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# The Grid's Invisible Constraint

A lack of standardized infrastructure data is holding back efforts to modernize the nation's electrical grid.

Maintaining the electrical grid is one of the central challenges of our time. The electrification of transportation and buildings, rapid growth in data centers and advanced manufacturing, integration of renewable energy, and increasing exposure to extreme weather are placing unprecedented demands on electrical transmission and distribution infrastructure. In demand hotspots, regional planners must determine whether existing infrastructure can safely support higher loads, or whether new transmission and distribution assets are required. Those determinations depend on knowing, with confidence, what already exists in the field—even when some of the equipment dates to the 1950s.

To most consumers, grid infrastructure appears interchangeable: poles, towers, conductors, and substations delivering electricity in the background of everyday life. But even a single steel transmission pole embodies a complex set of characteristics that determine its performance. Geometry, material properties, foundation design, attachment configurations, and designed loading all influence how a single structure responds to wind, ice, temperature, electrical demand, and the passing of time.

Often this critical information is incomplete, inconsistent, or inaccessible. Different utilities, and often different departments within the same utility, capture different attributes of grid infrastructure, in different formats, and at different stages of an asset's lifecycle. When complete information exists, it is not guaranteed to be in a form that allows for validation or reuse across planning, operations, and analytics.

Over time, representations of the grid can become a patchwork of partial truths rather than a coherent, authoritative description of physical reality.

As a transmission line engineer for assessment teams in California and Puerto Rico, I have witnessed and worked to repair this patchwork personally. In the field, I learned how much history and context are contained in every data point—every asset and component of distribution and transmission infrastructure. The interpretation of these data points influences design decisions, material allocations, crew safety, cost, and project delivery. When engineers and planners lack consistent structural data about the grid, they depend on assumptions and guesswork.

Today, the US energy sector receives near-failing grades from expert observers—a state often blamed, accurately, on lack of investment and aging physical assets. But the task of improving and investing is hindered by the lack of standardized, high-quality data about the grid's physical infrastructure. This missing information makes the grid harder to operate, upgrade, and explain to regulators and the public. Even advanced analytics and digital tools cannot compensate for fragmented system knowledge, inconsistent asset records, and disconnected operational understanding. Of course, meaningful modernization of the grid requires better technology, but that cannot be installed without a more complete understanding of how the grid's physical, operational, and organizational components function together as an integrated system.

### Lessons from the field

After a disaster, the first step utilities take toward recovery, rebuilding, and upgrading the grid is to do a field damage assessment. Field assessment is an exercise in both physical observation and systems analysis. Utilities begin by deploying crews of linemen, engineers, and other stakeholders to identify visible damage, inaccessible areas, immediate safety concerns, and restoration priorities by walking the lines to substations and generation facilities. At this stage, accuracy is paramount—for safety and for informing future planning. But accuracy can be lost if field crews have a limited understanding of how their observations will be interpreted and transferred throughout the broader utility ecosystem. The information they collect gets integrated into geographic information system platforms, which feed into various management and design systems engineers use to conduct more detailed assessments and structural inspections. From there, field data may ultimately pass through systems operated by utilities, engineering consultants, construction contractors, software platforms, regulators, and funding agencies, each with different reporting requirements, standards, and operational objectives.

Without standardized frameworks for organizing and managing this information, utilities risk creating fragmented datasets that limit visibility across programs, complicate decisionmaking, and reduce the long-term value of the assessments themselves.

For several years I served as a member of an assessment team in a grid infrastructure wildfire mitigation program in Southern California. The program, launched in 2019, aimed to identify structural conditions and environmental factors that could contribute to wildfire ignition and then to prioritize corrective action. The program contracted with vendors to capture high-resolution aerial videos and photos of transmission and distribution infrastructure.

From my position, I could see that physical and conceptual gaps in the field data limited its usability for decisionmaking. The aerial imagery often missed or obscured key components of engineering analysis: hardware interfaces, conductor attachment points, crossarm surfaces, insulator assembly elements, vegetation proximity, structure foundations, and grounding elements.

A further issue was that the tool we were supposed to use to collect and analyze data constrained the level of detail we could record. This lack of specificity undermined trust among the engineering and operations teams using the data to make decisions about prioritizing repairs in high-risk spots.

To deliver optimal results, our team had to fundamentally shift how we defined and collected data. The assessment team engaged directly with aerial inspection vendors to specify why certain views mattered, not just what to capture. They adjusted flight paths, camera angles, zoom levels, and focus to align imagery with engineering and risk assessment needs. Meanwhile, team members refined the collection and analysis tool, so that the data were more technically valuable. They standardized categories and improved formatting to support downstream analysis. In addition, the team created a framework to review completed assessments to validate conclusions and reconcile inconsistencies. This validation process ensured the observations met newly established program standards, adding an important layer of quality assurance and control. In this case, resolving data management deficiencies proved less costly than deferring the problem.

Something we realized in this process is that a key attribute of high-quality data is longevity: Data must be accurate at intake, but also remain functional after analysis and processing. Utility managers, analysts, and external advisors might easily assume the newest data hold the most value in a large dataset, but data recorded over time are what enables the kind of reliable trend analysis and contextual understanding that real-time and predictive applications need. As utilities continue to expand storm preparedness and resilience planning, they are increasingly pairing aerial inspection programs with artificial intelligence and machine-learning analytics for fire-risk mapping, vegetation management, and decision support for public safety power shutoffs. However, without disciplined data standards and validation processes, even the most advanced inspection technologies may fail to deliver meaningful insight.

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It is increasingly clear that sophisticated algorithms cannot compensate for poorly defined inputs. I saw this deficiency myself in the aftermath of Hurricanes Maria (2017) and Fiona (2022) in Puerto Rico, when data quality was an operational imperative—not just an administrative concern—for disaster recovery. During the power restoration efforts after Maria, I was on a field team conducting damage assessments, traversing the island and performing visual inspections along electric circuits to develop a comprehensive view of system damage. Later, in the recovery after Fiona, I worked in a program management office supporting the broader restoration effort across the island. In both events, a key to quick restoration was high-quality observations. Inaccurate or inconsistent damage classifications could misallocate resources, expose crews to unnecessary risk, or hamper recovery.

After Fiona, I fully understood how damaging fragmented data frameworks are in disaster recovery. Post-storm rebuilding efforts require utilities to engage the full infrastructure data lifecycle at once: design, construction, inspection, operations, and program management. Working across these stages provides an end-to-end view of how data flow, or fail to flow, through a complex utility program.

Back-to-back hurricanes in 2017 (Hurricanes Irma and Maria), plus a series of earthquakes in 2019 and 2020, meant that construction on many recovery projects had barely started before new damage assessments were made. Emergency repairs and overlapping reconstruction efforts during Fiona obscured the distinction between newly damaged assets and those already under repair or planned for restoration. But the US Federal Emergency Management Agency administered the responses to Maria and Fiona with different public assistance mechanisms to deploy recovery funds, meaning that every damage claim had to be attributed to a specific storm to secure funding. Inconsistencies that might have been tolerable within a single system became liabilities when data had to be linked to multiple systems of record. To keep projects moving forward, our team had to redesign processes and tools and conduct large-scale data cleansing in parallel with the time-critical restoration.

The challenges in Puerto Rico were acute because they unfolded under pressure, across overlapping programs, and within multiple funding streams. But they are also emblematic of a more systemic issue: When data are not treated as durable, interoperable assets, even routine infrastructure programs begin to accumulate inefficiencies that compound over time. After a disaster, seemingly bureaucratic details like these quickly become critical hurdles to power restoration. Considering data deficiencies ahead of time should be a fundamental part of disaster preparedness and everyday maintenance.

## The real costs of poor data

Today, infrastructure data across the US grid are treated as a byproduct rather than a critical asset, an approach that has significant costs. When planners lack standardized data on existing corridors and structures, they rely on generalized models rather than measured realities. The result may be overengineered infrastructure that increases cost and land use impacts or underengineered systems that introduce operational risk. Either outcome undermines confidence in grid improvements, and both carry tangible financial and operational consequences that customers end up feeling. Industry analyses show that inconsistent asset data undermine efficiency, inflate both capital and maintenance costs, and slow decisionmaking across organizations.

Every new initiative—whether storm hardening, reconductoring, capacity expansion, or wildfire mitigation—begins by rediscovering the same infrastructure. Crews remeasure structures, engineers revalidate assumptions, and planners rebuild models that should already exist. This redundancy consumes scarce labor and engineering capacity, even as the industry faces workforce constraints.

When infrastructure data are incomplete, utilities are forced to design around uncertainty instead of measured conditions. Engineers often default to conservative assumptions to manage risk and avoid the costs of reworking projects during construction. This strategy can translate into overbuilt designs, unnecessary replacements, and expanded right-of-way impacts that raise material, labor, and permitting costs.

Uncertainties also spill into regulatory and investment decisionmaking. When confidence in underlying asset records is low, planners are forced to repeatedly validate assumptions, reconcile inconsistencies across systems of record, and initiate additional field verification before work can proceed. These steps extend planning cycles, slow project approvals, and complicate regulatory submissions as utilities work to build defensible technical narratives from incomplete or fragmented records. That uncertainty carries forward into external engagement, where investment decisions must be justified against infrastructure data that are not always consistent, traceable, or easily explained.

As a result, decisions become harder to defend both technically and politically, which further slows permitting. Public support for infrastructure investment depends on

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whether stakeholders believe the underlying decisions are credible, transparent, and grounded in reality. Without the right data to describe the system, even well-intentioned projects lose clarity and defensibility.

**Toward a new understanding of the grid**

The grid has unexpectedly landed at the center of several contemporary political debates, including how to surmount permitting hurdles to maintain US competitiveness, accommodate the energy demands of the data center boom, and build disaster resilience. These are questions for serious democratic engagement, but a greater understanding of existing infrastructure is required to inform policy in any direction. A common structural language for describing grid assets consistently across their lifecycle would transform the assessment capabilities of the engineers, planners, analysts, and asset managers who must make sense of today's landscape of material and modeled infrastructure.

In Europe, transmission system operators have adopted standardized grid models through the Common Grid Model Exchange Specification, developed by the European Network of Transmission System Operators for Electricity and based on the International Electrotechnical Commission's Common Information Model.

Under this framework, operators across more than 30 countries exchange detailed, machine-readable grid models that include topology, equipment attributes, and operating states. These standardized models support coordinated planning, contingency analysis, and capacity calculations across borders. Independent conformity testing ensures that vendor tools can exchange data reliably without custom translation layers.

The US grid operates under different institutional conditions, but the underlying principle remains the same. A national data standard for electrical grid infrastructure in the United States would establish baseline expectations for core asset attributes and terminology, field-data collection requirements and accuracy thresholds, standardized condition and damage classifications, metadata and provenance tracking, quality assurance and quality control processes across vendors and programs, and interoperability across planning, operations, and regulatory use cases.

Such a standard would benefit both the public and private sectors. Utilities would reduce duplicative work and improve decision quality. Regulators would gain more consistent visibility into system conditions and risks. Engineering firms, data acquisition vendors, equipment manufacturers, and construction crews would operate within clearer expectations, reducing friction and uncertainty.

Efforts to address these challenges are emerging, but from regulatory institutions rather than system operators. The National Association of Regulatory Utility Commissioners recently developed a Grid Data Sharing Framework to help state commissions evaluate when and how to make grid data available to third parties. While not a technical standard, the framework reflects a growing recognition that consistent, structured data are essential for planning, interconnection, and investment. By organizing questions around use cases, data definitions, impacts, and governance, the framework provides a common lens for navigating data access in an increasingly complex system. As such, it represents an important institutional step toward a more standardized and interoperable understanding of grid infrastructure in the United States.

Standardized infrastructure data can fundamentally improve how utilities manage supply chains for capital as well as operations and maintenance programs. When asset records clearly define material types, quantities, and configurations, utilities can link infrastructure data directly to material accounting systems and suppliers. This connection enables more accurate forecasting, reduces over-ordering and shortages, and shortens procurement cycles. In an era of constrained manufacturing capacity and volatile supply chains, these efficiencies matter.

Much of the US grid is well engineered but poorly described. Fundamentally, a shared data foundation would allow advanced analytics and AI tools to deliver on their promise: to support safer, more resilient, and more reliable electric infrastructure. Ultimately, the challenge is to understand the grid well enough to modernize it responsibly. The future of grid modernization depends not only on what the industry builds next, but on how fully it commits to building a shared and enduring understanding of the system itself.

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