	18 indicators – supply mix, CO_2, efficiency, access	No quantitative aggregation or composite score
Abu-Rayash & Dincer (2021)	Energy sustainability and resilience	Global (203 countries)	1990-2019 panel analysis	MCDA + Entropy Weight + Index Aggregation	Normalized to [0, 1]; entropy weights	Energy security, efficiency, access, renewables	Does not fully capture institutional stability
Abubakar et al. (2015)	Energy and development index	Nigeria	National	AHP + Entropy Hybrid MCDA	Weighted sum (0–1)	Energy use, GDP growth, social development	Small data sample; expert bias in AHP
Brown et al. (2007)	Energy security evolution	USA	National policy framework	Indicator trend analysis	Normalized trends	Availability, affordability, efficiency, environment	Descriptive; no composite aggregation
De Vito et al. (2017)	Renewable integration efficiency	EU-28	National energy performance	Entropy Weight + TOPSIS	Entropy weights; Euclidean distance	Renewables share, emissions, cost, innovation	Static snapshot; lacks long-term validation
Huang et al. (2020)	Provincial energy transition index	China (31 provinces)	Regional transition readiness	Fuzzy Comprehensive Evaluation	Entropy weights + Fuzzy membership	Economic, technical, environmental dimensions	Subjectivity in fuzzy membership grading
Iddrisu & Bhattacharyya (2015)	Energy development index	Sub-Saharan Africa	National	Composite indicator method	Equal weights (0–1 scaling)	Electricity access, per capita use, CO_2	Missing data for rural areas
Kemmler & Spreng (2007)	Energy sustainability index	India	National energy system	MCDA + Indicator Normalization	Equal weights (0–1 scale)	Equity, security, environment	No time-series updating mechanism

Patlitzianas et al. (2008)	Renewable energy readiness index	Mediterranean / EU	Policy and infrastructure readiness	Regression + Policy indicator scoring	Normalization to [0–1]; regression-based weights	Policy, investment, R&D, renewable share	Data comparability limits cross-country synthesis
Razmjoo et al. (2019)	Sustainable Energy Development Index (SEDI)	Iran	National energy sustainability	AHP + Entropy + COPRAS	Hybrid weighting; normalized 0–1	Economic, environmental, technical, policy	Limited to national context
Salarvand et al. (2010)	Provincial energy sustainability ranking	Iran (regional)	Sub-national	TOPSIS (MCDA)	Distance-based normalization	Efficiency, energy intensity, access	Static, lacks temporal dynamics
Sharma et al. (2019)	Energy transition readiness	South Asia	Regional	Entropy + Grey Relational Analysis	Entropy weights; grey normalization	Energy access, renewables, cost, emissions	Minimal qualitative stakeholder engagement
Tsai (2010)	Energy sustainability via national indicators	Taiwan	National	PSR framework + Weighted sum	Weighted aggregation; PSR-based normalization	Supply, consumption, CO_2 emissions, renewables	Only two explicit energy indicators in TSDI
Vera & Langlois (2007)	UN energy sustainability framework	Global	Methodological template	Indicator development & standardization	None (conceptual benchmark)	Accessibility, efficiency, environment, affordability	No empirical case data
Wang et al. (2020)	Dynamic energy security	China	National time-series (1990–2017)	Functional Data Analysis + Entropy	Dynamic functional weighting	Energy supply, consumption, environmental	Complexity limits replication

	index (DESI)						
Zhong et al. (2020)	Sustainable urbanization index	China (East, Central, West)	Urbanization & regional disparities	Entropy weighting + Survey analysis	Entropy-based weights; standardized z-scores	Economic, social, ecological, rural-urban heterogeneity	Survey biases; administrative disparities
Mayer et al. (2004)	Multidisciplinary review of sustainability indices (ecological, economic, thermodynamic)	Global conceptual	Cross-disciplinary taxonomy of indices	Narrative review + comparative framework	N/A	Resilience, carrying capacity, green income, exergy	No empirical data; purely conceptual
Narula & Reddy (2015)	Comparison of energy security and sustainability indices	Global (100+ countries)	Benchmark index comparison	Indicator decomposition & correlation analysis	Normalization (0–1), rank aggregation	ESI, IIESR, EAPI country scores	Dependent on secondary datasets
Romero & Linares (2014)	Exergy-based sustainability indicator framework	Global conceptual	Energy system efficiency and thermodynamic balance	Systematic review + theoretical model	N/A (thermodynamic ratios)	Physical & chemical exergy, irreversibility loss	Difficult to operationalize for policy
Shortall & Davidsdottir (2017)	National energy sustainabilit	Iceland	National policy assessment	Expert interviews + comparative index analysis	Qualitative scoring vs OECD/IISD criteria	Affordability, equity, environment, efficiency, security	Limited quantitative data integration

	y performance						
Streimikiene & Siksnelyte (2016)	Electricity market sustainability	12 OECD countries	Market liberalization and sustainability performance	Linear regression + comparative MCDA	Weighted scoring (Economic/Social/Env.)	Affordability, competitiveness, CO_2 intensity, equity	Static year snapshot