

# Obsolescence as a Governance Object: A Circular Economy Framework for Regulated Infrastructure

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## Abstract

Circular economy (CE) policy has largely developed around product markets, where ecodesign, repairability requirements, and extended producer responsibility now form a substantial regulatory layer. In regulated energy infrastructure, where replacement decisions are shaped by depreciation schedules, regulatory review cycles, and procurement rules, these tools have made limited progress. This perspective aims to explain why, and to identify what would be required to address it. Developing a conceptual argument from the electricity sector and generalizing it to regulated network infrastructure, and drawing on recent work on smart grid governance and the economics of infrastructure regulation, the paper distinguishes two modes through which obsolescence is produced. In product markets it is openly recognized and targeted by policy; in regulated infrastructure it is generated by institutional mechanisms whose mandates do not include lifecycle outcomes, leaving the premature replacement of functioning assets untreated as a governable issue. The paper shows that this institutional mode is structurally resistant to self-correction, and argues that bridging the gap requires defining obsolescence as an explicit governance object, with a clear institutional locus and a mandate for lifecycle outcomes, rather than extending existing CE instruments.

**Keywords** Circular Economy Policy · Energy Transition · Energy Infrastructure · Infrastructure Governance · Asset Lifetimes · Obsolescence Governance

## 1. Introduction

The energy transition is not just about new technologies, but it is also a large-scale infrastructure renewal (IEA, 2023). Much of today's electricity grid was built in the postwar period and is now reaching the end of its expected life (IEA, 2023), just as the system is being reshaped around distributed generation, electric mobility, and digital control (Di Silvestre et al., 2018). Over the next two decades, substantial portions of grid capacity will be replaced or upgraded (Heussaff & Zachmann, 2025), alongside the rollout of meters, sensors, and communication systems needed for digital operation (IEA, 2023). What is retired, and what replaces it, will shape material use, embodied emissions, and resource demand for decades to come. Decisions about replacement are therefore not technical details at the margins of the transition. They are central to whether the shift to low-carbon energy actually reduces material pressure or ends up intensifying it. The scale is considerable. Grid infrastructure is material-intensive, drawing heavily on copper, aluminium, and steel, and global grid investment, currently around USD 400 billion per year, is widely judged insufficient relative to the pace of electrification and renewable deployment (IEA, 2025). At the same time, supply chains for core grid components are under acute strain, with lengthening lead times and sharply rising prices for utility-scale transformers (IEA, 2025). This combination matters for the argument that follows. When the physical inputs to grid renewal are scarce and increasingly costly, the premature retirement of functioning assets is not a

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marginal inefficiency but a diversion of constrained material and manufacturing capacity away from the expansion the transition requires.

Circular economy (CE) policy has advanced quickly in response to these concerns. Over the past decade, it has moved from a broad idea to a set of concrete tools. Ecodesign rules, reparability indices, extended producer responsibility, and right-to-repair legislation now form a substantial layer of regulation in product markets (Kirchherr et al., 2023; Maitre-Ekern, 2021; Abdelmeguid & Corsini, 2026). The trajectory of this policy field has been one of progressively defining obsolescence as a problem and building instruments that intervene where it is produced. In regulated energy infrastructure, however, progress has been limited (Reindl et al., 2024). Studies of circularity in infrastructure consistently document barriers but stop short of locating where, institutionally, obsolescence is produced. Here, replacement is not driven by design choices or consumer behavior but by depreciation schedules, regulatory review cycles, and procurement rules. Recent work on smart grid governance points to the core issue: the institutions making these decisions are not tasked with evaluating lifecycle outcomes, and existing CE tools rarely reach the points where retirement decisions are actually made (Pardalis et al., 2026).

This perspective builds on that insight. It argues that obsolescence in regulated infrastructure is produced in a fundamentally different way than in product markets. Bridging the gap between CE policy and energy infrastructure therefore requires more than extending existing tools. It requires recognizing and defining a form of obsolescence that current policy does not yet treat as something that can be governed. The gap, in other words, is not only one of policy coverage but of how the problem has been conceptualized in the literature. Existing scholarship documents that circularity stalls in infrastructure without specifying the institutional mechanism through which obsolescence is produced, or the conditions under which it could be governed. Addressing this is the aim of this perspective. The argument is developed from the electricity sector, where the dynamics of postwar grid renewal, regulated asset bases, and standards-driven replacement are most visible. The institutional pattern it describes, however, is characteristic of regulated network infrastructure more broadly, with implications that extend beyond electricity alone.

The argument proceeds in three steps. It first distinguishes how obsolescence is produced in product markets from how it is produced in regulated energy infrastructure. It then examines the institutional mechanisms, depreciation regimes, regulatory cycles, and procurement and standards, through which infrastructure obsolescence is generated and sustained. Finally, it sets out what would be required to make this form of obsolescence an explicit object of governance, before considering the implications for regulated network infrastructure more broadly.

## 2. Two Modes of Producing Obsolescence

Obsolescence is not a single, uniform process. In product markets, where CE policy has focused most of its attention, it emerges from design decisions, software lifecycles, market turnover, and end-of-life systems. Importantly, it is also openly recognized as such. Policies like right-to-repair, ecodesign standards, and extended producer responsibility treat obsolescence as a defined problem and intervene directly where it is created (Maitre-Ekern & Dalhammar, 2016; Svensson-Hoglund et al., 2021; López-Bermúdez & Vence, 2025). The CE policy framework is still evolving, but the object of governance is clear. Obsolescence in product markets is visible, debated, and addressed through dedicated policy tools, although recent critiques note that many CE interventions still leave deeper structural and economic drivers of obsolescence insufficiently governed (Svensson-Hoglund et al., 2021; López-Bermúdez & Vence, 2025).

In regulated energy infrastructure, the situation is different. Infrastructure sectors are often characterized by long asset lifetimes, centralized ownership structures, and high institutional resistance to change, conditions that complicate CE implementation compared to product markets (O'Leary et al., 2024). Replacement decisions are concentrated in a small number of institutional settings: depreciation schedules set through price controls, procurement specifications written by utilities, and technical standards defined by sector bodies (Pardalis et al., 2026). These are not market-driven processes. They are governed by accounting rules, regulatory procedures, and compliance requirements. Each of these mechanisms can lead to assets being retired. A depreciation schedule, for example, spreads cost recovery over a fixed period. Once that period ends, replacement becomes the default option, regardless of physical condition (Kuosmanen & Nguyen, 2020; Brunekreeft & Rammerstorfer, 2021; Bovera et al., 2024). Regulatory reviews revisit assumptions only at set intervals. Updated standards can render existing equipment non-compliant, even if it still functions (Reindl et

al., 2024). In all these cases, obsolescence is not an explicit objective. It is a byproduct of pursuing other goals, cost recovery, reliability, or standardization. As a result, obsolescence in regulated infrastructure is rarely treated as something to be governed in its own right. No mandate explicitly addresses it. No policy category captures how it is produced. Even where the phenomenon is documented, there is no clear institutional space in which it can be acted upon (Reindl et al., 2024; Coenen et al., 2023; O’Leary et al., 2024; Dordai et al., 2026).

This makes the two modes of obsolescence fundamentally different. They differ not only in where decisions are made, but also in whether obsolescence is recognized as a policy issue at all. CE policy is well suited to the product-market context, where it can target design and production decisions. Extending those tools into infrastructure may help at the margins, but it does not address the core issue: in these settings, obsolescence has not yet been defined as something that policy is meant to govern. This aligns with broader critiques that CE implementation often remains concentrated around downstream interventions rather than systemic institutional transformation (Kirchherr & Hartley, 2025). Closing this gap is therefore not just about applying existing instruments more widely. It requires first making obsolescence visible as a governance object in its own right.

### 3. How Institutional Obsolescence is Produced and Sustained

If obsolescence in regulated infrastructure is produced institutionally, two questions follow. How does this happen in practice, and why does it continue even as its effects become clearer? Three mechanisms play a central role: depreciation regimes, regulatory review cycles, and procurement and standards frameworks.

Depreciation schedules are often treated as descriptions of asset lifetimes, but in practice they are forward-looking financial commitments. They determine how capital costs are recovered over time and are designed to be stable and predictable. Once an asset reaches the end of this period, replacement becomes likely, not because it has failed, but because its role in the financial structure has ended (Bovera et al., 2024; Brunekreeft & Rammerstorfer, 2021; Kuosmanen & Nguyen, 2020; Pardalis et al., 2026). This predictability is essential for investment, but it also disconnects replacement decisions from actual physical condition. Regulatory review cycles introduce a different constraint. Energy systems are governed through periodic reviews, typically every four to eight years. Within each cycle, rules remain largely fixed; changes occur in discrete steps between cycles (Jamash, 2021; Joskow, 2024). This means that new information about asset performance or alternative solutions does not feed into decisions continuously. It accumulates and is only considered when the next review opens. Procurement rules and technical standards act as gatekeepers. Equipment must meet current specifications at the point of purchase or installation. When standards change, existing assets may no longer comply, even if they are still functional (Coenen et al., 2023; Qazi & Appolloni, 2022). In most cases, the system is not designed to manage this mismatch. Replacement becomes the default response, often aligned with the next investment cycle. Together, these mechanisms generate obsolescence as part of normal system operation, not as a failure or exception.

The persistence of this pattern can be traced to three reinforcing dynamics. First, mandate insulation. The institutions involved are not tasked with managing obsolescence. Regulators focus on cost recovery and reliability. Procurement bodies prioritize cost certainty and compliance. Standards organizations aim for technical consistency. Sustainability concerns may be present, but they are framed in terms of emissions, efficiency, or renewable integration, not in terms of extending asset lifetimes (Reindl et al., 2024). This pattern is also visible in recent repair governance debates, where policy instruments often fail to address the institutional and economic mechanisms driving premature replacement (López-Bermúdez & Vence, 2025). As a result, premature replacement does not appear as a problem within the mandates that guide decision-making. Second, weak feedback. The system does not translate premature replacement into a signal that demands action. Asset turnover shows up as investment, procurement, or compliance, categories that are already expected and monitored. What CE policy would identify as obsolescence is not captured in the metrics used to evaluate performance. Existing governance frameworks often emphasize transparency and market coordination while leaving core drivers of obsolescence largely untouched (López-Bermúdez & Vence, 2025). The issue is not the absence of information, but the absence of a framework that makes it meaningful. Third, lack of coordination, a problem also identified in circular energy supply chains where implementation is constrained by coordination complexity, fragmented regulation, and weak multi-actor governance (Dordai et al., 2026). Responsibilities are fragmented across institutions that rarely operate within a shared framework.

Energy regulators, environmental agencies, procurement bodies, and standards organizations each act within their own domains. No mechanism brings lifecycle, cost, and material considerations together in a single decision space (Ateş et al., 2024; Markard et al., 2020; Serrano-Arévalo et al., 2026).

These dynamics reinforce one another. Together, they make the system resistant to change and help explain why premature replacement persists (Meadowcroft & Rosenbloom, 2023; Rosenbloom et al., 2020). More broadly, CE implementation failures often stem not from a lack of technical solutions, but from fragmented governance structures and the incremental character of existing policy interventions (Kirchherr & Hartley, 2025). Addressing it will require more than refining existing tools, it will require redefining how the problem itself is understood and governed.

## 4. Making Obsolescence a Governance Object

If obsolescence persists because it is not recognized within governance, then reform must begin by defining what, exactly, is to be governed. This is less about adding new tools and more about making the object itself visible and actionable. Doing so requires clarity on three points: what the object is, where it sits institutionally, and what kind of mandate it implies. This emphasis on identifying where intervention should occur is consistent with sustainability transitions research highlighting the importance of defining policy intervention points within socio-technical systems (Kanger et al., 2020).

The object is the premature replacement of functioning infrastructure assets. More precisely, it is the gap between when an asset is retired for institutional reasons, through depreciation schedules, standards updates, or procurement cycles, and how long it could continue to operate. This definition is intentionally narrow. It does not cover all material use or environmental impacts, which are already partly addressed elsewhere. Instead, it isolates a specific, measurable phenomenon: assets being replaced while still technically viable. This object cuts across three domains, regulation, accounting, and procurement, none of which currently take responsibility for it (Kanger et al., 2020; Pardalis et al., 2026). Regulators focus on cost recovery and reliability, accounting defines depreciation, and procurement enforces standards. In each case, premature replacement appears only indirectly, if at all. To govern it, there must be a clear institutional point where such decisions can be examined as instances of obsolescence, not just as routine investment, compliance, or cost recovery. This distinction matters because policy interventions that lack a clearly specified governance object risk addressing symptoms of obsolescence without intervening in the institutional conditions through which it is reproduced (López-Bermúdez & Vence, 2025).

That, in turn, requires a specific mandate: responsibility for lifecycle outcomes. This means evaluating replacement decisions not only in terms of cost and reliability, but also in terms of material use and asset longevity. It is not a broad sustainability objective, but a focused requirement to identify and address the premature retirement of working assets. Once defined in this way, the implications for reform become clearer. Three conditions are essential: responsibility, visibility, and integration (Kanger et al., 2020). This emphasis on identifying intervention points is consistent with systems-based CE research emphasizing that sustainability transitions depend not only on circular practices themselves, but also on the alignment of governance capacities, institutional coordination, and innovation systems (Xie et al., 2026).

First, responsibility must be assigned to an actor with the authority to act. In many cases, this could be the sector regulator, but only if its mandate is expanded to include lifecycle considerations (Reindl et al., 2024). Without that, even a formally responsible body would lack the authority to intervene. Second, the object must become visible within the system. This requires new forms of reporting. One practical step would be asset-lifecycle reporting tied to regulatory review cycles, where utilities disclose the gap between technical and accounting lifetimes and justify replacement decisions accordingly (Coenen et al., 2020). The aim is to make premature replacement visible at the point of decision, not after the fact. Third, there must be a place where fragmented responsibilities come together, since circular energy transitions depend on governance arrangements that combine policy instruments, institutional capacity, enforcement, and multi-actor coordination (Dordai et al., 2026). A possible mechanism is a lifecycle review requirement before major replacement programs, bringing regulators, procurement bodies, and other relevant actors into a single evaluative process. Existing proposals, on depreciation reform (Brunekreeft & Rammerstorfer, 2021; Oberle et al., 2024) or circular procurement (Qazi & Appolloni, 2022; Coenen et al., 2023), touch parts of this issue, but lack a shared object around which to align.

What emerges is not a new policy instrument, but a clearer definition of what is to be governed. A specific, measurable form of obsolescence, located within institutions and tied to an explicit mandate.

While the argument has been developed from the electricity sector, the underlying institutional pattern is not unique to it. Infrastructure systems may require circularity approaches distinct from those developed for buildings or consumer products (Byers et al., 2025). Replacement decisions concentrated in depreciation schedules, regulatory review cycles, and standards-driven specifications are characteristic of regulated infrastructure more broadly, including water, gas, and district heating. Each sector introduces its own scope conditions: water regulators carry explicit public health and environmental mandates that shape how lifecycle considerations enter decision-making; gas networks face decommissioning rather than renewal pressures as demand declines (Oberle et al., 2024); and district heating operates with longer asset lifetimes that shift the timing of misalignment without resolving it. Examining these parallels in depth, and identifying where the framework requires adjustment, is a task for further research.

## 5. Conclusion

Circular economy policy has developed primarily around product markets, where it can target design, production, and consumption. Regulated infrastructure is where that approach reaches its limits. Here, replacement decisions are shaped by depreciation schedules, regulatory cycles, and standards. The institutions involved act within mandates that prioritize cost, reliability, and compliance. Premature replacement emerges as a byproduct of these objectives, and remains largely invisible because it is not defined as a problem to be governed.

Extending existing CE tools into this space can help, but it does not address the core issue. What is missing is not another instrument, but a clearly defined object of governance. That object is the premature replacement of functioning infrastructure. Making it governable requires defining it precisely, locating it within institutional structures, and assigning responsibility to actors with the authority to act.

This perspective is conceptual, and its limits follow from that. It identifies how premature replacement is produced in regulated infrastructure and argues for treating it as an object of governance, but it does not measure how much occurs or test the proposed mandate against a specific regulatory regime. The argument is developed from the electricity sector and extended to regulated network infrastructure by analogy. How far it carries to gas, water, or rail remains to be examined, as does its variation across jurisdictions with different regulatory models and depreciation conventions. Assigning responsibility for lifecycle outcomes indicates where reform might begin rather than specifying the instrument through which it would work. These limitations also indicate directions for future research. Estimating the scale of institutionally driven replacement, comparing regulatory regimes and infrastructure sectors, and developing the mandate through which lifecycle responsibility could be exercised.

The next step for circular economy policy is therefore conceptual as much as practical. It involves deciding what counts as something that can, and should, be governed. What policy can address ultimately depends on what it is able to see.

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## Declarations

**Competing Interests** The authors declare no competing interests.

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