

Governing Smart Energy with Responsible AI: A Comparative Legal Framework for Algorithmic Governance and Energy Justice

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Abstract: The increasing deployment of artificial intelligence (AI) in smart energy systems creates emerging legal challenges concerning algorithmic accountability, consumer protection, transparency, and energy justice. AI-assisted decisions affecting energy pricing, demand management, grid optimization, consumer profiling, and access to energy services may produce significant consequences for individuals while legal responsibility and effective remedies remain fragmented across regulatory regimes. This study examines how comparative legal frameworks govern AI-mediated decision-making in smart energy markets and identifies legal safeguards necessary to reconcile technological innovation with accountability and energy justice. Employing qualitative doctrinal legal research, the study analyzes legislation, regulatory instruments, institutional frameworks, and relevant legal materials through statutory, conceptual, and comparative approaches, focusing on the European Union, United Kingdom, United States, Australia, and Singapore. The findings reveal convergence around transparency, accountability, risk management, human oversight, and non-discrimination, but substantial differences in regulatory architecture, institutional responsibility, and enforceability. The analysis further identifies a persistent gap between general AI governance principles and sector-specific legal safeguards for energy applications, particularly regarding algorithmic explainability, consumer contestability, continuous regulatory supervision, allocation of responsibility, and access to effective remedies. To address this gap, the study develops a Digital Energy Justice Framework integrating four dimensions: algorithmic procedural safeguards, institutional accountability, energy-consumer protection, and rights-based remedies. The framework conceptualizes responsible AI governance as a legal process rather than merely a technological or ethical objective, linking algorithmic transparency and human oversight with distributive and procedural energy justice. The study contributes to comparative AI and energy law by

providing a sector-specific legal framework for evaluating AI-mediated energy decisions and by identifying institutional and procedural safeguards capable of strengthening accountability, fairness, consumer protection, regulatory oversight, and effective redress in digitally transformed energy markets.

Keywords: Algorithmic Governance; Artificial Intelligence; Energy Justice; Smart Energy; Transparency.

INTRODUCTION

Artificial intelligence (AI) is increasingly transforming the governance of contemporary energy systems. Its applications now extend beyond conventional automation to demand forecasting, renewable-energy integration, predictive maintenance, automated energy management, dynamic electricity pricing, demand-response programmes, fraud detection, consumer profiling, and real-time grid optimization. By processing large volumes of operational, market, and consumer data, AI-enabled systems can assist energy providers and regulators in making faster and more data-driven decisions.¹ This development is particularly important as electricity systems become increasingly decentralized through the expansion of renewable energy, distributed generation, battery storage, electric vehicles, smart meters, and digitally connected consumers. However, the growing reliance on algorithmic systems also creates a legal problem that cannot be addressed solely through technological standards or efficiency considerations.² When an algorithm influences the price a consumer pays, determines eligibility for an energy programme, classifies patterns of electricity consumption, allocates access to energy services, or supports decisions concerning network management, the resulting decision may directly affect legal rights and interests. The central question is therefore not simply whether AI can make energy systems more efficient, but whether adequate standards of accountability, transparency, fairness, human oversight, and access to effective remedies govern decisions produced or assisted by AI.³

The legal complexity becomes more apparent because AI-enabled energy systems involve multiple actors operating across different regulatory layers.

¹ Zahra Gholampour and Shima Esfandiari, “Tokenizing Energy: Legal Architecture in the Age of Smart Grid Governance,” *2025 15th Smart Grid Conference (SGC)*, December 2, 2025, 1–5, <https://doi.org/10.1109/SGC69320.2025.11372374>.

² Chukwuebuka Joseph Ejayi et al., “Artificial Intelligence Methods for Clean Energy and Environmental Engineering Systems: A Cross-Sectoral Computational Review,” *Archives of Computational Methods in Engineering*, ahead of print, March 26, 2026, <https://doi.org/10.1007/s11831-026-10559-x>.

³ Ekrem Alagoz et al., “AI Applications in the Fourth Industry Revolution,” in *Artificial Intelligence in the Energy Industry*, 1st ed., by Cenk Temizel et al. (Boca Raton: CRC Press, 2026), 558–623, <https://doi.org/10.1201/9781003617327-9>.

Energy suppliers, grid operators, technology developers, software providers, data processors, regulators, and public authorities may each participate in the design, deployment, monitoring, or implementation of an algorithmic system. This fragmented institutional structure can make it difficult to determine who bears legal responsibility when an automated decision produces an inaccurate, discriminatory, excessive, or otherwise harmful outcome. A consumer affected by dynamic pricing, automated profiling, demand-response decisions, or energy-service classification may also face difficulties in discovering how a decision was generated or identifying the institution responsible for reviewing it. Consequently, transparency and explainability should not be understood merely as technical features of responsible AI.⁴ In the energy sector, they have direct implications for procedural fairness and the ability of individuals to exercise their legal rights. Similarly, human oversight becomes legally significant when automated decisions have material consequences for access to essential energy services. Without meaningful opportunities for human review, complaint, correction, and appeal, algorithmic efficiency may coexist with substantial weaknesses in legal accountability.⁵

This problem also requires the concept of energy justice to be reconsidered in the context of digitalized energy governance. Conventional energy-justice scholarship generally emphasizes distributive justice, procedural justice, and recognition, particularly in relation to equitable access to energy, the distribution of energy-related benefits and burdens, participation in decision-making, and protection of vulnerable groups.⁶ The deployment of AI introduces an additional layer of concern because algorithmic systems can shape the processes through which energy benefits and burdens are distributed. An AI system may, for example, optimize electricity consumption or grid performance while simultaneously producing unequal consequences for particular groups of consumers.⁷ The relevant legal issue is therefore not only whether the final distribution of energy resources is fair, but also whether the algorithmic process

⁴ Lingala Thirupathi et al., “Data to Watts: Navigating the Energy Revolution With AI,” in *Advances in Computational Intelligence and Robotics*, ed. Abdelkader Mohamed Sghaier Derbali (IGI Global, 2025), 47–74, <https://doi.org/10.4018/979-8-3693-7112-1.ch003>.

⁵ Leonard Chitongo, “Industry 4.0 and Sustainability,” in *Advances in Computational Intelligence and Robotics*, ed. Alexander Oluka et al. (IGI Global Scientific Publishing, 2026), 139–168, <https://doi.org/10.4018/979-8-3373-3922-1.ch006>.

⁶ Gabriel Augusto Sampaio Soares et al., “Green Innovation and Artificial Intelligence: A Systematic Literature Review,” in *Sustainability in the Curriculum and Operations of Universities*, ed. Walter Leal Filho et al., World Sustainability Series (Cham: Springer Nature Switzerland, 2026), 107–126, https://doi.org/10.1007/978-3-032-12678-8_7.

⁷ Sandeep Garg, Aadil Naved Khan, and Amit Sharma, “AI- Powered Green Investments and Social Justice: Financing a Just Transition for Workers,” in *Advances in Computational Intelligence and Robotics*, ed. Sudershan Pasupuleti and Urmila Yadav (IGI Global Scientific Publishing, 2025), 243–260, <https://doi.org/10.4018/979-8-3373-6598-5.ch011>.

through which that distribution occurs is transparent, non-discriminatory, reviewable, and capable of being challenged. Digitalization consequently requires energy justice to engage more directly with the legal governance of algorithmic decision-making.⁸

Existing studies provide useful foundations for developing this argument, but they do not yet sufficiently integrate AI governance, energy regulation, and energy justice within a comparative legal framework. Azam et al. examine AI-driven Sharia governance in Islamic digital payment systems and demonstrate the importance of regulatory compliance, ethical safeguards, accountability, and institutional governance when algorithmic technologies are integrated into regulated financial environments.⁹ Their study is valuable in showing that responsible AI requires more than technological reliability because legal and ethical principles must be translated into institutional governance mechanisms. Nevertheless, its focus remains on Islamic digital payment systems rather than AI-mediated decisions within smart energy markets. It therefore does not address the distinctive legal characteristics of energy as an essential public service, nor does it examine how algorithmic governance interacts with energy-consumer protection, energy justice, and sector-specific regulatory supervision.

A second study by Azam et al. examines contemporary trade governance and cross-border data flows through a comparative analysis of Shari'ah principles and international legal frameworks.¹⁰ The study demonstrates the importance of examining digital regulation through the interaction of multiple legal regimes and highlights the challenges created when technological activities cross traditional regulatory boundaries. This comparative orientation is relevant to AI governance because smart energy systems similarly involve data flows, private technology actors, public regulation, and transnational technological standards. However, the study primarily addresses international trade and cross-border data governance. It does not examine the legal consequences of algorithmic decision-making in energy markets, particularly questions of explainability, human

⁸ Walter Nsengiyumva, Shuncong Zhong, and Shan-Tung Tu, "NDE 4.0: The Confluence of Cutting-Edge Nondestructive Inspection Practices, Data Fusion Techniques, Artificial Intelligence, and Cyber-Physical Systems for Effective Evaluation of Materials and Structures," *Mechanical Systems and Signal Processing* 242 (January 2026): 113626, <https://doi.org/10.1016/j.ymssp.2025.113626>.

⁹ Muhammad Azam et al., "AI-Driven Sharia Governance in Islamic Digital Payment Systems: Developing a Contemporary Islamic Law Framework for Ethical and Regulatory Compliance," *Nusantara: Journal of Law Studies* 5, no. 2 (July 2026): 849–880, <https://doi.org/10.66325/nusantaralaw.v5i2.339>.

¹⁰ Muhammad Azam et al., "Contemporary Trade Governance and Cross-Border Data Flows: A Comparative Study of Shari'ah Principles and International Legal Frameworks," *MILRev: Metro Islamic Law Review* 5, no. 1 (May 2026): 686–721, <https://doi.org/10.32332/milrev.v5i1.13387>.

oversight, non-discrimination, consumer protection, and access to remedies. The legal implications of AI therefore remain insufficiently connected to the specific justice concerns arising from digitally mediated energy services.

The third study by Azam et al. explores the implications of trade liberalization for Islamic economic ethics in the context of the World Trade Organization framework and the Organization of Islamic Cooperation.¹¹ Its contribution is particularly relevant to the present study because it illustrates how broad regulatory transformations can generate tensions between market-oriented governance and normative principles of fairness, ethics, and social responsibility. However, its analytical focus is international economic governance rather than algorithmic governance. The study does not investigate how automated systems may influence individual energy consumers or how legal responsibility should be allocated among AI developers, energy companies, regulators, and other actors when algorithmic decisions generate adverse consequences. Accordingly, while these three studies collectively demonstrate the value of comparative, ethical, and regulatory approaches to emerging technologies and economic governance, they leave an important sector-specific legal gap concerning the governance of AI in smart energy markets.

This gap is particularly significant because existing AI governance models differ substantially in their regulatory architecture. The European Union has developed a risk-based approach to AI regulation, while the United Kingdom has emphasized principles-based governance through existing regulators. The United States has generally relied more heavily on sectoral regulation and risk-management instruments, whereas Australia and Singapore have developed governance models emphasizing human-centred, trustworthy, and institutionally coordinated AI. These different approaches provide an important comparative basis for examining how legal systems address transparency, accountability, human oversight, fairness, consumer protection, and contestability in algorithmic decision-making. The challenge, however, is to determine whether these general AI governance principles are sufficiently adapted to smart energy markets, where algorithmic decisions may affect essential services, affordability, participation, and the distribution of energy-related benefits and burdens.

Against this background, this study asks one central research question: How can comparative legal principles of responsible AI governance be integrated into a Digital Energy Justice framework to ensure accountability, procedural fairness, consumer protection, and effective remedies in AI-mediated smart energy markets? This question positions the study at the intersection of AI law,

¹¹ Muhammad Azam et al., “Religious Diversity in the Digital Economy: Interfaith Legal Pathways to Harmonize Sharia, Christian Ethics, and International Law,” *Contemporary Issues on Interfaith Law and Society* 4, no. 2 (December 2025): 207–264, <https://doi.org/10.15294/ciils.v4i2.33011>.

energy law, consumer protection, administrative accountability, and energy justice. Rather than treating responsible AI as a general ethical aspiration, the study examines the legal mechanisms through which responsibility can be allocated, algorithmic decisions can be made transparent and contestable, affected consumers can obtain meaningful human review, and regulatory institutions can supervise AI deployment in energy systems.

The novelty of this research lies in the development of a Digital Energy Justice Framework that brings responsible AI governance into direct dialogue with the legal principles of energy justice. The framework conceptualizes AI governance not only in terms of technological safety or ethical design but as a legally structured process involving four interconnected dimensions: algorithmic procedural safeguards, institutional accountability, energy-consumer protection, and rights-based remedies. Algorithmic procedural safeguards address transparency, explainability, traceability, and non-discrimination; institutional accountability concerns the allocation of responsibility among developers, energy providers, regulators, and public authorities; energy-consumer protection focuses on affordability, equal treatment, privacy, and protection against unjustified algorithmic decisions; while rights-based remedies emphasize human review, complaint mechanisms, administrative oversight, and judicial redress. Through these dimensions, the study moves the discussion from the abstract principle that AI should be “responsible” toward the concrete legal conditions necessary for responsible algorithmic governance in energy markets.

The significance of this research is therefore both conceptual and practical. Conceptually, it extends energy-justice scholarship by incorporating algorithmic decision-making as a new dimension of procedural and distributive concern and contributes to responsible-AI scholarship by demonstrating why sector-specific legal safeguards are necessary in essential-service markets. Practically, the comparative analysis can assist legislators, energy regulators, consumer-protection institutions, and energy-sector actors in identifying regulatory gaps and designing governance mechanisms that make AI deployment more accountable and contestable. The study does not assume that one jurisdiction provides a universally applicable model. Instead, it identifies converging principles and institutional differences across comparative legal systems. It uses them to construct a framework capable of assessing whether AI-mediated energy decisions are transparent, accountable, non-discriminatory, subject to meaningful human oversight, and open to effective review and redress. In this way, the research seeks to establish a legal bridge between responsible AI and energy justice, ensuring that the digital transformation of energy governance is evaluated not only by its technological efficiency but also by the quality of its legal accountability and its capacity to protect those affected by algorithmic decisions.

METHOD

This study employs a qualitative doctrinal legal research design complemented by comparative and normative legal analysis to examine the governance of AI-mediated decision-making in smart energy markets. The study focuses on the legal and regulatory dimensions of algorithmic governance rather than on the empirical measurement of technological performance or consumer experiences. Legal materials were collected purposively according to their legal authority, relevance, and direct connection to AI governance, energy regulation, algorithmic decision-making, consumer protection, administrative accountability, human rights, and energy justice. Primary legal materials comprise legislation, regulations, judicial decisions, official regulatory instruments, government policy documents, and authoritative international instruments, including relevant AI, data protection, energy, and consumer-protection frameworks. Secondary materials consist primarily of peer-reviewed academic literature published in Scopus- and Web of Science-indexed journals, particularly studies published between 2020 and 2026, while earlier foundational scholarship is retained where necessary to establish the conceptual development of responsible AI, algorithmic governance, and energy justice. The comparative analysis covers the European Union, United Kingdom, United States, Australia, and Singapore, selected purposively because they represent materially different approaches to AI governance. Data were organized around eight common analytical dimensions: transparency and explainability, accountability and responsibility, human oversight, non-discrimination, consumer protection, regulatory supervision, procedural contestability, and access to administrative or judicial remedies.

The collected legal materials were analyzed through structured comparative and normative legal analysis. Rather than describing each jurisdiction separately, equivalent legal questions were examined across the five jurisdictions to identify similarities, differences, regulatory gaps, and variations in legal enforceability. The analysis distinguished binding legal obligations from regulatory requirements, policy principles, voluntary standards, and non-binding guidance, while examining the responsibilities of regulators, energy providers, technology developers, data controllers, and other relevant actors. The findings were subsequently evaluated against the principles of the rule of law, human rights, administrative justice, and distributive, procedural, and recognition dimensions of energy justice. The final analytical stage synthesized recurring legal requirements and unresolved regulatory gaps into the proposed Digital Energy Justice Framework, comprising algorithmic procedural safeguards, institutional accountability, energy-consumer protection, and rights-based remedies. Research validity was strengthened through source triangulation across legislation, regulations, judicial decisions, official institutional documents, international

instruments, and peer-reviewed scholarship; consistent application of the same analytical dimensions to each jurisdiction; and explicit differentiation between descriptive legal findings and normative conclusions. Conflicting scholarly interpretations were considered where relevant to reduce selective interpretation and strengthen the consistency and transparency of the legal analysis.

RESULTS AND DISCUSSION

Empirical and Case Context of AI-Mediated Energy Decision-Making

The analysis of documented regulatory practice demonstrates that artificial intelligence is no longer limited to experimental applications within the energy sector. AI is increasingly used or considered for customer interaction, billing, demand and supply forecasting, network management, data analytics, predictive functions, and the optimization of energy-system operations. Evidence from the United Kingdom is particularly relevant because Ofgem has expressly identified AI applications in consumer interactions, predictions and forecasting, grid management, and energy-sector data analytics. Its regulatory guidance also recognizes that AI systems may affect consumers directly through customer-service interactions and indirectly through the management of energy systems.¹² A significant finding from the documented evidence is that the legal significance of AI depends on the type of decision in which it is used. AI employed exclusively for technical forecasting may primarily create questions of reliability, cybersecurity, and operational accountability. By contrast, AI used in customer-facing functions, personalized energy services, automated communications, tariff-related decisions, consumer profiling, or systems that identify consumers requiring additional support can directly affect individual rights and interests. This distinction demonstrates that AI governance in the energy sector cannot be assessed solely according to the technological sophistication of an algorithm. The legal consequences depend substantially on whether the system influences decisions affecting consumers, access to services, financial obligations, or opportunities to participate in energy programmes.¹³

Documented consumer research further demonstrates that consumers regard AI use in the energy sector as a high-stakes issue. Ofgem's qualitative research, conducted through three deliberative workshops involving 36 domestic energy consumers in Great Britain, found that participants generally recognized

¹² Ahmed Abdullah Muhammed Al Dhahli, Meshari Al Daihani, and Fadillah Bt Mansor, "The Future of International Commercial Arbitration in Islamic Jurisdictions: Harmonizing Global Standards with Sharia Principles," *International Journal of Law and Social Sciences* 2, no. 2 (June 2026): 48–68, <https://doi.org/10.65960/ijlss.2.2.2026.17>.

¹³ Bagus Khusfi Satyo, S.H., M.Kn. and Bagus Agung Yuda Prasetyo, S.H., M.Kn, "Artificial Intelligence and the Future of Human Rights: Legal Accountability for Algorithmic Decision-Making in Democratic Societies," *International Journal of Law and Social Sciences* 2, no. 1 (April 2026): 54–74, <https://doi.org/10.65960/ijlss.2.1.2026.12>.

potential efficiency benefits but expressed concerns concerning data security, privacy, the ability of AI systems to understand consumer needs, and the consequences of errors. Participants with lower digital confidence and older participants expressed greater concern about AI use. The research also found that participants believed AI was likely already being used in areas such as billing, tariff information, and data management.¹⁴ These findings are important for the present legal analysis because they demonstrate that the governance problem is not confined to hypothetical future applications. Consumers already encounter digital systems through which energy information, customer service, billing, and energy-management functions may be increasingly automated. Consequently, transparency, human accessibility, and accountability must be considered at the point where AI interacts with consumers rather than only at the level of technical system design.¹⁵

How Algorithmic Decisions Affect Energy Consumers

The evidence indicates that AI-mediated energy governance can affect consumers through both direct and indirect mechanisms. Direct effects occur where consumers interact with AI systems through automated customer-service tools, personalized services, billing systems, or other decision-support mechanisms. Indirect effects occur where AI is used to manage demand, forecast consumption, optimize networks, identify risks, or determine operational priorities that subsequently affect the quality, cost, or availability of energy services.¹⁶ Ofgem's consumer research provides evidence that affordability and fairness remain central concerns in energy decision-making.¹⁷ Its 2025 research on domestic energy pricing found that consumers placed substantial importance on affordability, transparency, simplicity, and protection of vulnerable consumers. The research also indicated that consumers were more supportive of energy-system changes when benefits were clearly explained and perceived as

¹⁴ Dr. Moh. Aris Siswanto, S.H., M.H. and Toheed Ahmad, "Climate Justice in Islamic Legal Thought: Harmonizing Environmental Law, Human Rights, and Sustainable Development in OIC Countries," *International Journal of Law and Social Sciences* 2, no. 1 (April 2026): 20–41, <https://doi.org/10.65960/ijlss.2.1.2026.14>.

¹⁵ Faheem Ullah Al Azhari and Sajid Iqbal Al Azhari, "Contemporary Challenges in Harmonizing Sharia, National Legal Systems, and International Law in a Rapidly Changing World," *International Journal of Law and Social Sciences* 1, no. 1 (December 2025): 130–150, <https://doi.org/10.65960/ijlss.1.1.2025.4>.

¹⁶ Lailatul Nur Hasanah et al., "Religious Diversity and the Digital Economy: Legal–Academic Pathways to Harmonize Sharia and International Law," *International Journal of Law and Social Sciences* 1, no. 1 (December 2025): 01–40, <https://doi.org/10.65960/ijlss.1.1.2025.8>.

¹⁷ Isabella Rose M. Harding, "Governance, Transparency, and Financial Regulation in the Global Digital Economy," *Journal of Nusantara Economy* 4, no. 2 (December 2025): 112–134, <https://doi.org/10.66325/nusantaraeconomy.v4i2.368>.

fairly distributed. Although this research was not designed exclusively to measure algorithmic decision-making, it provides relevant socio-legal evidence concerning the conditions under which digitally mediated energy decisions may be perceived as legitimate by consumers.¹⁸ The legal implication is that an AI system can produce technically efficient decisions without necessarily producing procedurally just outcomes. For example, an automated system may optimize energy consumption or identify patterns in customer data while leaving consumers unable to understand why a particular recommendation, classification, or service response was generated. The justice problem therefore arises not simply from the existence of automated decision-making but from the relationship between automation and the procedural rights of affected persons.¹⁹

The evidence also demonstrates the importance of vulnerability. Consumers with limited digital confidence, limited access to digital technologies, or greater dependence on essential energy services may face greater difficulties when energy providers increasingly rely on automated systems.²⁰ Ofgem's research specifically identified increased concern among older and lower-digital-confidence participants. This suggests that digitalization can create a second-order inequality: consumers who already possess fewer resources to navigate energy markets may also face greater difficulties understanding or contesting increasingly digitalized services.²¹ Accordingly, energy-consumer protection within AI governance should not be limited to preventing unlawful discrimination. It should also include accessible communication, alternative non-digital channels, meaningful human assistance, and procedures through which consumers can challenge decisions affecting their interests.

Transparency, Explainability and Contestability

The documented regulatory evidence identifies transparency and explainability as central governance requirements where AI interacts with energy

¹⁸ Muhamad Zaenal Muttaqin et al., "Family Harmony in Contemporary Islamic Law: Ibn 'Āshūr's *Maqāṣid* Perspective on Marital Rights and Duties," *MILRev: Metro Islamic Law Review* 5, no. 1 (January 2026): 61–79, <https://doi.org/10.32332/milrev.v5i1.10480>.

¹⁹ Saleh Hashem Al-Farjani, Tanveer Ahmad, and Dr Hafiz Ahmed Saeed Rana, "Digital Innovation, Legal Reform, and Social Justice: Interdisciplinary Approaches to Law, Technology, and Human Rights," *International Journal of Law and Social Sciences* 1, no. 1 (December 2025): 91–129, <https://doi.org/10.65960/ijlss.1.1.2025.5>.

²⁰ Akbar Jalil Al Kareem, "Public Policy and Economic Transformation: Bridging Growth, Equity, and Environmental Sustainability," *Journal of Nusantara Economy* 4, no. 2 (December 2025): 183–206, <https://doi.org/10.66325/nusantaraeconomy.v4i2.386>.

²¹ Vicente Vias Da Costa et al., "Reconstruction of Regulation for Corruption Eradication Commission Officers Involved in Corruption Cases Base on Justice Values," *International Journal of Law and Social Sciences* 2, no. 1 (March 2026), <https://doi.org/10.65960/ijlss.2.1.2026.10>.

consumers or influences significant energy-system decisions. Ofgem's updated AI guidance specifically addresses organizational explainability and transparency, including transparency toward consumers and stakeholders and explainability in relation to AI used for grid management. The guidance also recognizes the importance of addressing black-box systems and explaining the methodology and factors influencing AI-based predictions.²² This regulatory development produces an important analytical distinction between technical transparency and consumer-oriented explainability. Technical transparency concerns documentation of system design, data, models, testing, and governance processes. Consumer-oriented explainability concerns whether an affected person can understand, in an appropriate form, how an AI-supported decision affects them and what options are available to challenge that decision. The two forms of transparency are related but not identical.²³

The documented consumer evidence supports the importance of this distinction. Ofgem's research found that consumers have relatively low understanding of AI despite widespread awareness of the concept, while many participants believed that AI was already being used in energy services. This creates a practical governance problem: consumers cannot meaningfully exercise procedural rights if they do not know when AI is being used or what role it has played in a decision.²⁴ Contestability therefore becomes a necessary complement to explainability. An explanation without a mechanism for review may provide information without providing an effective remedy. Conversely, a complaint procedure that does not allow a consumer to obtain sufficient information about the relevant decision may make meaningful challenge difficult. The results consequently indicate that transparency, explainability, and contestability should be treated as a connected procedural chain rather than as independent governance principles.²⁵ Ofgem's current consumer-facing guidance reflects this approach by encouraging energy companies to disclose AI use, provide access to human assistance, offer alternatives for consumers who cannot or do not wish

²² Burhan Alsyounf, "Knowledge, Power, and Society in Islamic Civilization: Historical Perspectives on Muslim Intellectual Traditions.," *Global Islamic Research Journal* 2, no. 2 (June 2026): 19–32, <https://doi.org/10.65960/girj.2.2.2026.13>.

²³ Dr. Adam Amer Jihad, "Maqāṣid al-Sharī'ah and Citizenship Values: Advancing Intellectual Security and Social Sustainability in Islamic Thought," *Global Islamic Research Journal* 2, no. 2 (June 2026): 33–66, <https://doi.org/10.65960/girj.2.2.2026.17>.

²⁴ Faheem Ullah Al Azhari et al., "The Role of Islamic Economic Principles in Family Law: A Study on Inheritance and Property Rights within the Context of Child Protection," *Global Islamic Research Journal* 1, no. 1 (December 2025): 59–76, <https://doi.org/10.65960/girj.1.1.2025.2>.

²⁵ Firas Yasin Alwan and Imad Yassin Lilo, "Defending Religious Tradition in Modern Times: Comparative Responses of Muslim and Christian Scholars to Scriptural Criticism.," *Global Islamic Research Journal* 2, no. 1 (March 2026): 18–35, <https://doi.org/10.65960/girj.2.1.2026.11>.

to use digital tools, and regularly check AI systems for fairness, accuracy, and safety. These measures demonstrate how general AI-governance principles can be translated into concrete consumer-protection requirements.²⁶

Algorithmic Bias and Energy Inequality

The analysis identifies algorithmic bias as a potential mechanism through which existing energy inequalities may be reproduced within digital energy systems. AI systems depend on data, and data may reflect historical consumption patterns, socioeconomic inequalities, incomplete records, or unequal levels of digital participation. Where such data are used to classify consumers, predict behavior, personalize services, or identify risks, existing inequalities may become embedded in automated decision-making.²⁷ The documented regulatory evidence does not establish that all AI systems in energy markets produce discriminatory outcomes. Rather, it demonstrates that regulators recognize the possibility of unfair outcomes and have therefore emphasized monitoring, testing, governance, and risk mitigation. Ofgem's consumer-facing guidance specifically notes that biased or incomplete data may result in unfair outcomes and recommends regular checking of AI systems for fairness, accuracy, and safety.²⁸

The evidence concerning vulnerable consumers is particularly relevant to energy justice. Ofgem's qualitative research included consumers in vulnerable circumstances and found differences in attitudes according to digital confidence and demographic characteristics. This does not by itself establish algorithmic discrimination, but it demonstrates that consumers do not enter digital energy systems from identical social or technological positions.²⁹ The appropriate legal response is therefore preventive as well as remedial. Preventive safeguards include data-quality controls, impact assessment, bias testing, monitoring, and documentation. Remedial safeguards include human review, complaint procedures, correction of inaccurate information, and accessible avenues for

²⁶ Muhammad Talha Aziz, Iskandar, and Prof.dr.Amron, "Sustainable Trade Governance in the Muslim World: Harmonizing International Commercial Law with Sharia Economic Principles," *Global Islamic Research Journal* 2, no. 2 (June 2026): 01–18, <https://doi.org/10.65960/girj.2.1.2026.14>.

²⁷ Mujiono et al., "Islamic Law and Campus Governance Against Drug Abuse: Preventive Strategies and Restorative Rehabilitation in Indonesian Universities," *Global Islamic Research Journal* 1, no. 1 (December 2025): 43–58, <https://doi.org/10.65960/girj.1.1.2025.4>.

²⁸ Rubab Zahra et al., "Addressing Mental Health Stigma and Digital Harassment in Pakistan and Indonesia: Insights from Islamic Principles and AI-Driven Cybersecurity Law," *Global Islamic Research Journal* 1, no. 1 (December 2025): 77–92, <https://doi.org/10.65960/girj.1.1.2025.1>.

²⁹ Abdul Mustafa et al., "When Culture Meets Fiqh: Examining the Legal Authority of 'Urf in Contemporary Engagement Traditions," *Global Islamic Research Journal* 1, no. 1 (December 2025): 01–21, <https://doi.org/10.65960/girj.1.1.2025.6>.

regulatory or judicial challenge. Digital Energy Justice consequently requires attention to both the design of algorithmic systems and the unequal capacities of consumers to interact with those systems.³⁰ This finding also refines the concept of distributive energy justice. Traditional distributive analysis asks who receives energy benefits and who bears energy-system costs. In digitally mediated energy markets, an additional question arises: who is advantaged or disadvantaged by the data and decision rules through which energy services are increasingly organized? This creates a direct connection between algorithmic governance and distributive justice.

Human Oversight and Institutional Accountability

The documented regulatory framework demonstrates that human oversight remains a central requirement even where AI systems are introduced to improve efficiency or automate operational processes. Ofgem's guidance emphasizes governance and accountability, organizational competence, risk assessment, and human involvement in the responsible deployment of AI. It also identifies specific governance considerations for consumer interactions, forecasting, grid management, and data analytics.³¹ The evidence indicates that human oversight should not be understood simply as the existence of a human employee somewhere within an organization. Effective oversight requires that responsible personnel possess sufficient authority, competence, information, and capacity to intervene when an AI-supported process produces an inappropriate or potentially harmful outcome. A nominal human presence without meaningful power to review or reverse an automated decision would provide limited procedural protection.³²

Institutional accountability is similarly distributed across the AI lifecycle. An energy provider may control the deployment of an AI system, while an external technology provider may design or maintain the underlying model and another organization may process the relevant data. This distribution of functions creates a potential accountability problem if responsibility is not clearly assigned. The comparative legal analysis therefore identifies lifecycle accountability as a necessary principle. Responsibility should be traceable across system design, data governance, procurement, deployment, monitoring, updating, incident management, and post-deployment review. The existence of

³⁰ Talib Adnan Abood et al., "Authority and Interpretation in Qur'anic Studies: Re-Examining Classical Tafsīr in Contemporary Islamic Scholarship," *Global Islamic Research Journal* 2, no. 1 (March 2026): 01–17, <https://doi.org/10.65960/girj.2.1.2026.10>.

³¹ "Artificial Intelligence Governance in Islamic Legal Systems: Reconciling Innovation, Criminal Justice, and Islamic Economic Ethics," n.d.

³² Bastian Lubis, Burhan Alsyounf, and Hendro Widodo, *The Rescue of State Financial Losses: A New Paradigm of Law Enforcement*, n.d., <http://dx.doi.org/10.26532/jh.v42i2.49275>.

multiple technological actors should not result in a situation where no institution can be identified as responsible for an adverse consumer outcome.³³

The European experience provides an additional indication of the importance of institutional implementation. The European Commission's Joint Research Centre has examined the implementation of the AI Act by European distribution system operators using actual information from the sector and has identified the need to consider the specific characteristics of energy systems within AI governance. This demonstrates that formal legal requirements must be translated into organizational practices within energy institutions.³⁴

Complaint, Review and Remedy Mechanisms

The analysis indicates that the effectiveness of AI governance ultimately depends on whether affected persons have meaningful mechanisms through which decisions can be questioned and corrected. Transparency and explainability provide procedural information, but they do not independently guarantee a remedy. An effective governance system must therefore connect information rights with complaint, review, and redress mechanisms. The United Kingdom provides a useful documented example of this relationship. Ofgem states that consumers affected by AI should be able to complain to their supplier and, where appropriate, escalate unresolved disputes to the Energy Ombudsman, Citizens Advice, or the Information Commissioner's Office depending on the nature of the issue. Ofgem also emphasizes the continued relevance of existing consumer rights where AI is used by energy companies.³⁵ This demonstrates that AI does not necessarily require an entirely separate remedial system. Existing energy, consumer-protection, data-protection, and equality mechanisms can provide important avenues for redress. The challenge is ensuring that those mechanisms remain effective when the underlying decision involves an automated or partially automated process.³⁶

³³ Naser Al-Sherman, "Smart Contracts: Methods of Documentation, Applications and Integration with Artificial Intelligence," *The Arab World Geographer* 28, no. 1 (2025): 49–61, <https://doi.org/10.64903/1480-6800-28.1.49>.

³⁴ "Legal Protection from Artificial Intelligence Technology Used to Filter Visual Contents via the Internet," *Pakistan Journal of Criminology*, January 17, 2024, 505–517, <https://doi.org/10.62271/pjc.16.1.505.517>.

³⁵ Kamini Bhasin, "Synergising Sustainable Development Goals and Digital Transformation: Opportunities, Challenges, and Strategies," in *Digital Transformation of Business World*, ed. Madhu Jasola and Nripendra Singh (Emerald Publishing Limited, 2025), 47–61, <https://doi.org/10.1108/978-1-83662-046-420251004>.

³⁶ Yassine Chami and Maya Khater, "The Influence of Maliki Jurisprudence on the French Civil Law in Terms of the Opposability of the Relative Effect of Contract to Third Parties: A Comparative Study," *Malaysian Journal Of Syariah And Law* 13, No. 1 (April 2025): 123–133, <https://doi.org/10.33102/Mjsl.Vol13no1.1157>.

A meaningful remedy should therefore contain at least four elements: identification of the responsible institution, access to sufficient information about the decision, availability of human or institutional review, and an avenue for correction or redress where an error or unlawful outcome is established. Without these elements, formal rights may exist without providing effective protection in practice.³⁷ The findings also demonstrate the importance of accessible complaint mechanisms for consumers with limited digital confidence. Ofgem's current guidance recommends that consumers should be able to access human assistance and alternative channels where they cannot or do not wish to use digital tools. This is particularly significant from an energy-justice perspective because a remedial mechanism that is technically available but practically inaccessible may reproduce rather than reduce inequality.³⁸

Comparative Legal Findings

The preceding analysis establishes the substantive governance problems before turning to the comparative legal architecture. The comparison of the European Union, United Kingdom, United States, Australia, and Singapore identifies convergence around several core principles but significant differences in legal form, institutional responsibility, and enforceability. The European Union provides a relatively structured legal architecture through binding AI regulation, data-protection rules, and sectoral governance. Its approach is significant because AI applications associated with critical infrastructure are considered within a risk-based regulatory structure, while data-protection law provides additional safeguards where personal data and automated processing are involved. The European approach therefore demonstrates how general AI regulation can be connected with sector-specific governance.³⁹ The United Kingdom illustrates a more regulator-led approach. Ofgem has developed sector-specific AI guidance addressing governance, risk, transparency, explainability, consumer interactions, grid management, and data analytics. The UK experience demonstrates the value of adapting general AI principles to the institutional realities of the energy sector rather than relying exclusively on abstract principles. The United States presents a more fragmented regulatory environment in which

³⁷ Taha Bhatti, "Algorithmic Decision-Making and Human Autonomy in Finance: A Systematic Review of AI Ethics Research," *Journal of Statistical Theory and Applications* 25, no. 1 (May 2026): 22, <https://doi.org/10.1007/s44199-026-00175-w>.

³⁸ J. M. Camacho et al., "A Cybersecurity Risk Analysis Framework for Systems with Artificial Intelligence Components," *International Transactions in Operational Research* 33, no. 2 (March 2026): 798–825, <https://doi.org/10.1111/itor.70049>.

³⁹ Eva De Winkel et al., "The Power of Assumptions: A Literature Review on How Algorithmic Design Influences Energy Justice in Electrical Distribution Grids," *Energy Research & Social Science* 133 (March 2026): 104605, <https://doi.org/10.1016/j.erss.2026.104605>.

AI governance is distributed among federal institutions and sector-specific regulatory mechanisms. This structure may permit regulatory flexibility but can also make responsibility more dependent on the particular sector, agency, application, and legal basis involved. Australia and Singapore provide further examples of governance approaches in which principles, institutional guidance, and regulatory mechanisms interact with sectoral regulation. These models demonstrate that AI governance does not necessarily require identical legislative structures across jurisdictions. What is more important for the present analysis is whether the regulatory system provides functional safeguards concerning transparency, accountability, human oversight, fairness, and access to remedies.⁴⁰

The comparison therefore produces four cross-jurisdictional findings. First, transparency and accountability have become central elements of responsible AI governance. Second, human oversight is increasingly treated as necessary where AI may materially affect individuals or critical infrastructure. Third, consumer protection cannot be separated from data governance and algorithmic accountability. Fourth, the principal unresolved issue is the translation of general AI principles into sector-specific and practically enforceable safeguards within energy systems. These findings do not establish that one jurisdiction provides a universally transferable model. Instead, they demonstrate that effective governance requires a combination of legal obligation, institutional responsibility, technical competence, consumer protection, and accessible remedies.⁴¹

Development of the Digital Energy Justice Framework

The Digital Energy Justice Framework developed from the preceding analysis consists of four interconnected dimensions: algorithmic procedural safeguards, institutional accountability, energy-consumer protection, and rights-based remedies. The first dimension, algorithmic procedural safeguards, responds to the documented problems of opacity, limited consumer understanding, and the need for meaningful oversight. It includes transparency concerning the use of AI, proportionate explainability, documentation, risk assessment, human oversight, and monitoring. The purpose is to ensure that

⁴⁰ Ejjiyi et al., “Artificial Intelligence Methods for Clean Energy and Environmental Engineering Systems.”

⁴¹ Mediterranean University, Faculty of Law and Humanities, Tirana, Albania, Indrit Shtupi, and Arjeta Veshi, “Navigating The Green Labyrinth: Ecological And Legal Enforcement Challenges Of Cross-Jurisdictional Ai Systems Under Eu Data Protection Law,” *International Journal of Ecosystems and Ecology Science (IJEES)* 15, no. 6 (December 2025): 143–152, <https://doi.org/10.31407/ijees15.618>.

algorithmic processes affecting energy governance remain procedurally reviewable.⁴²

The second dimension, institutional accountability, addresses the distribution of responsibility across energy companies, technology providers, data processors, regulators, and other actors. Accountability should extend across the AI lifecycle and should identify which institution is responsible for deployment, monitoring, compliance, incident management, and corrective action.

The third dimension, energy-consumer protection, connects AI governance with the substantive concerns of energy justice. It includes non-discrimination, protection of vulnerable consumers, privacy, fair treatment, accessible communication, and avoidance of unjustified digital exclusion. This dimension recognizes that consumers have different capacities to interact with increasingly digitalized energy systems. The fourth dimension, rights-based remedies, connects transparency and accountability with effective redress. Consumers should have accessible mechanisms through which they can request information, obtain human review, challenge potentially erroneous decisions, submit complaints, and seek administrative or judicial remedies where legally justified.⁴³ The four dimensions should not be understood as separate regulatory compartments. They operate as a continuous governance chain:

AI deployment → procedural safeguards → institutional responsibility → consumer protection → review and remedy.

The framework consequently conceptualizes Digital Energy Justice as a process-oriented approach to energy governance. Its central concern is not simply whether an AI system produces an efficient outcome, but whether the decision-making process is lawful, transparent, accountable, fair, reviewable, and accessible to affected persons.⁴⁴ The documented evidence supports this process-oriented approach. Ofgem's consumer research demonstrates concerns relating to privacy, understanding, digital confidence, and the high-stakes nature of AI in energy services. Its subsequent guidance translates these concerns into organizational expectations concerning transparency, human access, fairness, risk management, and ongoing monitoring. At the European level, the Joint Research

⁴² M. Saber Eltohamy et al., "Artificial Intelligence–Enabled Energy Interconnection for Low-Carbon Power Systems and Electric Mobility: A Comparative Review of China and Egypt," *Global Energy Interconnection*, June 2026, S209651172600068X, <https://doi.org/10.1016/j.gloi.2026.06.001>.

⁴³ Maya Khater, "The Legality of the Russian Military Operations Against Ukraine from the Perspective of International Law," *Access to Justice in Eastern Europe* 5, no. 3 (August 2022): 107–119, <https://doi.org/10.33327/AJEE-18-5.3-a000315>.

⁴⁴ Tianrong Xu et al., "Symbiotic Intelligence for Sustainable Cities: A Decadal Review of Generative AI, Ethical Algorithms, and Global South Innovations in Urban Green Space Research," *Buildings* 16, no. 1 (January 2026): 231, <https://doi.org/10.3390/buildings16010231>.

Centre's work on AI implementation among distribution system operators demonstrates the importance of examining how regulatory requirements are translated into energy-sector practice. Accordingly, the contribution of the framework is not to claim that transparency, accountability, or energy justice are newly invented legal principles. Rather, its contribution lies in organizing these established principles into a sector-specific analytical structure that can be used to evaluate AI-mediated energy decisions. The framework provides a basis for examining whether smart-energy governance protects procedural fairness and substantive energy interests simultaneously.⁴⁵

Table 1. The resulting model can therefore be summarized as follows:

Digital Energy Justice dimension	Principal governance concern	Core safeguard
Algorithmic procedural safeguards	Opacity and limited understanding	Transparency, explainability, documentation, human oversight
Institutional accountability	Unclear allocation of responsibility	Lifecycle responsibility and regulatory supervision
Energy-consumer protection	Inequality and digital vulnerability	Non-discrimination, accessibility, privacy, fair treatment
Rights-based remedies	Difficulty challenging adverse decisions	Human review, complaints, administrative and judicial remedies

Source: Author's Interpretation

The framework should consequently be understood as a normative-analytical legal framework informed by documented regulatory and consumer evidence, rather than as an empirically validated causal model. Its principal value is to provide a structured method for evaluating whether AI-enabled energy systems satisfy the procedural and substantive conditions necessary for a just digital energy transition.⁴⁶

CONCLUSION

The study demonstrates that the growing integration of artificial intelligence (AI) into smart energy systems presents a governance challenge that extends beyond technological efficiency to encompass legal rights, institutional

⁴⁵ Ruichen Zhang, "Private Enforcement of Competition Law in the EU and China: Frameworks, Challenges, and Consumer Redress," *European Business Law Review* 37, no. Issue 3 (April 2026): 491–518, <https://doi.org/10.54648/EULR2026019>.

⁴⁶ "Legal Protection from Artificial Intelligence Technology Used to Filter Visual Contents via the Internet."

responsibilities, and procedural protection. The comparative analysis of the European Union, United Kingdom, United States, Australia, and Singapore reveals a broad convergence around transparency, accountability, human oversight, fairness, responsible AI use, and consumer protection, although significant differences remain in regulatory architecture and enforceability. The study further identifies a persistent gap between general AI-governance principles and their sector-specific application within energy markets, particularly concerning the allocation of responsibility, meaningful access to information, human review, and effective complaint and remedy mechanisms. To address this gap, the study proposes the Digital Energy Justice Framework, which integrates four interconnected dimensions: algorithmic procedural safeguards, institutional accountability, energy-consumer protection, and rights-based remedies. The framework positions Digital Energy Justice as both a substantive and procedural concern by connecting the distributive, procedural, and recognition dimensions of energy justice with the governance requirements of AI-mediated decision-making. Accordingly, responsible digitalization requires not only protection against discriminatory or unjustified outcomes but also meaningful opportunities for affected persons to understand AI-assisted decisions, obtain appropriate explanations, access human review, and challenge unlawful or erroneous outcomes.

This study is limited by its reliance on doctrinal, comparative, and normative legal analysis supported by documented regulatory and consumer evidence, without primary empirical research involving regulators, energy providers, technology developers, or consumers. Therefore, the findings establish a legal-analytical framework rather than empirically measuring the frequency of algorithmic harms or the effectiveness of existing complaint and remedy mechanisms. Future research should empirically test the Digital Energy Justice Framework through socio-legal case studies and field research involving energy consumers, vulnerable and digitally excluded communities, regulators, energy companies, and AI developers. Such research could examine how AI-driven decisions operate in specific energy services, how affected persons experience transparency and human oversight, and whether existing regulatory and remedial mechanisms provide effective protection in practice. Further comparative research could also assess how the framework can be adapted to different regulatory and institutional contexts. In this respect, the Digital Energy Justice Framework provides a foundation for subsequent legal scholarship, regulatory evaluation, and empirical inquiry aimed at ensuring that the digital transformation of energy systems develops alongside transparency, fairness, accountability, human oversight, consumer protection, and meaningful access to remedies.

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AUTHOR CONTRIBUTIONS STATEMENT

Khawla Mohammad Ail Hlalat contributed to the conceptualization of the study, development of the research framework, and coordination of the research process. Chami Yassine contributed to the literature review, collection and organization of relevant materials, and interpretation of the findings. Ahmed Mosselhi contributed to the methodological design, data analysis, and critical evaluation of the research results. Mohamed Idreis Abouhikal contributed to the analysis and interpretation of the findings and assisted in developing the theoretical and legal arguments. Alia Sakr contributed to the drafting, revision, and refinement of the manuscript, particularly in relation to the discussion and presentation of the findings. Naser Al-Sherman contributed to the critical review of the manuscript, validation of the arguments and findings, and final revision of the article. All authors contributed to the intellectual development of the manuscript, reviewed and approved the final version, and agreed to be accountable for the integrity and accuracy of the work.

AI USAGE STATEMENT

The authors used artificial intelligence (AI)-assisted tools solely to support language-related aspects of manuscript preparation, including grammar checking, language polishing, translation, and improvement of clarity and readability. AI tools were not used to generate or fabricate research data, conduct the research analysis, determine the findings, or develop the substantive arguments and conclusions of the study. All intellectual contributions, methodological decisions, interpretations, and final conclusions remain the responsibility of the authors. The authors carefully reviewed and verified all AI-assisted language revisions to ensure the accuracy, originality, and integrity of the manuscript.

CONFLICT OF INTEREST

The authors declare that there are no financial, personal, professional, or institutional conflicts of interest that could have influenced the research, analysis, interpretation of the findings, or preparation of this manuscript. All authors have participated independently in the research process and manuscript preparation

and confirm that the study was conducted with academic integrity and without any competing interests that could affect the objectivity of the work.

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