Supplementary Materials

Table S1. Operational definitions of criteria and sub-criteria used in the AHP model

Level	Dimension	Sub-criterion	Operational definition (used for expert evaluation)
Level 2	Benefits	Economic and financial attractiveness	The extent to which a policy improves project profitability, reduces investment risk, enhances return on investment, or improves access to financial resources for biomass energy projects.
Level 2	Benefits	Energy security and system resilience	The contribution of a policy to enhancing national energy security, diversifying the energy mix, and improving system reliability through stable and dispatchable biomass power generation.
Level 2	Benefits	Environmental benefit	The degree to which a policy reduces greenhouse gas emissions, mitigates air pollution, supports waste valorization, and contributes to environmental sustainability goals.
Level 2	Benefits	Rural and community development	The potential of a policy to generate rural employment, support local income generation, strengthen agricultural value chains, and promote inclusive community development.
Level 2	Constraints	Regulatory uncertainty	The extent of ambiguity, inconsistency, or unpredictability in laws, regulations, permitting procedures, and power-purchase agreements that may increase perceived investment risk.
Level 2	Constraints	Financial barrier	Barriers related to capital availability, financing costs, interest rates, access to credit, subsidy uncertainty, and overall financial feasibility of biomass energy projects.
Level 2	Constraints	Technological barrier	Constraints arising from technology maturity, operational reliability, maintenance requirements, equipment availability, and technical performance risks of biomass conversion systems.
Level 2	Constraints	Feedstock supply instability (climate-adjusted)	The risk of insufficient or unreliable biomass feedstock supply due to yield variability, seasonal availability, logistics disruption, and climate-related factors such as drought, heat stress, and irregular rainfall.
Level 2	Constraints	Information and social acceptance barrier	Barriers associated with limited public awareness, community resistance, misinformation, and lack of social trust toward biomass energy projects, excluding formal policy communication measures.

Table S2. Description of policy alternatives and illustrative examples used in the AHP model

Policy alternative	Scope and operational description	Illustrative policy instruments and examples
Law and regulatory policy	Legal and institutional measures aimed at reducing regulatory uncertainty and improving policy consistency and enforceability for investors.	Streamlined licensing and permitting; standardized PPAs; improved regulatory transparency and inter-agency coordination; legal revisions to reduce approval delays.
Economic and privatization-initiated policy	Market-based and financial instruments designed to reduce financial barriers and enhance economic attractiveness and project bankability.	Feed-in tariffs (FITs); tax incentives; low-interest loans and credit guarantees; PPP schemes; privatization initiatives.
Research and development (R&D) policy	Policy measures supporting technological innovation to address technological barriers and improve system reliability and efficiency.	Public R&D grants; pilot and demonstration projects; technology testing and certification; efficiency improvement programs.
Public relations and community collaboration policy	Instruments aimed at improving information availability, social acceptance, and stakeholder engagement in biomass projects.	Community consultation; public awareness campaigns; stakeholder engagement platforms; benefit-sharing mechanisms.
Environmental policy	Regulatory and incentive-based instruments to manage environmental impacts and ensure compliance with sustainability requirements.	Emission standards; EIA requirements; sustainability certification schemes; incentives for low-emission and waste-to-energy technologies.

Table S3. One-at-a-time (OAT) sensitivity analysis under ±50% perturbation of sub-criterion weights

Sub-criterion	Shock	Law and Regulatory	Economic and Privatization	R&D Policy	Public Relations	Environmental Policy	Top Alternative
Economic attractiveness	+50%	0.320	0.243	0.174	0.148	0.116	Law & Regulatory
Economic attractiveness	-50%	0.297	0.236	0.188	0.152	0.126	Law & Regulatory
Energy security	+50%	0.309	0.240	0.180	0.151	0.120	Law & Regulatory
Energy security	-50%	0.312	0.240	0.180	0.149	0.120	Law & Regulatory
Environmental benefit	+50%	0.307	0.238	0.180	0.153	0.123	Law & Regulatory
Environmental benefit	-50%	0.314	0.242	0.180	0.147	0.117	Law & Regulatory
Rural development	+50%	0.304	0.237	0.180	0.155	0.125	Law & Regulatory
Rural development	-50%	0.317	0.243	0.180	0.145	0.114	Law & Regulatory
Regulatory uncertainty	+50%	0.315	0.240	0.179	0.148	0.117	Law & Regulatory
Regulatory uncertainty	-50%	0.304	0.240	0.181	0.152	0.123	Law & Regulatory
Financial barrier	+50%	0.312	0.242	0.179	0.149	0.118	Law & Regulatory
Financial barrier	-50%	0.307	0.237	0.181	0.152	0.123	Law & Regulatory
Technological barrier	+50%	0.306	0.240	0.188	0.146	0.120	Law & Regulatory
Technological barrier	-50%	0.315	0.240	0.170	0.155	0.119	Law & Regulatory
Feedstock instability	+50%	0.309	0.240	0.180	0.150	0.121	Law & Regulatory
Feedstock instability	-50%	0.311	0.240	0.180	0.150	0.119	Law & Regulatory
Info & social acceptance	+50%	0.309	0.239	0.180	0.151	0.121	Law & Regulatory
Info & social acceptance	-50%	0.311	0.241	0.180	0.149	0.119	Law & Regulatory

Table S4. Summary of OAT (±50%) robustness results and rank stability assessment

Baseline scores	**Law and Regulatory**	**Economic and Privatization**	**R&D Policy**	**Public Relations**	**Environmental Policy**
Score	0.31	0.24	0.18	0.15	0.12
Score ranges across OAT shocks (±50%)	**Law & Regulatory**	**Economic & Privatization**	**R&D Policy**	**Public Relations**	**Environmental Policy**
Min	0.297	0.236	0.170	0.145	0.114
Max	0.320	0.243	0.188	0.155	0.126

Rank stability check	
Number of OAT scenarios	18
Top alternative changed in any scenario?	No
Any rank reversal among all 5 policies?	No

Table S5. Decision matrix representation of the AHP aggregation process for biomass-energy policy prioritization

Node/Element	Goal	Benefits	Constraints	Economic	Energy	Environment	Rural	Supply	Institute	Fin	Tech	Info	Final score
Benefits	**0.560**	**0.000**	**0.000**	**0.487**	**0.209**	**0.095**	**0.209**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.00**
Constraints	**0.440**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.065**	**0.260**	**0.212**	**0.519**	**0.060**	**0.00**
Economic growth & financial attractiveness	0.273	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00
Energy security & system resilience	0.117	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00
Environmental benefit	0.053	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00
Rural & community development	0.117	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00
Feedstock supply instability	0.029	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00
Regulatory uncertainty	0.114	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00
Financial barrier	0.093	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00
Technological barrier	0.228	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00
Information & social acceptance barrier	0.026	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00
Law and regulatory policy	0.000	0.000	0.000	0.350	0.320	0.200	0.220	0.280	0.450	0.400	0.300	0.250	0.31
Economic & privatization-initiated policy	0.000	0.000	0.000	0.300	0.250	0.180	0.200	0.220	0.250	0.300	0.250	0.200	0.24
Research and development (R&D) policy	0.000	0.000	0.000	0.150	0.180	0.170	0.180	0.200	0.150	0.150	0.250	0.200	0.18
Public relations & community collaboration policy	0.000	0.000	0.000	0.100	0.150	0.250	0.220	0.150	0.100	0.100	0.100	0.200	0.15
Environmental policy	0.000	0.000	0.000	0.100	0.100	0.200	0.180	0.150	0.050	0.050	0.100	0.150	0.12
Final scores	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**1.00**

Table S6. Conceptual comparison of decision-support approaches under uncertainty

Criterion	Crisp AHP (This study)	Fuzzy / Neutrosophic MCDM	Probabilistic / Scenario-based models
Treatment of uncertainty	Addressed via expert consistency and sensitivity analysis	Explicit modeling of linguistic ambiguity and expert hesitation	Explicit stochastic representation using probability distributions
Transparency	High; intuitive pairwise comparison and traceable weights	Moderate; membership and belief functions increase abstraction	Moderate to low; dependent on probabilistic assumptions
Data requirements	Low; relies primarily on expert judgments	Moderate; requires fuzzy/neutrosophic parameter specification	High; requires historical data or scenario probabilities
Interpretability for policymakers	High; results easily communicated	Moderate; interpretation less intuitive for non-technical users	Lower; results sensitive to statistical assumptions
Suitability for policy prioritization	High; effective for strategic screening and ranking	Moderate; useful when expert ambiguity dominates	High for operational planning, limited for early policy ranking
Computational complexity	Low	Moderate to high	High
Typical application focus	Policy evaluation and stakeholder-driven prioritization	Decision-making under subjective uncertainty	Dynamic risk and scenario analysis
Representative references	Saaty (1980)	Zadeh (1965	Clemen & Reilly (2001)