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AI-Based Energy Democracy: Smart Grids, Citizen Participation, and Decentralized Decision-Making

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Abstract

Energy democracy calls for a transformation of energy systems from centralized, expert-led infrastructures into participatory arrangements in which citizens have meaningful control over production, distribution, consumption, and governance. At the same time, AI-enabled smart grids are increasingly shaping how energy decisions are optimized, automated, and coordinated across decentralized networks. However, the democratic implications of these technologies remain insufficiently examined, as most AI applications in the energy sector continue to prioritize efficiency, reliability, and technical optimization over citizen agency, deliberative decision-making, transparency, and equitable power distribution. This article develops a conceptual framework for AI-based energy democracy by synthesizing insights from energy democracy theory, participatory governance, AI ethics, and decentralized energy systems literature. Rather than presenting empirical findings, the article offers a theoretical contribution that links core democratic values with specific AI functions in smart grids. The proposed framework identifies how AI can support citizen participation, decentralized coordination, collective decision-making, and more accountable forms of energy governance, while also highlighting risks such as technocratic control, algorithmic opacity, exclusion, data asymmetries, and unequal access to digital infrastructures. The article introduces a democratic-AI alignment matrix and a risk-and-safeguards analysis to clarify how AI systems can be designed to strengthen, rather than undermine, democratic energy transitions. The framework suggests that AI can either reinforce centralized and technocratic modes of control or enable more inclusive, participatory, and distributed forms of energy governance. By articulating design principles and safeguards for democratic AI in smart grids, this article provides a roadmap for ensuring that digital innovation amplifies citizen voice, redistributes decision-making power, and contributes to a more just and democratic energy transition.

Keywords Smart grid, AI, Energy democracy, Citizen participation, Decentralized decision-making, Democratic governance

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Introduction

Energy democracy has emerged as a response to centralized, carbon-intensive, and expert-dominated energy systems, emphasizing citizen control, collective ownership, and justice in the energy transition. Burke and Stephens frame energy democracy as a sociotechnical project that links decarbonization with redistribution of power, while Becker and Naumann show that the concept has become a broad vocabulary for energy alternatives [1, 2]. AI introduces a dual-edged possibility into this agenda because it could support distributed coordination, but it may also reinforce technocratic control

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if embedded in opaque platform infrastructures. The central question is therefore not whether AI should be used in smart energy systems, but how it should be democratically governed.

The gap addressed in this article is that AI in energy is often assessed through efficiency, reliability, optimization, and automation rather than democratic agency. Szulecki's conceptualization of energy democracy highlights popular sovereignty, participatory governance, and civic control, yet many AI applications in smart grids remain detached from these political commitments [3]. Van Veelen and Van Der Horst similarly argue that energy democracy requires connecting energy systems to democratic theory, which suggests that algorithmic systems should be evaluated according to who controls them, who benefits from them, and who can contest their outputs [4]. This gap becomes increasingly important as smart grids convert everyday energy behavior into data, forecasts, classifications, and automated recommendations.

A democratic framework for AI in energy must therefore be proactive rather than corrective. Van Veelen's analysis of community energy governance shows that democratic outcomes do not automatically arise from local or decentralized projects, because participation must be organized through concrete institutions and decision rules [5]. Hess likewise shows that energy democracy depends on social mobilization, institutional struggle, and collective agency, not only technological substitution [6]. AI-based energy democracy should consequently be designed around participation, deliberation, transparency, equity, and accountability from the outset.

This article contributes an original conceptual framework for AI-based energy democracy by integrating smart grid infrastructure, citizen participation, and decentralized decision-making. The framework treats AI as a civic capacity that could help citizens interpret energy choices, deliberate over trade-offs, and coordinate collective action, while also requiring safeguards against algorithmic capture. Building on work on smart grid sociotechnical dimensions by Meadowcroft, Stephens, Wilson, and Rowlands, the article positions grid architecture itself as politically consequential [7]. The sections that follow define the democratic foundations of the framework, map AI functions to democratic principles, and propose participation architectures for energy communities. **Figure 1** shows the participation–governance framework for AI-based energy democracy.

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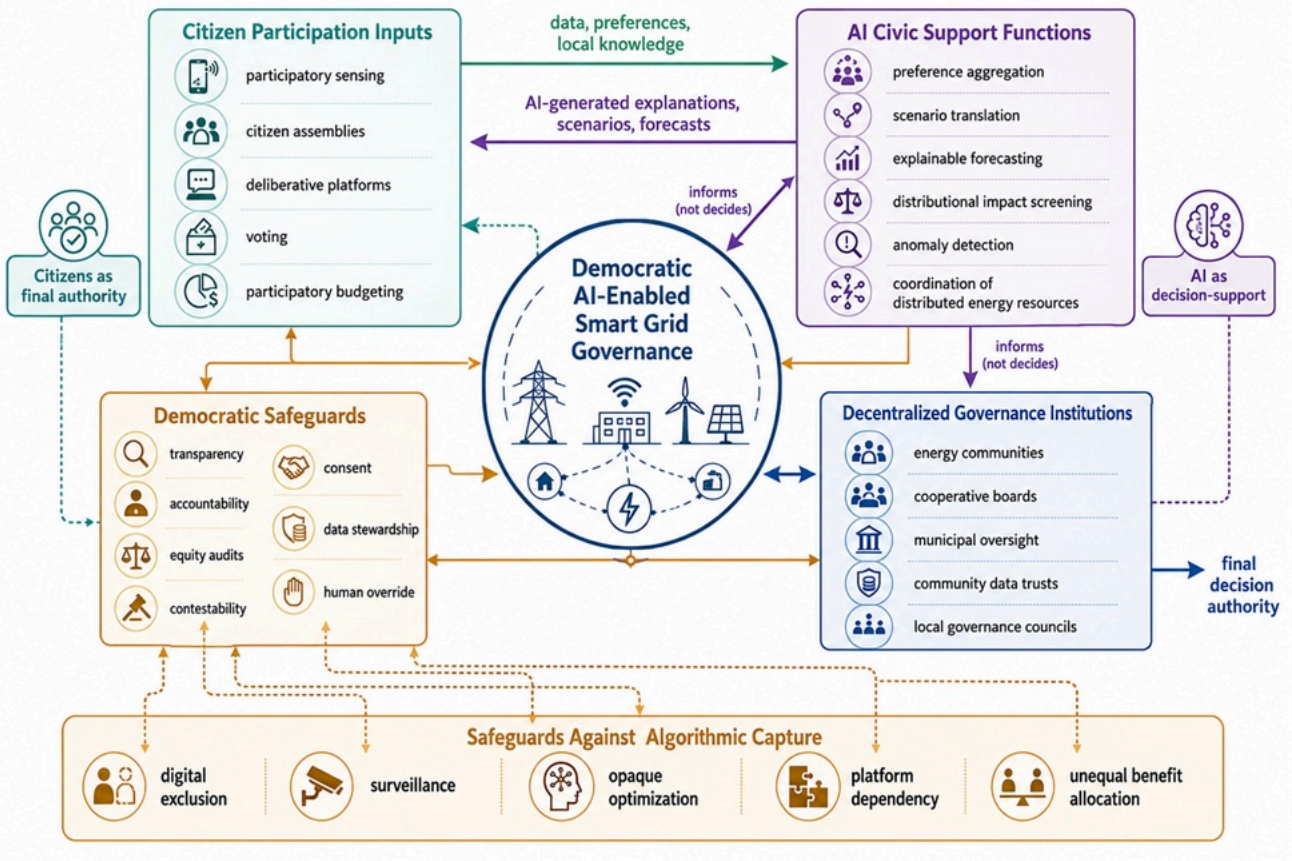

Figure 1. Participation–Governance Framework for AI-Based Energy Democracy

Background

Energy democracy: principles and practice

Energy democracy can be defined as the effort to democratize energy systems by expanding citizen participation, collective control, distributive justice, and public accountability across energy production, distribution, and consumption. Szulecki and Overland conceptualize energy democracy as a process, outcome, and goal, which is useful because AI-based governance must be assessed not only by final decisions but also by the procedures through which decisions are produced [8]. Wahlund and Palm further emphasize that energy citizenship and participation are central to democratic transitions, suggesting that citizens should not be reduced to data points or flexible demand resources [9]. In this article, energy democracy is therefore understood as a normative and institutional project that seeks to redistribute decision-making authority within energy systems.

Smart grids as political infrastructures

Smart grids are not neutral technical upgrades because they reorganize information flows, authority, visibility, and control within energy systems. Meadowcroft, Stephens, Wilson, and Rowlands show that smart grids have social dimensions that shape public acceptance, regional governance, and user participation, making infrastructure design inseparable from democratic possibility [7]. Milchram, Künneke, Doorn, Van De Kaa, and Hillerbrand demonstrate that smart grid experiments can embed or neglect justice depending on how values are translated into technical design [10]. Smart grids should therefore be understood as political infrastructures that can either widen democratic participation or intensify centralized surveillance and control.

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AI for citizen engagement and deliberation

AI could enable new forms of citizen engagement by summarizing complex energy information, supporting deliberation, identifying community preferences, and helping citizens understand trade-offs among affordability, reliability, sustainability, and autonomy. Throndsen and Ryghaug's work on material participation shows that energy citizenship can be produced through interaction with technologies, which implies that AI interfaces may shape how people experience their role in energy governance [11]. Savelli and Morstyn argue that social relationships matter in smart energy communities, suggesting that AI should support cooperation rather than treat households as isolated optimizing agents [12]. In this sense, democratic AI should function as deliberative support infrastructure rather than merely as automated control.

Decentralized decision-making in energy communities

Decentralized energy decision-making includes community energy projects, local flexibility markets, cooperative energy management, peer coordination, and shared governance of distributed resources. Ford, Maidment, Vigurs, Fell, and Morris provide a framework for smart local energy systems that highlights transition context and impacts, which is relevant because local energy systems require coordination across households, technologies, institutions, and values [13]. Knox, Hannon, Stewart, and Ford show that smart local energy systems can generate injustices unless questions of inclusion, representation, and distribution are explicitly addressed [14]. Decentralization should therefore be treated as a democratic opportunity only when local authority is combined with inclusive governance mechanisms.

Current gaps in democratic AI for energy

The current literature on AI and smart grids often foregrounds technical performance, explainability, and system management, while the democratic meaning of AI-enabled energy governance remains underdeveloped. Omitaomu and Niu survey AI techniques in smart grids, demonstrating the breadth of technical applications but also indicating the need for stronger social and political framing [15]. Machlev, Heistrene, Perl, Levy, Belikov, Mannor, and Levron show that explainable AI can improve interpretability in energy and power systems, yet explanation alone does not guarantee democratic accountability [10]. The missing element is a framework that links AI capability to citizen authority, contestability, and collective decision-making.

Conceptual Foundation

Defining AI-based energy democracy

AI-based energy democracy can be conceptualized as the democratic design, use, and governance of AI-enabled smart grid systems to expand citizen agency, collective control, and accountable decision-making in energy transitions. This definition draws from Burke and Stephens' emphasis on sociotechnical transition goals and policy instruments, but extends it by asking how algorithmic systems should be institutionally governed [1]. It also builds on Van Veelen and Van Der Horst's argument that energy democracy must be connected to political theory, because AI systems redistribute authority through data access, classification, optimization, and recommendation [4]. The framework therefore treats AI not as an autonomous decision-maker, but as a democratically bounded tool for collective energy governance.

The spectrum of democratic AI

Democratic AI in energy can be placed on a spectrum from informational AI to consultative AI, deliberative AI, co-decision AI, and citizen-controlled AI. Judson, Fitch-Roy, and Soutar's question of whether energy democracy has a digital future is important because digital tools may either extend democratic participation or substitute platform interaction for genuine public control [16]. Jobin, Ienca, and Vayena's review of AI ethics guidelines shows that transparency, fairness, accountability, and responsibility are common ethical principles, but energy democracy requires these principles to be translated into participatory institutions [17]. The highest democratic level is reached when citizens can shape AI objectives, question outputs, and alter governance rules rather than merely receive information.

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Design principles for democratic AI in energy

The proposed framework rests on four design principles: accountability, transparency, subsidiarity, and inclusion. Noorman, Espinosa Apráez, and Lavrijssen argue that AI and energy justice must be considered together, which supports the claim that algorithmic energy systems should be evaluated according to fairness and institutional responsibility [18]. Melnyk, Cox, Ghorbani, and Hoppe show that value dynamics in energy democracy are complex and evolving, so AI systems should allow public values to be negotiated rather than fixed by designers [19]. Subsidiarity further implies that decisions should be made at the most local democratic level compatible with system reliability, while inclusion requires that marginalized citizens have meaningful access to AI-mediated governance.

Democratic Dimensions and AI Functions in Smart Grids

Mapping democratic values

AI-based energy democracy begins by mapping democratic values onto smart grid functions, rather than adding participation after technical design has already been completed. Participation concerns who can enter decision processes; deliberation concerns whether citizens can reason together about trade-offs; transparency concerns whether algorithmic processes can be understood; equity concerns whether benefits and burdens are fairly distributed; and accountability concerns whether decisions can be challenged. Smith, Torres Contreras, Brisbois, Lacey-Barnacle, and Sovacool show that inclusive innovation is central to just transitions, which means AI systems should be judged by whether they widen or narrow the social basis of energy decision-making [20]. These democratic values provide the evaluative core of the framework.

AI capabilities for democracy

AI capabilities relevant to energy democracy include preference aggregation, scenario translation, deliberation support, anomaly detection, explanation generation, and coordination of distributed energy resources. Machlev, Heistrene, Perl, Levy, Belikov, Mannor, and Levron show that explainable AI can make energy system outputs more interpretable, which could support democratic scrutiny when paired with participatory oversight [10]. Binyamin, Ben Slama, and Zafar discuss AI-powered energy community management in smart homes, illustrating how AI could coordinate renewable resources while raising questions about who defines community objectives [21]. AI should therefore be designed to support collective reasoning and accountable coordination, not simply optimize energy behavior on behalf of citizens.

Governance mechanisms for democratic AI

Democratic AI requires governance mechanisms that make algorithmic functions visible, contestable, and institutionally accountable. Fiander, Walker, Rowlands, Devine-Wright, Wilson, Soutar, and Gupta emphasize public participation and support for local energy system change, which suggests that AI governance should include citizen panels, cooperative boards, and community review procedures [22]. Khayyat and Sami's discussion of AI-based energy community management further indicates that technical coordination requires institutional rules for consent, data use, and decision authority [23]. The framework therefore proposes algorithmic audits, participatory design mandates, local data governance bodies, appeal procedures, and public-interest performance criteria as core governance mechanisms. **Table 1** aligns democratic principles with corresponding AI functions, smart grid applications, and governance mechanisms, illustrating how participatory and accountable AI systems can be operationalized within democratic energy infrastructures.

Table 1. Alignment of Democratic Principles with AI Functions and Governance Mechanisms

Democratic Principle	AI Function	Smart Grid Application	Governance Mechanism

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Participation	Preference elicitation and inclusive agenda mapping	Identifying community priorities for demand response, shared storage, tariff design, and local renewable investment	Citizen assembly approval of AI objective functions before deployment
Deliberation	Scenario explanation and trade-off visualization	Translating technical grid choices into understandable social, environmental, and affordability consequences	Public deliberation panels with access to plain-language model explanations
Transparency	Explainable forecasting and decision traceability	Showing why flexibility requests, load-shifting recommendations, or local dispatch decisions are proposed	Mandatory explanation logs and community-accessible algorithmic registers
Equity	Distributional impact screening	Detecting whether AI recommendations place disproportionate burdens on low-income, elderly, or digitally excluded households	Equity audits with authority to suspend or revise harmful AI rules
Accountability	Contestability and appeal routing	Allowing citizens to challenge automated energy classifications, access decisions, or flexibility obligations	Independent ombudsperson and cooperative governance review process
Subsidiarity	Localized optimization within democratic constraints	Supporting neighborhood-level energy balancing without removing authority from local institutions	Local governance boards that define boundaries for AI autonomy
Collective ownership	Data stewardship and shared benefit allocation	Managing household, community, and grid data as a common resource rather than private platform property	Community data trusts with consent, access, and benefit-sharing rules
Democratic resilience	Risk detection and institutional feedback	Identifying emerging concentration of control, exclusion, or manipulation in AI-mediated energy platforms	Periodic democratic impact assessment with public revision rights

Citizen Participation Architectures

Participatory sensing and data commons

Participatory sensing can allow citizens to contribute local knowledge about comfort, affordability, outages, energy needs, and environmental priorities, but democratic value depends on how such data are owned and governed. Tarasova's call to rethink energy democracy with greater attention to social inclusion is relevant because data-intensive participation can exclude those without digital access, technical literacy, or trust in institutions [24]. Rajaperumal, Aly, and El-Saadany describe AI's role in advancing smart, sustainable, and secure energy systems, but democratic use requires that sensor data do not become a one-way extraction channel from citizens to platform operators. Data commons and community data trusts could enable citizens to decide what is collected, how it is used, and which collective benefits should result.

Deliberative platforms for energy choices

AI-augmented deliberative platforms could help citizens compare energy pathways, examine distributional consequences, and reason collectively about local energy priorities. Jørgensen, Ma, Kosek, Kazmi, and Shaker's scoping review of European Union AI regulation indicates that regulatory frameworks increasingly matter for energy AI, which supports the need to connect deliberative platforms with enforceable governance standards. Such platforms should not manipulate citizens toward preselected technical options; instead, they should make assumptions visible, present competing values,

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and support reasoned disagreement. In AI-based energy democracy, deliberative tools would be expected to enhance civic judgment rather than replace it.

Direct voting and budgeting via AI

Direct voting and participatory budgeting could allow energy communities to decide how shared resources, flexibility revenues, infrastructure investments, or energy-efficiency funds are allocated. Balamurugan, Manoharan, Kumar, and Sathya describe the expanding role of AI in smart grids, but democratic deployment requires that optimization remains subordinate to collective decision rules. AI could help structure proposals, identify conflicts, estimate qualitative implications, and support accessible participation, yet final authority should remain with citizens or democratically accountable institutions. This architecture can be conceptualized as citizen-led algorithmic support, where AI informs collective judgment without converting democratic choice into automated management.

Decentralized Decision-Making and Collective Governance

Multi-agent systems for community self-management

Multi-agent systems could enable energy communities to coordinate distributed generation, storage, flexible demand, and local balancing while preserving plural decision centers. Omitaomu and Niu describe how AI techniques can support smart grid control and forecasting, but an energy democracy perspective requires these capabilities to be embedded within collective rules rather than treated as purely technical optimization [15]. Community self-management would therefore require agents to represent democratically defined priorities, such as affordability, resilience, emissions reduction, and shared benefit allocation. Multi-agent coordination can be conceptualized as democratic only when citizens can shape the goals, constraints, and escalation rules under which automated agents operate.

Blockchain, DAOs, and algorithmic trust

Blockchain-based governance, decentralized autonomous organizations, and distributed ledgers may foster trust in energy communities by recording transactions, votes, consent decisions, and benefit-sharing arrangements. However, Judson, Fitch-Roy, and Soutar caution that the digital future of energy democracy depends on whether digital infrastructures deepen public control or merely create new forms of platform dependency [16]. In this framework, algorithmic trust should not be reduced to cryptographic verification, because democratic trust also requires representation, deliberation, accountability, and the possibility of revision. Blockchain and DAO-like structures could support energy democracy only when they remain subordinate to public-interest governance and accessible citizen participation.

Risks of algorithmic capture

Algorithmic capture occurs when AI systems appear to decentralize decision-making while actually concentrating agenda-setting power in software vendors, grid operators, data controllers, or technically privileged actors. Van Veelen shows that community energy projects must negotiate democratic practice rather than assume it, which suggests that AI-mediated decentralization can reproduce hierarchy unless authority is institutionally redistributed [5]. Knox, Hannon, Stewart, and Ford similarly show that smart local energy systems may generate injustices when participation and distribution are weakly designed [14]. AI-based energy democracy must therefore diagnose capture risks before deployment, especially where optimization objectives, data access, and interface design are controlled by actors who are not democratically accountable. **Table 2** outlines the major risks that AI systems pose to energy democracy and identifies democratic safeguards designed to protect participation, transparency, equity, accountability, and collective control within AI-enabled energy systems.

Table 2. Risks to Energy Democracy from AI and Democratic Safeguards

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Risk	Description	Democratic Principle Threatened	Safeguard
Algorithmic capture	AI systems define feasible choices, priorities, or trade-offs before citizens deliberate	Participation and accountability	Citizen approval of AI objectives, public algorithmic registers, and independent audits
Digital exclusion	Participation depends on digital literacy, connectivity, smart devices, or platform access	Equity and inclusion	Offline participation channels, assisted access, multilingual interfaces, and equity impact review
Surveillance normalization	Smart grid data are used to infer household behavior beyond legitimate energy governance needs	Privacy and autonomy	Data minimization, community data trusts, purpose limitation, and consent renewal
Opaque optimization	Citizens cannot understand why energy recommendations, flexibility requests, or allocation decisions occur	Transparency and contestability	Explainability requirements, decision logs, and appeal procedures
Platform dependency	Community energy governance becomes dependent on proprietary AI systems or vendor-controlled infrastructure	Collective ownership and subsidiarity	Open standards, public procurement rules, and cooperative ownership of critical digital tools
Manipulative participation	AI systems frame choices in ways that steer citizens toward preferred institutional outcomes	Deliberation and agency	Deliberative oversight, interface audits, and plural presentation of alternatives
Unequal benefit allocation	AI prioritizes households or assets that already have technical capacity and flexible resources	Equity and distributive justice	Distributional audits, benefit-sharing rules, and targeted support for underserved groups
Regulatory capture	Incumbents shape AI governance rules to protect market power while using democratic language	Accountability and public value	Public-interest regulation, civic representation in sandboxes, and conflict-of-interest disclosure

Hybrid human-AI governance models

Hybrid human-AI governance models should balance AI's capacity for coordination with the democratic requirement that final authority remain contestable and socially accountable. Savelli and Morstyn emphasize the importance of social relationships in smart energy communities, indicating that collective trust cannot be replaced by automated calculation [12]. Noorman, Espinosa Apráez, and Lavrijssen connect AI with energy justice, which supports governance models in which communities can accept, reject, revise, or suspend AI recommendations [18]. A democratic hybrid model would therefore combine automated analysis, citizen deliberation, accountable institutional review, and clear procedures for human override.

Risks, Barriers, and Democratic Safeguards

Digital exclusion and the participation gap

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Digital exclusion is a central barrier to AI-based energy democracy because citizens with limited connectivity, language access, technical literacy, trust, or time may be excluded from AI-mediated participation. Tarasova argues that energy democracy requires deeper attention to social inclusion, which is especially important when participation is mediated through smart meters, apps, dashboards, or digital voting systems [24]. Smith, Torres Contreras, Brisbois, Lacey-Barnacle, and Sovacool show that inclusive innovation is essential for just transitions, suggesting that AI participation systems should be designed around the most excluded users rather than idealized digital citizens [20]. Democratic safeguards should therefore include offline participation, community intermediaries, accessibility standards, and equity review before AI tools are used for collective decisions.

Opacity, manipulation, and trust

Algorithmic opacity can undermine democratic trust when citizens cannot understand how AI systems classify needs, recommend actions, allocate flexibility, or prioritize investments. Machlev, Heistrene, Perl, Levy, Belikov, Mannor, and Levron show that explainable AI can improve interpretability in energy systems, but democratic trust also requires the right to question and contest explanations [10]. Jobin, Ienca, and Vayena identify transparency and accountability as recurring principles in AI ethics guidelines, yet these principles become meaningful only when attached to institutional remedies [17]. Democratic AI should therefore include explanation duties, contestation rights, interface audits, and public review of how model outputs shape energy decisions.

Institutional resistance and regulatory capture

Institutional resistance may arise when incumbent utilities, platform providers, or regulators treat democratic AI as a threat to existing authority, revenue models, or expert control. Hess shows that energy democracy is shaped by mobilization and institutional conflict, which implies that AI-based energy democracy will not emerge from technical design alone [6]. Jørgensen, Ma, Kosek, Kazmi, and Shaker show that AI regulation in the energy sector is becoming increasingly important, but regulation may still be captured if citizens and communities are not represented in governance processes. Safeguards should include public-interest mandates, participatory regulatory sandboxes, civic representation in AI procurement, and disclosure of conflicts of interest.

Designing democratic resilience

Democratic resilience means that AI-enabled energy systems should be able to detect exclusion, respond to contestation, revise harmful rules, and preserve civic authority during disruption. Rajaperumal, Aly, and El-Saadany describe AI as a tool for secure and sustainable smart energy systems, but resilience should be understood institutionally as well as technically. Milchram, Künneke, Doorn, Van De Kaa, and Hillerbrand show that justice must be designed into electricity systems, which suggests that resilience requires value-sensitive governance rather than after-the-fact correction [10]. Democratic resilience could be supported through periodic audits, citizen review cycles, transparent failure reporting, and the ability to suspend AI functions that undermine public control.

Policy, Regulation, and Institutional Design

Enabling democratic AI through regulation

Regulation can enable democratic AI by requiring transparency, participatory design, data rights, fairness assessment, and accountability mechanisms for AI-enabled energy systems. Niet, Van Est, and Veraart argue that governing AI in electricity systems requires reflection on legal and institutional arrangements, which supports the need for regulation that treats AI as a governance technology rather than a neutral tool [25]. Jørgensen, Ma, Kosek, Kazmi, and Shaker further show that European Union laws and regulations are increasingly relevant to AI in the energy sector, suggesting that energy democracy should be integrated into regulatory compliance rather than left to voluntary ethics. Policy should therefore require democratic impact assessments, public consultation, explainability standards, and enforceable rights to challenge AI-mediated energy decisions.

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Institutional innovations for energy democracy

Institutional innovations for AI-based energy democracy could include public-interest AI labs, community data trusts, cooperative digital platforms, citizen energy assemblies, and municipal oversight boards. Melnyk, Cox, Ghorbani, and Hoppe show that energy democracy involves dynamic values within community energy initiatives, which suggests that institutions must allow values to be renegotiated as technologies and social priorities change [19]. Fiander, Walker, Rowlands, Devine-Wright, Wilson, Soutar, and Gupta emphasize public participation in local energy system change, supporting the need for civic institutions that connect local knowledge with technical decision support [22]. These innovations would help ensure that AI serves democratic empowerment rather than consolidating decision-making in expert or corporate systems.

Evaluation Strategy for the Democratic AI Framework

Democratic legitimacy and impact assessment

The framework should be evaluated through democratic legitimacy rather than technical performance alone. Szulecki's account of energy democracy emphasizes democratic control, while Szulecki and Overland's process-outcome-goal formulation suggests that evaluation must examine procedures, institutional arrangements, and consequences [3, 8]. A democratic impact assessment would ask whether AI expands participation, improves deliberation, clarifies accountability, distributes benefits fairly, and enables contestation. This approach avoids treating legitimacy as public acceptance of a predetermined technology and instead evaluates whether citizens have real authority over AI-enabled energy governance.

Participatory validation and co-design

Participatory validation means that citizens, community organizations, local authorities, and energy users should test whether AI tools reflect lived priorities, understandable explanations, and fair decision rules. Throndsen and Ryghaug show that energy citizenship can emerge through material participation, which implies that validation should examine how people interact with AI-enabled infrastructures in practice [11]. Wahlund and Palm's review of energy democracy and energy citizenship further supports the view that participation is not merely consultation but a condition of democratic transition [9]. Co-design processes should therefore shape AI objectives, interface language, data governance rules, and escalation procedures before systems become operational.

Transferability and context sensitivity

AI-based energy democracy must be transferable across contexts without assuming that one institutional model fits all energy systems. Ford, Maidment, Vigurs, Fell, and Morris show that smart local energy systems are shaped by transition context and impacts, which suggests that democratic AI frameworks must adapt to local governance capacity, infrastructure, ownership patterns, and social trust [13]. Becker and Naumann's mapping of energy democracy debates also shows that energy alternatives are politically diverse, meaning that democratic AI may take cooperative, municipal, community-owned, or hybrid forms [2]. Transferability should therefore be evaluated through contextual fit, institutional capacity, and the ability to preserve democratic principles under different regulatory and infrastructural conditions.

Limitations

Conceptual abstraction and the need for pilots

This article offers a conceptual framework rather than empirical validation, and its claims require future testing through democratic pilots, participatory design processes, and institutional experimentation. Binyamin, Ben Slama, and Zafar

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discuss AI-powered energy community management, while Khayyat and Sami similarly examine AI-based energy community management in smart homes, but conceptual design still needs real-world governance assessment before practical adoption [21, 23]. The framework does not report performance metrics, participation rates, or implementation outcomes, because its purpose is to clarify democratic design requirements. Future research should examine how different communities interpret, adapt, or resist AI-based governance tools in situated energy contexts.

Power dynamics and the limits of technology

A second limitation is that AI cannot by itself overcome the structural power relations embedded in energy markets, infrastructure ownership, regulatory systems, and digital platforms. Van Veelen and Van Der Horst argue that energy democracy must be connected to political theory, which cautions against treating technological decentralization as equivalent to democratic control [4]. Burke and Stephens similarly frame energy democracy as a sociotechnical transition that requires policy instruments and institutional change, not only new technical tools [1]. The framework should therefore be read as a democratic governance model for AI, not as a techno-solutionist claim that AI can automatically democratize energy systems.

Conclusion

AI-based energy democracy offers a way to rethink smart grids as infrastructures of civic empowerment rather than systems of passive optimization. The framework developed in this article shows how AI could support participation, deliberation, transparency, equity, accountability, subsidiarity, and collective ownership. Its central contribution is to connect democratic theory with concrete AI functions in smart grid governance.

The article also emphasizes that technology is not neutral. The same AI capabilities that could enable collective coordination may also centralize authority, intensify surveillance, exclude vulnerable citizens, or transform participation into symbolic interface interaction. Democratic outcomes therefore depend on design choices, institutional safeguards, ownership arrangements, and the ability of citizens to contest algorithmic authority.

Future work should move toward democratic experimentation, citizen-led AI governance, and community-based institutional design. Energy communities, regulators, utilities, and civic organizations should collaborate to test governance models that keep AI accountable to public values. AI can contribute to energy democracy only when citizens retain the authority to define goals, revise systems, and govern the energy transition collectively.

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