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Compelled Flexibility and Lock-in to Dispersion? Imperatives in Japan's Energy Policy

Ayako Takemi

Research Center for Advanced Science and Technology, University of Tokyo, Japan

Correspondence: Ayako Takemi (takemi@g.ecc.u-tokyo.ac.jp)

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Abstract

In the wake of the war in Ukraine, escalating tariff regimes, and instability in the Middle East, rethinking the relationship between energy security and the energy transition has become imperative. This article examines Japan's energy policy as a critical case in which the pursuit of energy security under severe structural constraints can give rise to a form of "compelled flexibility" that drives the simultaneous pursuit of diverse technological pathways beyond mere industrial preference—an "institutionalization of optionality." It further identifies a risk inherent in this institutionalization: as contractual, organizational, fiscal, and diplomatic commitments accumulate across parallel pathways, institutions intended to stabilize energy security can paradoxically internalize a "lock-in to dispersion," progressively raising the costs of future convergence. The article argues for governance designs that enable technological convergence in a way that is functional to decarbonization.

Keywords

compelled flexibility; energy security; green transformation (GX); Japan; lock-in to dispersion

1. Introduction

In the wake of the war in Ukraine, escalating trade competition, and instability in the Middle East, how energy security should be positioned has come under renewed scrutiny. This question has gained further salience within the energy transition, which is being pursued amid various forms of political and economic instability.

The question this article poses is what institutional consequences a strong energy security imperative can produce. In analyses of Japan, fine-grained, interest-based explanations have often taken precedence. Yet beneath them lies a strong energy security imperative rooted in structural constraints. The article asks

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what happens—institutionally—in such a critical case, when the imperatives of transition and energy security are confronted simultaneously. Focusing on the institutional dimension in particular, it identifies how this sense of urgency is translated into the institutionalization of preserving optionality itself—an institutionalization of optionality—and points to the risk inherent in that translation: a lock-in to dispersion. Lock-in to dispersion denotes a self-reinforcing process whereby the parallel institutionalization of multiple technology pathways accumulates contractual, organizational, fiscal, and diplomatic commitments, progressively elevating the political and economic costs of convergence. Dispersion, in this usage, is the spreading of investment, institutional support, and political commitment across many parallel technology pathways rather than their concentration on a few; convergence denotes the reverse movement—the progressive narrowing of institutional support toward fewer pathways.

The remainder of this article proceeds as follows. Section 2 clarifies the study's position within the literature and its concepts. Section 3 details the rationale for selecting Japan as a critical case, along with the methodology. Section 4 analyzes the process by which this pressure is translated into institutional commitments, examining the Green Transformation (GX) Promotion Act, the Long-Term Decarbonized Power Source Auction (LTDA), and the Asia Zero Emission Community (AZEC). Section 5 discusses the implications of these findings.

This article aims to offer both empirical contributions to the analysis of Japanese policy and broader theoretical advancements. It cautions against a one-dimensional understanding, arguing that (carbon) lock-in in Japan is not straightforward and requires new conceptualizations of the kind attempted here. While traditional political-economy analyses often centered on actor-level vested interests remain prevalent and highly relevant, this study underscores the fundamental structural factors underlying these dynamics.

The analysis then posits that in the 2020s two converging factors—geopolitical shocks that re-amplified supply-side security imperatives and strong political commitments to advance the transition despite (or precisely because of) these shocks—manifested in concrete institutional formations, and demonstrates through the illustrative cases how this pressure dictates a pathway toward diversification. It argues that when compelled flexibility, which seeks to expand optionality, is formalized through the institutionalization of optionality—accompanied by long-term structural fixity—it paradoxically internalizes the risk of a lock-in to dispersion.

Finally, the discussion reflects on these findings from a governance-design perspective, elucidating the paradox between institutionalization of optionality and lock-in to dispersion, and emphasizing the necessity of exit strategies.

2. Existing Research and Scope of the Study

2.1. Empirical Reassessment of Japan's Energy Policy

Japan's energy policy has been subjected to a variety of analyses. One important current, extending to general discourse, is the emphasis on Japan's fossil fuel dependence. Multi-pathway approaches have been characterized as variants of incumbent preservation (Climate Action Tracker, 2024); Japan has been identified as one of the world's largest public financiers of fossil fuels, and criticism has been directed at

Japan's promotion of ammonia co-firing in coal-fired power generation because of the technology's limited emissions-reduction efficacy (Kiko Network, 2026; Oil Change International, 2022). At the academic level, a substantial body of scholarship has characterized Japan's energy trajectory in terms of entrenchment in fossil fuels. Trencher and colleagues, in particular, have offered fine-grained analyses of the perpetuation of coal-fired power as a composite of material and institutional factors (Trencher et al., 2020, 2024).

A second strand analyzes Japan's energy policy from the standpoint of utility and interest, regardless of the technology in question—a very broad literature that overlaps with the first but is not confined to fossil fuels. Moe (2012, 2015) has addressed this problem with precision, arguing that the interest structure comprising the Ministry of Economy, Trade and Industry (METI), electric utilities, and the nuclear industry determines the fate of renewable energy.

Importantly, the existing literature, particularly the socio-technical strand, stands not in opposition to this article's argument but in a mutually reinforcing relationship. At the same time, this article's claims—compelled flexibility and lock-in to dispersion—differ in the following respects: (a) regarding the traditional criticism of Japan's fossil fuel dependence, it differs in that Japan is in fact attempting to invest in a diversified manner; (b) while not contradicting various lock-in analyses, it differs in its emphasis on structural constraints as the fundamental background factor, and/or the self-binding nature of institutions themselves, not just vested interests and profit motives. Kucharski and Unesaki (2018) address the institutional dimension with a similar intent but focus mostly on Japan's institutional shift.

This article suggests that what existing analyses describe is more parsimoniously explained by a structural driver that the academic literature has seldom theorized as an independent analytical category—though one that policy documents have long acknowledged (Agency for Natural Resources and Energy [ANRE], 2025c): the imperative, under conditions of extreme energy vulnerability, to hedge across multiple technological pathways because no single pathway can credibly promise sufficiency. Crucially, this structural vulnerability is not merely another source of lock-in analogous to external shocks reinforcing existing technological attachment (Trencher et al., 2020); it operates as an antecedent condition that incentivizes multi-pathway hedging even within a decarbonization agenda, generating diversification as a rational strategic response. The intent is not to displace existing lock-in theory but to foreground a more foundational factor whose analytical potential remains relatively underdeveloped—one that has become particularly consequential after 2020, as the simultaneous pressures of Net Zero commitments and supply security generated institutional responses that the traditional framework was not designed to capture.

2.2. Institutionalized Diversification and the Governance of Dispersion

The dimension most central to this article's contribution concerns the governance risks arising when diversification is institutionally entrenched. Stirling's influential framework argues that diversity—encompassing variety, balance, and disparity—can strengthen resilience in the face of ignorance and surprise, though cautioning that it must be assessed alongside system properties such as portfolio interactions (Stirling, 2007). Recent work has problematized this association more directly, distinguishing multiple resilience capacities, noting trade-offs with undesirable resilience, and highlighting governance-mode conditioning (Jesse et al., 2019; Scordato & Gulbrandsen, 2024), yet the governance implications are only beginning to be explored.

A parallel literature has theorized carbon lock-in as the self-reinforcing attachment of energy systems to specific fossil fuel technologies (Seto et al., 2016; Unruh, 2000). The exnovation literature, which studies the deliberate governance of decline, phase-out, or withdrawal, as distinct from the promotion of new alternatives, has elaborated phase-out governance combining niche support with incumbent destabilization (David, 2017; Kivimaa & Kern, 2016; Markard, 2018). Recent work has further shown that path-dependent lock-in dynamics can emerge even within renewable energy systems themselves (Eitan & Hekkert, 2023). These studies share a common analytical architecture: lock-in is theorized as attachment to a specific technology or technological configuration, and exnovation presupposes an identifiable phase-out target.

What remains less developed, however, is the analytical link between the conditions under which diversification is pursued and the institutional consequences it generates. Where diversification arises less as a discretionary portfolio optimization than as a response to structural constraints that foreclose pathway narrowing, the dynamics of institutionalization may differ qualitatively from those envisaged in portfolio-level accounts of diversity (Stirling, 2007). So may the governance burdens that such institutionalization accumulates. This article addresses that gap by proposing the concept of lock-in to dispersion and grounding it empirically in the case of a structurally vulnerable state. The concept constitutes a variant within the broader family of lock-in mechanisms, distinguished by its object and trajectory: not attachment to a particular technological trajectory, but to the condition of maintaining multiple trajectories as such—a governance burden that may intensify precisely as transition advances.

3. Methodology

Through qualitative analysis, this study examines how the institutionalization of optionality took form in Japan's energy governance. Japan—navigating decarbonization amid high fossil fuel import dependency, insularity, and grid isolation—represents a critical case where tensions between energy security imperatives and climate norms are most acutely manifest (Flyvbjerg, 2006). While the study avoids overgeneralization, its implications are suggestive for other cases.

Drawing on process tracing (George & Bennett, 2005) and historical institutionalist perspectives (Pierson, 2004), the analysis prioritizes reconstructing the sequence through which policy discourse and institutional design translate "optionality" into governance structures. The periods following the oil crises and the Fukushima accident are treated as antecedent conditions, and the period from the 2050 carbon neutrality declaration (2020) through the Ukraine crisis (2022) to the present is treated as a critical juncture (Capoccia & Kelemen, 2007) in which a re-intensified security paradigm—shaped by post-2022 geopolitical and geoeconomic shocks (see Kuzemko et al., 2022, for the European context)—collided with decarbonization norms. Accordingly, this study closely examines policy developments and discourses emerging from this post-2022 shift.

Data collection comprises document analysis of primary sources—policy directives, legislative texts, and operational materials from implementing agencies—supplemented by semi-structured elite interviews with practitioners from METI and the International Energy Agency (IEA), conducted under conditions of anonymity (Bowen, 2009; Tansey, 2007).

4. Japan as Compelled Flexibility

4.1. Revisiting the Analytical Lens: The Risk of Asserting Fossil Fuel Dependence

As Moe (2015) demonstrates, interest-structure-driven lock-in extends beyond fossil fuels to span diverse technologies including nuclear power, commanding significant explanatory power. At the same time, fossil fuel dependence has developed as the most prominent and persistent critique of Japan's energy policy in general discourse, and examining it as an object in its own right is both needed and justified. However, several prominent features of Japan's recent energy trajectory sit uncomfortably within a fossil-fuel-dependence explanation alone.

First, Japan has committed extraordinary public and private investment to solar photovoltaics (PV). Following the introduction of a generous feed-in tariff (FIT) in 2012, installed capacity surged from approximately 6.6 GW in 2012 to over 90 GW by 2024 (IEA Photovoltaic Power Systems Programme, 2013, 2025). Purchase costs under the FIT and feed-in premium (FIP) schemes are projected at approximately ¥4.85 trillion for FY2025, with the renewable energy surcharge calculated from official assumptions at approximately ¥3.1 trillion (METI, 2025c). That the pace of new deployment has nonetheless decelerated in recent years—owing to land scarcity, community opposition reflected in some 250 municipal restrictive ordinances (Otake, 2024), and record grid curtailment (Varadan, 2025)—points not to a lack of commitment but to the structural constraints that Section 4.2 examines.

Second, Japan has directed major corporate and public investment toward offshore wind despite facing among the most adverse structural conditions of any country pursuing this pathway. A consortium led by Mitsubishi Corporation undertook three fixed-bottom projects totaling approximately 1.7 GW—an investment mobilized notwithstanding structural conditions, detailed in Section 4.2, that impose a durable cost premium over European offshore wind markets (Renewable Energy Institute & Aegir Insights, 2026). The consortium's withdrawal from all three projects in August 2025—after costs escalated far beyond the assumptions underlying its bids—underscores these adverse conditions; it does not, however, diminish the implications of the commitment itself (Mitsubishi Corporation, 2025).

Third, Japan's hydrogen investment extends well beyond the coal co-firing that has drawn the most critical attention, constituting a substantial autonomous commitment to a low-carbon pathway. The revised Basic Hydrogen Strategy targets ¥15 trillion in public–private investment over 15 years (Ministerial Council on Renewable Energy, Hydrogen and Related Issues, 2023). The Hydrogen Society Promotion Act (Act No. 37 of 2024; see Government of Japan, 2024) establishes a technology-neutral carbon intensity standard and legally mandates the Japan Organization for Metals and Energy Security (JOGMEC) to administer financial support. Under this legislative framework, a 15-year CfD-type price-gap support mechanism and an estimated ¥3 trillion budget are allocated (ANRE, 2025c). The depth of legislative, fiscal, and technological commitment to hydrogen as such further constrains the explanatory reach of carbon lock-in alone.

Notably, renewables' share of power generation has more than doubled since FY2012 (the FIT's introduction), reaching approximately 22% in FY2023 (ANRE, 2025c).

4.2. Why and How Compelled: Japan's Compound Structural Constraints

This section revisits the compound structural constraints of Japan that form the fundamental backdrop for its energy policy. What this article denotes by "compelled" is a condition wherein, prior to any consideration of policy preferences or desirability, structural factors narrow the set of available energy options and viable transition pathways, imposing upon the energy system what may be termed a "flexibility born of necessity." The analytical significance of the Japanese case resides not in the uniqueness of any individual constraint—many are observable in isolation elsewhere—but rather in their coincidence within a single advanced economy.

Specifically, Japan confronts: (a) a resource-poor status entailing extreme import dependency for primary energy; (b) pervasive disaster exposure, primarily seismic but extending to typhoons, landslides, and flooding; (c) an elongated North–South territorial configuration that distributes energy resources and demand unevenly; (d) predominantly mountainous topography that severely limits the land area deployable for energy infrastructure; (e) archipelagic insularity that renders grid interconnection with continental systems costly and complex (alongside geopolitical factors that further impede cooperation); (f) surrounding seas whose considerable depth and challenging hydrodynamics—including rapid currents and proximate deep-sea trenches—constrain offshore energy development; as well as more historically and institutionally mediated factors, including (g) a domestically fragmented grid architecture bifurcated between incompatible frequency zones; and (h) post-accident operational constraints on nuclear power—triggered by the seismic vulnerability identified in (b).

The foundational premise is resource scarcity. According to ANRE (the METI agency that drafts the Strategic Energy Plan), primary energy self-sufficiency stood at 12.6% in FY2022, with import reliance for oil, natural gas, and coal each exceeding 97%, while crude oil imports from the Middle East exceed 90% (ANRE, 2024, 2025c). This structural exposure to geopolitical disruption and price volatility underpins a policy posture that cannot afford excessive dependence on any single energy source (ANRE, 2025c).

Layered upon this resource vulnerability, constraints (b) through (d) collectively circumscribe the deployable scale of onshore renewables. Obane et al. (2020) estimate that contiguous land available for both PV and onshore wind—once legal regulations, land-use competition, and conservation designations are taken into account—amounts to merely 0.9% of total contiguous land; their modeled allocation of 25 GW of onshore wind and 64 GW of solar PV would meet only approximately 15% of 2018 national electricity demand. Disaster risk compounds this spatial scarcity: nationwide geographic information system analysis indicates that approximately 8.5% and 9.1% of the medium- and large-scale solar PV plants examined are sited in areas of elevated landslide and flood probability, respectively (Hao et al., 2021). Rooftop PV can partially bypass these land constraints: assuming panels on 70% of rooftops nationwide, one assessment estimates annual generation exceeding Japan's total 2022 output (Trang et al., 2025). That figure is based on a scenario that further presupposes nationwide use of EV batteries as distributed storage, and realization remains constrained by building stock, ownership fragmentation, and distribution-grid capacity.

Constraints (e) and (f) sharply narrow compensatory pathways available to other nations. Japan's insularity inhibits cross-border grid interconnection—routine across Europe and North America—while the domestic grid, fragmented across 10 regional operators and bifurcated between 50/60 Hz zones with only 2.1 GW of frequency conversion capacity—up from 1.2 GW (IEA, 2022) after the 2021 Hida-Shinano commissioning—impedes nationwide equalization of renewable resources (ANRE, 2025b). Geopolitical factors are also

pertinent in this regard. The broader Asia Super Grid concept, once explored as a possibility, has largely been set aside in recent years—both because Japan has prioritized a robust, genuinely nationwide domestic transmission network and because geopolitical tensions, rooted in the postwar period and intensifying in recent years, have weighed against it (Moe et al., 2024). Regarding the offshore wind implications of constraint (f), Japan's physical and industrial conditions impose further limitations. Water depths frequently exceeding 50–60 meters near shore render fixed-bottom foundations unsuitable, necessitating reliance on floating systems with substantial engineering and installation costs (Institute of Energy Economics, Japan, 2024a, 2024b), while typhoon and earthquake certification requirements and weather-constrained installation windows raise capital costs above European reference levels—a premium modeled at approximately 21% (Renewable Energy Institute & Aegir Insights, 2026), compounded by shortages of human resources and industrial capacity owing to limited offshore oil and gas experience (Institute of Energy Economics, Japan, 2024b). While the Japan Wind Power Association (JWPA) projects an optimistic target of 140 GW of wind by 2050—of which 60 GW is floating offshore (JWPA, 2023)—operational offshore wind stood at approximately 253 MW at the end of 2024 (JWPA, 2025). These circumstances do not uniformly preclude future investment, but they do manifest as risks against full commitment to any single technology.

The compound structural conditions enumerated in this section operate as a foundational driver analytically prior to, and not reducible to, industrial motives or path dependency. Practitioners emphasize that energy underpins all societal activities and is directly linked to the safety of life; this compelled element, in their view, operates as the most potent force driving Japan's simultaneous pursuit of renewable expansion, grid reinforcement, and non-fossil source diversification (Interview 2, Interview 3).

4.3. Response and Characteristics: Materialization and Institutionalization Amid Ambivalent Conditions

Japan's energy policy has been organized since the oil crises of the 1970s around reducing vulnerability to supply disruptions through fuel diversification, long-term contracts, stockpiling, and demand-side efficiency—codified as 3E (energy security, economic efficiency, and environment) and, post-Fukushima, as 3E+S with *safety* as a prerequisite (ANRE, 2025c; Hartwig et al., 2023). Yet for much of this period, diversification operated as optimization within the energy mix under security and cost constraints, rather than as the institutional construction of parallel decarbonization pathways. The momentum shifted markedly from the early 2020s, as the formal political commitment to 2050 Net Zero intensified decarbonization pressure while geopolitical shocks re-amplified supply-side security imperatives, increasingly driving the simultaneous maintenance of multiple pathways through dedicated institutional infrastructure.

The initial trigger that elevated compelled flexibility into an institutionalized form was the formal political commitment to 2050 carbon neutrality and the attendant imperative to accelerate investment. Prime Minister Suga declared this target in an October 2020 policy address (Ministry of the Environment, 2021), subsequently establishing the Green Innovation Fund (GI Fund) as an institutional apparatus providing long-term support, from R&D to societal implementation. The GI Fund's basic policy states that 2050 carbon neutrality "significantly advances previous government policies" and necessitates "substantial acceleration" through bold investment, crucially acknowledging that "plan shortfalls or mid-course revisions are naturally possible" (METI, 2021, p. 2, author's translation)—institutionally incorporating multi-technology exploration prior to convergence on any single pathway.

The second trigger—the energy crisis following the Ukraine invasion (2022) and emerging geoeconomic fragmentation and tariff escalation—foregrounded stable supply alongside Net Zero as dual justifications for institutional formation. The government's GX Basic Policy, formulated in the post-Ukraine context, treated stable energy supply as "the foundation of citizens' lives and business activities" to be secured alongside decarbonization and economic growth (Cabinet Secretariat, 2023, p. 1), a framework reiterated in the AZEC joint statement as "triple breakthrough" and "one goal, various pathways" (METI, 2025a, p. 1; Ministry of Foreign Affairs of Japan [MOFA], 2024a, p. 2). Cabinet Secretariat documents further position GX within a global shift where major economies increasingly pursue "government-led enhancement of competitiveness and security" amid shifting investor sentiment and geoeconomic fragmentation (Cabinet Secretariat, 2025, p. 5, author's translation).

Practitioners confirm that amid intensifying Net Zero pressure, supply anxieties, and nuclear restart constraints, there was little choice but to "bet" on diverse technologies (Interview 4, Interview 1). Accordingly, GX policy assumed the character of investment in new energy to dispel perceptions that decarbonization constrains growth (ANRE, 2023; Cabinet Secretariat, 2023; Interview 4), catalyzing institutions capable of attracting investment across a broad spectrum of options.

4.4. Specific Developments: How Flexibility Is Translated Into Institutional Commitments

The following section examines this process of institutionalization (in a broad sense) across three layers: the GX policy architecture, which institutionalizes the parallel pursuit of multiple pathways as national strategy; the LTDA, which concretizes long-term commitments through market design under that framework; and AZEC, which parallels this institutionalization internationally.

4.4.1. GX Promotion Act, GX Economic Transition Bonds, and GX Acceleration Agency

The GX Promotion legal architecture—comprising the GX Promotion Act (Act No. 32 of 2023; see Government of Japan, 2023), GX Economic Transition Bonds, and the GX Acceleration Agency (GXAA)—constitutes the overarching framework through which optionality is institutionalized as national strategy, spanning fiscal commitment, legislative schedule, and execution apparatus.

Japan's Climate Transition Bond (CTB) Framework explicitly grounds this architecture in structural vulnerability. The framework acknowledges that Japan is "surrounded by the sea on all sides, lacking international interconnections and pipelines," confronting constraints in energy supply architecture, and formulates GX as pursuing the simultaneous realization of stable energy supply, economic growth, and decarbonization (Cabinet Secretariat et al., 2025, p. 4). This three-part formulation embeds economic growth—and by extension industrial competitiveness and supply-chain continuity—as a co-equal objective alongside decarbonization, widening the range of policy considerations that can weigh against pathway narrowing.

The GX Promotion Act legislates a temporal architecture of front-loaded investment with deferred cost recovery. The act authorizes GX Economic Transition Bond issuance from FY2023 through FY2032 (a 10-year window of approximately ¥20 trillion). Redemption through fossil fuel surcharges and specified business operator contributions is stipulated by FY2050—a 27-year fiscal commitment from first issuance to final redemption. The sectoral investment strategy operationalizes this commitment by articulating

roadmaps across 16 priority areas. Although subject to priority criteria and eligibility standards, these roadmaps simultaneously establish government-backed investment viability across a broad portfolio of technologies including hydrogen, carbon capture and storage (CCS), next-generation renewables, nuclear, and industrial conversion (Cabinet Secretariat, 2024).

The execution apparatus is the GXAA, an authorized corporation established under the GX Promotion Act. GXAA is being positioned to administer carbon-pricing-related functions—including levy collection and emissions-trading market operations—as the mandatory emissions trading system (ETS) framework phases in, with participation obligations effective from FY2026 under the 2025 amendment to the act, while providing financial support through debt guarantees and equity investments that complement risks private financial institutions cannot absorb (GX Acceleration Agency, n.d.).

The CTB Framework states that "implementation of upfront investments towards these [roadmap] goals leads to the avoidance of lock-in during the transition" (Cabinet Secretariat et al., 2025, pp. 20–21). That claim, however, concerns carbon lock-in—attachment to incumbent fossil-fuel technologies. The institutional design's own temporal sequencing points to a second-order dynamic that the framework does not contemplate: mechanisms that fix investment across multiple pathways (bond issuance from FY2023, LTDA 20-year contracts from 2024) precede mechanisms that could promote convergence toward fewer pathways (as currently legislated, mandatory ETS participation from FY2026, fossil fuel surcharge from FY2028, paid auctions for the power sector from FY2033). By the time the most potent of these mechanisms—paid auctions—begins operating, nearly a decade of long-term investment contracts will have accumulated. The resulting commitments generate three mutually reinforcing forms of path dependence (Pierson, 2000): (a) fiscal lock-in, which arises through bond redemption obligations extending to 2050 that presuppose future carbon-pricing revenues; (b) asset lock-in, which stems from long-lived investments in hydrogen supply chains, CCS infrastructure, port facilities, and industrial conversion, with concrete commitments already including hydrogen price-gap support (Section 4.1) and nine design-stage JOGMEC-selected CCS projects targeting approximately 20 million tons of CO_2 storage annually (JOGMEC, 2024); and (c) policy-feedback lock-in, which operates through GXAA's expanding institutional mandate, advancing corporate adaptation to a multi-pathway system through investment, organizational restructuring, and regulatory compliance.

Germany's Renewable Energy Act establishes a statutorily anchored target of at least 80% of gross electricity consumption from renewables by 2030 (Government of Germany, 2025, § 1(2)). The US Inflation Reduction Act's (2022) clean electricity production credit (26 U.S.C. § 45Y) requires a greenhouse gas emissions rate "not greater than zero"—an emissions-based eligibility threshold. Japan's energy policy contains no comparable statutory mechanism that narrows the range of supported decarbonization pathways or imposes a terminal date on any of them; the Seventh Strategic Energy Plan's 2040 electricity-mix outlook (40–50% renewables, approximately 20% nuclear, 30–40% thermal) is indicative and lacks enforcement mechanisms (ANRE, 2025b, 2025c). The countervailing force against dispersion lock-in thus rests primarily on the phased strengthening of carbon pricing—a force whose timeline structurally lags behind investment commitments. Critical readings outside government reinforce this assessment: analysts at the Renewable Energy Institute argue that the GX-ETS design itself mutes the price signal—the initial allowance price ceiling (¥4,300/ton CO_2) rests on a fuel-switching cost window that lowers it, while benchmark tightening merely extrapolates historical efficiency gains (Hirose & Ohno, 2026).

4.4.2. Long-Term Decarbonized Power Source Auction

The LTDA, administered by the Organization for Cross-Regional Coordination of Transmission Operators (OCCTO), is a competitive capacity procurement mechanism that provides successful bidders with fixed-cost-level capacity revenue for 20 years in principle. By improving the predictability of long-term investment recovery for new decarbonized power sources, this mechanism illustrates how the maintenance of multiple technological pathways is embedded within a single institutional architecture.

OCCTO's explanatory materials frame pathway diversity not as an aspirational ideal but as a supply-constraint premise: a single source type cannot meet total demand, necessitating options beyond current practical-stage technologies (OCCTO, 2024a).

Building on this premise, the LTDA transforms multiple pathways into investable options through capacity procurement. The mechanism employs a multi-price auction with 20-year supply provision periods (METI, 2025b; OCCTO, 2024a, 2025). Decarbonized power sources and liquefied natural gas (LNG)-fired thermal power are recruited through separate quotas with technology-specific caps, yet the defining feature is that multiple technology tracks—nuclear, storage batteries, hydrogen co-firing, renewables, and conditional LNG—share a single institutional and contract framework. The first auction (2024) awarded approximately 9,766 MW across a broad range of these categories, with LNG capturing 5,756 MW of the initial 6,000 MW cumulative cap set for FY2023–2025 (OCCTO, 2024b).

The lock-in implications of this design follow from Pierson's (2000) framework of increasing returns in political institutions. Although 20-year capacity contracts are subject to adjustments and performance penalties, they provide a structural foundation for investment recovery. Once capital is deployed across multiple pathways simultaneously, sunk costs accumulate in parallel. Subsequent attempts to scale back any pathway collide with contractual obligations, contribution fund structures, and operational coherence costs, all of which elevate switching costs. The more pathways the institution incorporates, the more simultaneously established commitments accumulate, rendering resistance to convergence self-reinforcing.

This dynamic was amplified when LNG-fired thermal power was designated as eligible in response to the March 2022 supply-demand crisis in Eastern Japan (OCCTO, 2024a). ANRE guidelines require such LNG projects to initiate measures toward decarbonization within 10 years of commencing supply provision and to demonstrate, through a submitted roadmap, a pathway toward decarbonization by 2050 (ANRE, 2025a). However, incorporating transition-period options in the same contract mechanism nonetheless extends the scope of long-term commitments that must be unwound before convergence can proceed.

By comparison, the UK separates supply-capacity assurance (capacity market) from low-carbon technology promotion (Contracts for Difference, allocated through competitive, technology-constrained pots; Department for Energy Security and Net Zero, 2025; Ofgem, 2024)—an institutional division of labor that embeds periodic differentiation among technologies at the funding-allocation level. Japan's LTDA, by contrast, can accommodate both functions within a single long-term contract mechanism, concentrating the conduit through which institutionalization of optionality transmutes into convergence difficulty.

4.4.3. AZEC: From Domestic Optionality to International Institutions

The significance of AZEC—a Japan-led platform launched in 2023 with Australia and nine ASEAN member states—resides not in mere slogan-sharing but in extending domestically institutionalized "various pathways" to the international plane through interlocking functions. The AZEC Leaders' Joint Statements articulate a "triple breakthrough"—the simultaneous achievement of energy security, economic growth, and climate change countermeasures—proclaiming "one goal, various pathways" while emphasizing each nation's circumstances and pathway diversity (METI, 2025a, p. 1; MOFA, 2024a, p. 2). An "Action Plan for the Next Decade" encompasses the introduction of renewables and the acceleration of next-generation technologies alongside hydrogen, ammonia, carbon capture, utilization and storage (CCUS), and positions natural gas (including LNG) as playing an important role during the transition period (MOFA, 2024a). Crucially, AZEC legitimizes the parallel pursuit of "various and practical pathways" suited to post-crisis energy security environments, and fixes on this foundation a framework for translation into concrete cooperation across policy, markets, technology, and investment (METI, 2025a, p. 1; MOFA, 2024a, p. 2).

That AZEC has moved beyond slogans into project formation is evidenced by the 2nd Leaders' Meeting (October 2024): Japan's MOFA explicitly states that diverse pathways were confirmed under AZEC principles; that approximately 120 memorandums of understanding and other cooperation instruments were concluded between Japan and partner countries since the 1st Leaders' Meeting in December 2023; and that the Asia Zero Emission Center was launched (MOFA, 2024b)—primary evidence that AZEC is advancing as a bundle of institutions, projects, and organizations paralleling the domestic GX architecture. These instruments can be read here as accumulating institutional commitments rather than as realized investment flows.

The logic by which AZEC can generate lock-in following institutionalization can be organized into three circuits:

1. *Normative (legitimization) lock-in:* "One goal, various pathways" is reiterated as an international frame legitimizing nationally differentiated, practical transition pathways under energy security—not mere tolerance of diversity (MOFA, 2024a). Domestic policy is thus buttressed not only by domestic rationality but by the legitimacy of international cooperation frameworks, elevating the political cost of pathway convergence.
2. *Supply chain and infrastructure lock-in:* International cooperation in hydrogen, ammonia, CCUS, and LNG entails long-lived cross-border infrastructure—transport, ports, storage, and carbon capture facilities—whose accumulation mutually reinforces technology, institutions, and behavior, amplifying the cost of pathway alteration (Seto et al., 2016; Unruh, 2000).
3. *Diplomatic and relational lock-in:* As MOFA documents, cooperation instruments, the Asia Zero Emission Center, and a decadal action plan have accumulated (MOFA, 2024a, 2024b), this accumulation, this article infers, raises expectations and coordination costs within cooperative relationships. Considerations beyond investment rationality—relationship maintenance, reputation, regional strategy—render pathway review more complex.

AZEC has also been noted to carry intents beyond pure energy policy—securing regional ties and influence amid rising geopolitical risk (Takemi, 2026)—and criticism has been repeatedly raised that deploying technologies such as CCUS as green solutions externalizes the competitiveness and potential stranded

assets of domestic industry (Oil Change International, 2023, p. 8). AZEC's pronounced foreign- and industrial-policy character suggests that purely institutional self-binding becomes intertwined with socio-technical dimensions.

4.5. The Core Mechanism: Accumulation of Investment Viability Amplifies Convergence Difficulty

The mechanism shared across the foregoing cases is not that "institutions are difficult to halt" but that institutions simultaneously establish the conditions for investment across multiple pathways, and consequently long-lived assets, long-term contracts, operational capabilities, and international relationships accumulate—rendering convergence decisions increasingly arduous.

Convergence mechanisms exist within Japan's institutional design: the phased carbon-pricing schedule detailed in Section 4.4.1, alongside FIP auction systems. However, the efficacy of these mechanisms remains constrained. Mandatory participation proceeds under benchmark- and grandfathering-based free allocation, containing the initial price burden, and Japan's carbon pricing remains limited (Cabinet Secretariat, 2023); the existing carbon tax stands at ¥289/ton CO_2 (Ministry of the Environment, 2012). Moreover, the combined burden of the surcharge and paid auctions is, by design, to remain within the margin created by declining existing energy-related levies (Cabinet Secretariat, 2023). The critical point is therefore not whether convergence mechanisms exist but their weakness and their timing relative to investment commitments: the former structurally lag behind the latter, creating a window during which dispersion is institutionally reinforced before convergence pressures become operative. The institutional conditions for lock-in to dispersion are, at this juncture, structurally embedded in the design of Japan's energy transition governance.

5. Discussion

The analysis yields three implications: first, for the place of energy security within energy transition debates; second, for the institutional dynamics of lock-in to dispersion; and third, for the governance of exit, exnovation, and procedural contestability.

5.1. Energy Security in Transition Governance: Integration Without Absolution

The first implication concerns the positioning of energy security within transition governance. As Section 2 argued, the structural conditions that generate energy security imperatives have seldom been theorized as an independent analytical category. The empirical analysis in Section 4 adds a concrete institutional account of how energy security pressures are translated into policy architecture—and the governance problems that translation can generate.

Japan exemplifies how such structural circumstances directly shape transition pathways. Here, technology diversification does not self-evidently emerge as "the result of normatively desirable free choice." Instead, structural vulnerability combined with investment-acceleration imperatives accompanying Net Zero targets can render "maintaining optionality itself" as carrying substantive self-binding force. The point here is not an absolution whereby "because security exists, transition may be relaxed"; rather, it signifies that for nations with severe structural constraints, "vulnerability reduction" becomes essential precisely to advance the transition—the meaning of "energy security as low vulnerability" (Cherp & Jewell, 2014, p. 418). Where this

dimension is not incorporated as a design variable, transition frameworks risk tending toward one-size-fits-all prescriptions that dismiss context-specific pathways wholesale—a dismissal that, for severely constrained cases such as Japan, concerns not only governance design but the justice of the energy transition itself (Kortetmäki et al., 2025; see also Paris Agreement, 2015). Complementing previous research addressing how incumbent interests deploy discursive strategies to resist transition (Isoaho & Markard, 2020), this article notes that, even where security claims are grounded in genuine structural conditions, institutionalization of flexibility generates distinct governance problems—a dynamic the following sections examine as "lock-in to dispersion."

5.2. The Paradox of "Institutionalization of Optionality" and "Lock-In to Dispersion"

The second implication concerns the risk that institutionally guaranteeing flexibility carries substantive self-binding force. The mechanisms traced in Section 4 empirically specify how lock-in to dispersion operates: long-term contracts, standing funding sources, standing organizations, and supply chain designations accumulate across pathways, while the logic of stable supply during periods of crisis re-legitimizes dispersion as "insurance." Re-concentrating resources on fewer pathways therefore becomes politically difficult: each pathway now has contracts to honor, organizations to sustain, and constituencies to answer to. The concept does not prescribe an optimal policy mix but identifies a governance problem—and the distributional consequences it carries—that arises when pathway maintenance becomes institutionally self-purposive.

The LTDA's mixed bidding with 20-year capacity revenues concretely illustrates this, fixing capital, human resources, and policy attention in a thin, broad dispersion (ANRE, 2025a; METI, 2025b). The resulting dynamic constitutes lock-in at a distinct phase from conventional carbon lock-in (Seto et al., 2016)—not attachment to a specific technology but to maintaining multiple trajectories as such, a complementary concept whose governance implications differ accordingly.

Given the energy sector's inherent complexity, high costs, and strong path dependence (Goldthau & Sovacool, 2012), this self-reinforcement of dispersion is not exceptional but a consequence that naturally tends to materialize.

Crucially, this dispersion lock-in cannot be explained solely by "intent to preserve fossil fuels." Japan's basic plan renders geographic and resource constraints explicit (ANRE, 2025c). In nations with elevated vulnerability, compatibility between transition acceleration and stable supply assurance is politically demanded, with compelled flexibility readily institutionalized. Treating dispersion lock-in as a governable institutional dynamic, rather than a normative binary, thus proves more analytically productive. Framed in this way, dispersion lock-in also designates a structural unit of analysis: wherever compound constraints compel the parallel maintenance of pathways, the commitments that flexibility itself accumulates become a comparable object of inquiry. The Japanese case then reads not as an idiosyncrasy but as an early, acute instance of a configuration that other structurally constrained economies may come to share.

5.3. The Governance of "Exnovation": Exit Design and Two-Layer Procedural Contestability

The third implication pertains to the governance of exnovation—the deliberate, governed phase-out of established technologies and their supporting institutions—and to the design of exit. In Japan's energy

governance, institutions are thickly configured for "entry"—the introduction and parallel operation of new pathways—while "exit" design remains comparatively thin: there are few procedures through which the state can withdraw statutory support from, scale down, or terminate an underperforming pathway (as distinct from individual projects) once it has been institutionalized. The more institutional purpose is vested in maintaining flexibility, the more individual technology failures and inefficiencies are justified as "insurance," rendering exit decisions politically fraught. This aligns with what policy mix research terms the necessity of "creative destruction" (accompanying scaling down of the existing), not merely creation ("niche support"; Kivimaa & Kern, 2016).

As a concrete apparatus for exit design, the Organisation for Economic Co-operation and Development (OECD, 2023) observes that sunset clauses on fossil fuel use, applied to assets premised on future fuel switching, can contribute to reducing lock-in risk in transition finance. In this article's context, this can be reinterpreted as an exnovation mechanism that should be embedded throughout the institutionalization of optionality—not merely in transition finance. The point is not robust norms promoting withdrawal but, premised on the political conditions of compelled flexibility (vulnerability × Net Zero), embedding design that renders exit politically feasible. Examples include triggers that progressively scale down support where performance, cost, or supply chain conditions are unmet; caps that set explicit scale and temporal limits even when pathways are retained as insurance; and conditional replacement that automatically rationalizes existing pathway support contingent upon alternative pathway establishment.

However, such exit mechanisms function only when accompanied by procedures through which they actually operate, and justifications are scrutinized. This is because the institutionalization of optionality is accompanied by a further difficulty: as institutions become more complex and financialized, oversight grows more demanding. The danger that energy policy becomes a highly specialized "black box" with political issues absorbed within technocracy has been flagged in energy technocracy research (Chaiyapa et al., 2021). Combined with the tendency for crisis-time security logic to marginalize other policy values (Kuzemko et al., 2022), procedural safeguards should be evaluated not merely by whether venues for participation exist (the micro layer) but also by contestability (the macro layer). Echoing the discussion in Section 5.1, the latter concerns whether excessive securitization can be checked (Szulecki, 2020), whether the cost burdens of maintaining dispersion are justified, and whether exit decisions remain institutionally feasible—verified through mechanisms such as information disclosure, in-system representation, and knowledge incorporation.

In Japan, GX Implementation Council materials reference "progress reporting" and "review as needed" (Cabinet Secretariat, 2025, p. 4, author's translation). The issue, however, is not the existence of review but its institutional capacity. Existing review processes assess progress toward stated roadmap goals, but do not secure full authority to mandate pathway withdrawal, reallocate cross-pathway resources, or trigger automatic scale-down when performance thresholds are unmet. As long-term commitment mechanisms (LTDA and funding/executing bodies under the GX Promotion Act) accumulate in layers, policy reversibility declines, and the danger of advancing specialized black-boxing requires constant vigilance.

6. Conclusion

This article has reconstructed institutional formation mechanisms from the vantage point of "energy security as low vulnerability," taking Japan as a critical case. Central to the analysis is the proposition that structural

conditions constrain the feasible set of policy options and transition velocity, rendering full commitment to any single pathway difficult: technology diversification does not emerge as the outcome of desirable free choice but assumes a compelled character.

This compelled character has a generative side. Security pressure does not merely impede the transition—it can drive it. Crucially, security is not a blanket license to relax transition efforts. Rather, the more severe the structural constraints, the more essential vulnerability reduction (resistance to supply, grid, and input constraints) becomes precisely to advance the transition. In Europe, where interconnection and alternative procurement remain comparatively open, it has been suggested that security concerns can accelerate the transition (DNV, 2025). Yet to equate securitization generally with transition promotion renders invisible what happens in the process of institutionalization. At issue is not the presence or direction of pressure but the institutional form it assumes. In Japan, where no single pathway can credibly promise sufficiency, the same driving force was translated into the parallel institutionalization of multiple pathways. This article has traced what this can produce.

What this translation produced has a definite shape: compelled flexibility could materialize not as mere "diverse pathways" but as an "institutionalization of optionality." The commitments accumulating across pathways (contractual, organizational, fiscal, diplomatic) mutually elevate exit costs, and crisis-time stable-supply logic provides additional legitimacy for their maintenance. What this article has termed lock-in to dispersion is the risk that this accumulation—including the bias of institutional design toward entry and away from exit—becomes self-reinforcingly entrenched, not a settled outcome. Yet the direction of the trend is clear: the more earnestly a state with structural constraints invests in the transition, the thicker the institutional sediment through which future convergence must pass.

These findings carry broader implications for the theorization of lock-in. Existing lock-in frameworks have rested on the premise that the object of entrenchment—the specific technology or configuration to which a system becomes bound—is identifiable. Stirling's (2007) diversity framework positions diversity as a counterweight to lock-in, and adopts a design that evaluates portfolio characteristics at a given point in time; however, whether the commitments required to maintain diversity can themselves accumulate irreversibly lies outside its principal scope. Lock-in to dispersion occupies this gap. Its object is not a specific technology but the state of maintaining multiple pathways in parallel as such; because it manifests as flexibility, it is difficult to capture with an analytical apparatus built to detect entrenchment in specific pathways. The difference from conventional lock-in resides not in the direction of deepening but in the driving mechanism. Whereas the former typically operates against the transition—be it the structural inertia of the techno-institutional complex or the political mobilization of incumbent interests—the latter can be driven from within the effort of transition itself.

The implications of this dispersion dynamic are likely to grow in weight over time. As this article has shown, the dramatic post-2022 shift in the security environment accelerated the chain of institutionalization in Japan; the same tensions are prompting moves in other regions to translate energy security pressures not merely into transient market adjustments but into durable institutional architectures. Severe import dependence, grid isolation, disaster exposure—these conditions are shared, in varying degrees and combinations, by island economies and high-import-dependency states subject to simultaneous security and decarbonization imperatives. The analytical framework appears applicable beyond Japan, though comparative validation awaits future research.

These dynamics speak at once to a normative question and to one of governance design. Pathways rooted in context-specific structural conditions must be accorded their own legitimacy. Yet to respect a specific context does not place the institutional consequences driven by that context beyond scrutiny. Reconciling these two demands allows energy security to be framed as a substantive challenge within transition governance. The obstacles to transition do not arise solely from resistance to transition. They can also arise from the very act of building institutions for the transition itself. What should be asked is not merely "what" a system is locked into, but whether the institutional architecture maintaining multiple pathways preserves the capacity for future convergence and exit. Under the conditions of compelled flexibility, exit is by no means an easy decision. That is precisely why a design is needed that keeps an exit strategy alive within the institution—one that demands the most urgent governance attention.

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Supplementary Material

Supplementary material for this article is available online in the format provided by the author (unedited).

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About the Author



Ayako Takemi is an associate professor at the Research Center for Advanced Science and Technology, University of Tokyo. Her research focuses on science and technology policy and transnational governance, spanning areas including AI and emerging technologies, economic security, energy, and health. She serves on government advisory boards and previously worked at the World Health Organization, the World Bank, and McKinsey & Company. She holds a PhD in Law from the University of Tokyo and an MPH from Harvard.