

Assessing, monitoring and future proofing European Grids

Increasing transparency in the performance and the capabilities of Europe's electrical grids

*This paper updates T&D Europe's 2020 publication "**Assessing, monitoring and future proofing European Grids: Increasing transparency on the performance of electrical grids within the framework of the European Green Deal**"¹, and provides an updated assessment of output-based grid functionality indicators. T&D Europe's positions on the Strategic Roadmap for Digitalisation and Artificial Intelligence in the Energy Sector² and the Electrification Action Plan are presented in separate position papers and are therefore not covered in this document.*

Executive summary

Europe's electricity grids stand at a critical juncture, facing the unprecedented challenge of modernising aging infrastructure while simultaneously expanding capacity for massive electrification and renewable energy integration. Grid-enhancing technologies hold transformative potential, yet implementation remains limited and uneven across Member States, reflecting a structural misalignment between grid regulation and the requirements of the energy transition. While the EU Electricity Directive legally mandates National Regulatory Authorities (NRAs) to monitor smart grid development, implementation remains fragmented.

This paper outlines a decisive shift from measuring what operators install towards measuring what their grids can actually do. Europe does not need smart grids for their own sake, it needs grids that integrate renewables without curtailment, accommodate new demand without delay, maintain reliability despite growing complexity, and deliver all this affordably. This means transitioning from input-based indicators (tracking technology deployment) to outcome-based indicators focusing on the necessary grid functionalities: delivering capacity, managing security trade-offs, and coordinating seamlessly across borders. Aligning regulatory frameworks with these functional outcomes can help investments in smart technologies towards affordable, tangible, system-wide benefits, rather than incentivising the optimisation of isolated parameters

¹ T&D Europe (2020): "[Assessing, monitoring and future proofing European Grids: Increasing transparency on the performance of electrical grids within the framework of the European Green Deal](#)"

² T&D Europe (2026): "[Strategic Roadmap for the digitalisation and AI in the Energy Sector. Reaction from technology providers](#)"

at the expense of the overall system performance. This paper closes by outlining the political leadership required going forward.

Introduction

Europe's electricity grids stand at a crossroads. The infrastructure that powers our continent faces a dual challenge: modernising aging assets while simultaneously expanding capacity to accommodate the electrification of transport, heating, and industry alongside the integration of variable renewable energy sources. The European Commission³ estimates that grid-enhancing technologies could increase network capacity by 20-40% by 2040 and reduce costs by 35% compared to traditional expansion. Yet despite this potential, implementation remains limited and uneven across the Member States.

This paper demonstrates the benefit of transferring to output-based performance indicators which measure grid capabilities instead of technology deployment. The insights of these *grid functionality indicators* increase as the degree of harmonisation across the European Energy System advances, through the implementation of Grid Codes and flexibility use cases. Drawing on the 2025 T&D Europe study "*From Legacy to Leadership*"⁴, this paper argues that a resilient 'Grid of the Future' requires fundamentally rethinking of how the future power grid is being managed and regulated.

From Voluntary Vision to Legal Mandate: The Evolution of Smart Grid Monitoring

In 2020, T&D Europe published a comprehensive framework for grid smartness monitoring⁵ summarising numerous ongoing discussions and arguing that traditional regulation focused narrowly on cost-efficiency and current quality of service but failed to reflect preparedness for the fundamental changes resulting from the energy transition. The proposal recognised that Europe's grids need not just to perform well today, but to be ready for a radically different tomorrow, one characterised by bidirectional power flows, distributed generation, electrified transport, and the integration of millions of prosumers.

Article 59(1)(l) of the EU Electricity Directive⁶ mandates the NRAs to monitor and assess the performance of transmission and distribution system operators in relation to smart grid

³ [European Grids Package \(2025\)](#)

⁴ T&D Europe (2025): "[From Legacy to Leadership: Europe's Digital Grid Transformation: Why smart regulation is key to ensuring digital grids deliver value to all stakeholders](#)"

⁵ T&D Europe (2020): "[Assessing, monitoring and future proofing European Grids: Increasing transparency on the performance of electrical grids within the framework of the European Green Deal](#)";

⁶ [Electricity Directive \(2019\)](#)

development based on a limited set of indicators, and to publish a national report every two years with recommendations. The requirement is explicit and binding. The 2025 Copenhagen Energy Infrastructure Forum called upon ACER and CEER to deliver coordinated reports on common smart grid indicators at all voltage levels, including both output and input indicators⁷. Additionally, at the beginning of June 2026, the European Commission published its Strategic Roadmap on Digitalisation and AI for the Energy Sector⁸.

Yet despite a clear legal framework and political commitment, the current reality reveals a significant implementation gap. ACER's January 2026⁹ assessment confirms that progress in identifying and reporting smart grid indicators remains limited and uneven across Member States. While some countries have moved decisively, Portugal introduced 48 indicators in August 2024, Finland launched dynamic line rating indicators in December 2024, and Belgium applies capacity utilisation metrics for cross-border trade, many Member States are still in early development stages, grappling with fundamental questions about what to measure and how to measure.

This uneven implementation carries real consequences. Without harmonised indicators, Europe faces challenges in measuring progress, identifying best practices, or understanding where investments deliver the greatest value. Similarly, inconsistent measurement makes it more difficult for regulators to distinguish between operators that are effectively optimising grid functionalities and those continue to rely primarily on traditional network reinforcement. A lack of comparable data also can limit policymakers' ability to assess whether the energy transition is proceeding as efficiently as possible and whether public and private investment is being directed to the areas of greatest impact.

The Critical Shift: From Technology Deployment to Grid Functionalities within a European Energy System

The fundamental evolution between the 2020 industry vision and the 2026 regulatory framework is a deeper transformation in what gets measured and why. The 2020 T&D Europe proposal emphasised tracking the deployment of smart infrastructure, sensors, communication systems, and controllable devices as proxies for future readiness. These 'input' indicators aimed to answer the question: *'Will the installed technologies enable smarter grids?'*

In contrast, the 2026 focus should be on measuring outcomes. The 2025 T&D Europe Study 'From Legacy to Leadership' makes the case that actual grid functionalities and performance outcome,

⁷ [Copenhagen Energy Infrastructure Forum](#) (2026)

⁸ [Strategic Roadmap for Digitalisation and AI in the Energy Sector](#) (2026)

⁹ ACER (2026): [“Output performance indicators to monitor the application of electricity transmission grid-enhancing technologies”](#)

such as how effectively grids deliver capacity, reliability, efficiency, and flexibility, should be part of a grid-functionality indicator catalogue. These outcome-based performance indicators answer a different question: *'Are the technologies and operational practices we have deployed actually improving grid performance and delivering value to users?'*

This distinction matters profoundly. An operator can install thousands of sensors and achieve high scores on input indicators while failing to use that data to optimise operations or manage trade-offs. Conversely, an operator might deploy fewer technologies but use them strategically to enhance multiple grid functionalities simultaneously, increasing capacity during favourable conditions, maintaining security during stress events, integrating renewables without curtailment, and managing costs. Outcome-based performance indicators reveal which operators are genuinely transforming grid capabilities and performance rather than merely accumulating smart equipment.

The grid is no longer an independent asset; it has become a cornerstone of EU energy sovereignty, serving as the critical link between massive investments in power generation (wind, solar, and nuclear) and the priority to electrify demand while transitioning away from fossil fuels. This transition requires a flexible, resilient, and efficient system built around the grid. Consequently, the grid's evolution must align with the needs of both generation and end-users across multiple scales (local, national, and European), and across all time horizons (from seconds and minutes to days, months), and full seasons. Ultimately, this requires an integrated perspective of the energy system, recognising the critical role of the grid for the entire ecosystem.

The 2025 T&D Europe study *"From Legacy to Leadership"* identifies key functionalities that future grids must deliver: observability (comprehensive visibility into system state), controllability (ability to actively manage power flows and resources), automation (rapid response to changing conditions), integral data management (coherent information across operational domains), and data exchange within the grid ecosystem (coordination between actors). Performance indicators should assess how effectively operators develop and deploy these functionalities in ways that balance competing objectives rather than optimising individual metrics.

To be effective, outcome-based parameters must be defined with clarity and sufficient detail. They also require a broad design, as it is neither practical nor advisable to create a new output parameter for every new objective, or to frequently revise existing ones. The diminishing relevance of some objectives over time further highlights the necessity of an iterative process for reviewing and refining these target-oriented parameters.

ACER's January 2026 position paper¹⁰ proposes three output-based KPIs for transmission systems:

- The first, KPI_PET, measures the performance of existing transmission assets in real-time operations by comparing available operational capacity to standardised capacity. A value above one indicates that grid-enhancing technologies or improved operational practices have increased the usable capacity of existing grid assets.
- The second, KPI_SEC, measures the performance of operational security by comparing the cost of maintaining security with smart solutions versus without them.
- The third, KPI_GEP, assesses grid expansion performance by comparing the cost-effectiveness of smart solutions to conventional reinforcement.

In parallel, CEER proposes 14 output indicators across six dimensions for distribution networks, covering:

- renewable integration,
- electrification,
- continuity of supply,
- quality of supply,
- energy efficiency, and
- data availability for market participants.

All the suggested indicators focus mostly on those users of the system who manage to get connected. They do not address grid capabilities like connection queues, curtailed energy, time to approve new connection requests - just to give a few examples for grid functionalities. Regardless, together, these frameworks represent the most comprehensive attempt yet to make smart grid performance measurable, comparable, and actionable across Europe.

Excursus: Grid Utilisation as an Illustrative Example for Outcome-Based Grid-Performance Measurement

Grid utilisation represents one of the oldest parameters in power system management, tracked since the earliest days of electrification. However, it has remained focused almost exclusively on planning horizons, identifying where future bottlenecks will emerge, rather than operational

¹⁰ ACER (2026): [“Output performance indicators to monitor the application of electricity transmission grid-enhancing technologies”](#)

practice. According to the International Energy Agency ('IEA')¹¹ lack of grid capacity is emerging as critical bottleneck in many regions, driving higher levels of congestion and slowing the energy transition. Grid connection queues have reached record levels in several countries. Traditional grids typically operate at 20-30% and 60-70% of line capacity depending on grid topology and usage patterns. This underutilisation stems from conservative planning assumptions and static operational practices developed when generation was centralised, demand was predictable, and grids were designed for worst-case scenarios with substantial safety margins.

The IEA recognises that available grid capacity resides not primarily in new technologies but in the implicit security and capacity margins embedded in current operational practice and in the lack of operational grid visibility. Modern technologies and methods could safely access much of this locked-away capacity through three interrelated elements:

1. Enhanced visibility through advanced monitoring and sensors, providing accurate, current information about actual system conditions rather than conservative assumptions.
2. Dynamic operational rules allowing flexible response to actual conditions, adjusting security margins based on real-time data rather than static worst-case scenarios.
3. Controllable equipment with decentralised intelligence capable of acting on information immediately, enabling operators to optimise power flows and maintain security through active intervention.

These three elements form an integrated system. Sensors without dynamic rules provide information that cannot be acted upon. Dynamic rules without controllable equipment create requirements that cannot be met. Controllable equipment without visibility operates blindly. Only when all three work together does the system unlock its full potential, and this integration must be reflected in performance indicators.

The shift from input to outcome-based performance indicators defined by grid functionalities reflects a maturing understanding of what the energy transition requires. Europe does not need smart grids for their own sake. Europe needs grids that can integrate renewables without curtailment, accommodate new demand without delay, maintain reliability despite complexity, manage security under uncertainty, and deliver all this affordably. Grid-functionality indicators focus on these outcomes, ensuring that investments in smart technologies translate into tangible benefits across multiple dimensions rather than optimising single parameters at the expense of others.

¹¹ [IEA Electricity](#) (2026)

The Energy Trilemma: Managing Trade-offs Through Comprehensive Performance Measurement

Furthermore, grid utilisation not only demonstrates why functionality-based indicators are essential, it also illustrates the trade-offs inherent in the energy trilemma, the need for integrated measurement across multiple dimensions, the importance of data infrastructure, and the regulatory reforms required to align incentives with smart grid objectives.

At the heart of the smart grid challenge lies a fundamental reality: all grid management objectives involve trade-offs. The energy trilemma, balancing affordability, security of supply, and environmental sustainability, manifests in every operational and investment decision. Optimising one dimension often creates tensions with others, requiring careful management rather than the single-minded pursuit of any individual goal.

As previously described, increasing utilisation through dynamic operational practices and grid-enhancing technologies can unlock substantial capacity, defer costly infrastructure investment, and improve affordability. However, higher grid utilisation inherently involves trade-offs. Operating transmission lines closer to their thermal limits reduces safety margins, potentially increasing risk during unexpected events. More intensive use of equipment may accelerate aging and increase maintenance requirements. If poorly managed, these complexities could reduce system resilience. The goal, therefore, is not to maximise utilisation regardless of consequences, but to optimise it within acceptable security boundaries, extracting value from existing assets while maintaining reliability.

This is precisely why comprehensive outcome-based indicators addressing multiple grid functionalities are essential. A regulatory framework that measures only utilisation creates incentives to maximise capacity delivery potentially at the expense of security. A framework that measures only reliability creates incentives to maintain excessive margins at the expense of affordability. A framework that measures only renewable integration creates incentives to prioritise clean energy potentially at the expense of system stability.

Eventually the right balance of indicators could also be used to assess European competitiveness compared to other major economies. Examples for such indicators could be:

- **Decarbonisation Velocity:** Monitoring connection queuing times for wind and solar farms reveals whether decarbonisation is progressing at the necessary speed and whether digitalisation and infrastructure planning are sufficiently robust to support new generation,

- **Grid Absorption Capacity:** Tracking connection queuing times for large-scale demand, such as Data Centres, to measure the grid's ability to absorb new demand-side needs in a timely manner,
- **System Flexibility and Integration:** A key metric for flexibility is the frequency and duration of negative energy prices. Monitoring this metric across the five EU electricity zones would provide an internal benchmark for how well the system is integrating renewables and managing surplus, or
- **Strategic Sovereignty and Electrification:** The volume of gas and fuel imports as a measurement for Europe's energy sovereignty; coupled with the electrification rate of the demand side defines the grid's capacity to absorb new, decarbonised load¹².

Grid Functionalities as the Foundation for Future-Ready Regulation

The 'Grid of the Future' requires a system approach and regulatory frameworks addressing functionalities rather than isolated performance metrics. This distinction is subtle but profound. Technology-focused regulation specifies what equipment operators should deploy: smart meters, sensors, controllable transformers, energy storage. Metric-focused regulation specifies what outcomes operators should achieve: utilisation above X%, outage duration below Y minutes, renewable integration above Z%. Functionality-focused regulation specifies what capabilities the grid system must possess: the ability to observe conditions accurately, control flows dynamically, respond automatically to disturbances, manage data coherently, and coordinate across organisational boundaries.

This functionality-based approach offers several advantages. First, it creates technology neutrality, allowing operators to choose the most cost-effective solutions for delivering required capabilities rather than being locked into specific equipment mandates. An operator might achieve enhanced observability through advanced sensors, through better use of existing SCADA data, through integration of smart meter information, or through some combination, what matters is that the capability exists, not how it was achieved.

Second, it focuses on system-level performance rather than component-level deployment. A grid might have excellent sensors but poor data integration, resulting in information that cannot be used effectively for decision-making. It might have controllable equipment but inadequate automation, resulting in capabilities that cannot be deployed quickly enough during

¹² Note when benchmarked against the US and China, this rate should exclude baseline Data Centre consumption to focus specifically on the "fuel-switch" (the transition from fossil fuels to electricity).

disturbances. Functionality-based indicators assess whether the integrated system delivers required capabilities, not whether individual components exist.

Third, it naturally accommodates the trade-offs inherent in grid management. Functionalities can be assessed under different operating conditions (normal operations, stressed conditions, contingency events, restoration scenarios), revealing how well the system balances competing objectives. An operator might achieve high utilisation during normal conditions but maintain adequate security margins during stressed conditions, demonstrating effective trade-off management. Functionality indicators can capture this nuance in ways that simple utilisation or reliability metrics cannot.

Fourth, it aligns with how operators actually manage grids. Operators do not think primarily in terms of individual technologies or isolated metrics but in terms of capabilities: *"Can I observe what's happening across my network?"*, *"Can I control flows to manage congestion?"*, *"Can I respond quickly enough to disturbances?"*, *"Can I coordinate with neighbouring operators?"*. Indicators that reflect this operational reality are more likely to drive meaningful improvement than those focused on abstractions disconnected from daily practice.

Examples for first applications are the Germany's *"Anreizregulierung"* (incentive regulatory framework), and a Norwegian smart grid pilot¹³ that demonstrates how coordinated deployment of visibility, dynamic rules, and controllable equipment unlocks hidden capacity while maintaining or enhancing system security. This project shows that grid utilisation is not merely a theoretical concept, but a practical pathway to affordable energy transition, validated through real-world demonstration under actual operating conditions.

These approaches represent a first step toward a functionality-based indicator approach and shift the regulatory conversation from *"Did you install dynamic line rating?"* to *"Are you effectively managing the trade-off between capacity delivery and security across varying operating conditions?"*.

Implementing functionality-based indicators requires careful design to avoid excessive complexity or subjective assessment. The indicators must be measurable with available or reasonably obtainable data, comparable across operators with different starting points and contexts, and actionable in the sense that operators can identify concrete steps to improve performance.

¹³ [Norwegian smart grid pilot](#)

Data as Strategic Infrastructure: The Foundation for Performance and Accountability

Performance indicators, regardless of how thoughtfully designed, remain meaningless without the data infrastructure to populate them. This seemingly technical point carries profound strategic implications. Comprehensive, high-quality, consistent, and accessible data represents the foundation upon which both smart grid operations and meaningful regulatory oversight depend. Without this foundation, neither operators nor regulators can distinguish between genuine performance improvement and statistical noise, between best practices worth replicating and local anomalies, between operators maximising value and those merely going through the motions.

The data requirements for meaningful functionality-based indicators are substantial and multifaceted. At the most basic level, operators need actual visibility into grid topology, asset status, loading conditions, power quality, and system stability across all voltage levels. This requires sensors, communication systems, and data management platforms capable of collecting, transmitting, storing, and processing enormous volumes of information with high reliability and low latency. For transmission systems, much of this infrastructure already exists through SCADA and energy management systems, though coverage and quality vary. For distribution systems, particularly at medium and low voltage levels, visibility remains limited in many Member States, with operators relying on periodic measurements, customer complaints, and engineering estimates rather than continuous monitoring.

Beyond basic visibility, functionality indicators require harmonised data management across operator departments, breaking down the internal silos that have traditionally separated planning, operations, and maintenance functions. Effective performance depends on understanding not just current conditions but asset health, weather forecasts, market schedules, contingency scenarios, and coordination requirements with neighbouring operators. This information typically resides in different systems managed by different teams using different data formats and updating cycles. Integrating this information into a coherent operational picture requires substantial investment in data platforms, standardised interfaces, and organisational change.

The challenge extends beyond individual operators to cross-operator coordination, particularly the TSO-DSO cooperation essential for managing increasingly bi-directional power flows and distributed energy resources. When solar generation on distribution networks affects transmission-level congestion, or when transmission-level constraints require distribution-level flexibility activation, operators need shared situational awareness and coordinated decision-

making. This requires not just technical interoperability but governance frameworks defining data-sharing responsibilities, liability allocation, and decision authority.

At the European level, cross-border systems supporting EU-wide monitoring and planning add another layer. ACER's monitoring of remaining available margin in flow-based capacity calculation regions already demonstrates the value of European-level data integration, enabling regulators to assess how effectively existing transmission capacity is used and how innovative grid technologies contribute to increasing available capacity. Extending this approach to comprehensive functionality assessment would provide transparency into European grid performance, enabling benchmarking, best practice identification, and evidence-based policymaking.

Yet, building this data infrastructure requires sustained investment at a time when operators face competing demands on limited capital budgets. Sensors, communication systems, data platforms, and cybersecurity measures represent substantial costs, particularly for distribution operators serving dispersed rural areas where the business case for digitalisation may appear less compelling than in dense urban centres. Without regulatory frameworks that recognise data infrastructure as essential investment, worthy of cost recovery and potentially incentive rewards, deployment will remain patchy and incomplete.

This is where the connection between data infrastructure and performance indicators becomes strategic. Mandating functionality-based indicators creates regulatory demand for the data infrastructure needed to populate them. Operators cannot report on system flexibility without comprehensive monitoring. Regulators cannot assess grid flexibility standardised data formats and reporting templates. The indicators themselves drive investment in data infrastructure, creating a virtuous cycle where better data enables better indicators, which in turn justifies further data investment.

The data infrastructure required for functionality indicators, however, serves multiple purposes beyond regulatory reporting. The same sensors that enable utilisation monitoring also support outage detection, power quality assessment, asset health management, and customer service. The same data platforms that calculate utilisation metrics, also enable advanced distribution management systems, voltage optimisation, and integration of distributed energy resources. The same communication networks that transmit utilisation data also support smart metering, demand response, and electric vehicle charging coordination. Data infrastructure is not a cost centre supporting regulatory compliance, but a strategic asset enabling operational excellence across multiple dimensions.

European policymakers recognise the foundational role of a data infrastructure, including European data spaces, for the energy transition. The role of smart grid indicators as the key driver

for building this infrastructure, however, is not yet being recognised. The implementation of grid-functionality indicators requires regulatory frameworks that ensure cost recovery for data investments, financial incentives that reward data quality and accessibility, and, where market mechanisms prove insufficient, direct public investment. Without this recognition, the ambitious frameworks for smart grid indicators developed by ACER and CEER will remain partially implemented, undermined by inadequate data infrastructure.

Strategic Incentives: Aligning Regulation with Digital Reality

The relationship between performance indicators and financial incentives represents one of the most delicate challenges in smart grid regulation. On the one hand, indicators without monetary consequences inevitably receive less attention than those tied to bonus-penalty systems, particularly in organisations managing multiple competing priorities with limited resources. On the other hand, premature linkage of novel indicators to financial consequences risks perverse outcomes, gaming behaviour, and operator resistance that undermines the entire framework.

This tension is particularly acute during the current phase of grid transformation, which requires enormous investments in digitalisation, advanced data processing, IT/OT security, and organisational capability development. These investments differ fundamentally from traditional grid infrastructure in their cost structure, risk profile, and value delivery timeline. Traditional infrastructure investments are capital-intensive, with costs concentrated upfront and value delivered over decades through physical asset operation. Digital investments often involve substantial operating expenditure for software licenses, cloud computing, cyber-security, and skilled personnel, with value delivered through improved decision-making, operational optimisation, and enhanced flexibility rather than physical capacity expansion.

Traditional regulatory frameworks developed for capital-intensive utilities struggle to accommodate this reality. Rate-of-return regulation that allows cost recovery plus a return on capital investment naturally favours physical infrastructure over software and services. Regulatory asset bases that include physical equipment but exclude intangible assets systematically disadvantage digital solutions. Depreciation schedules designed for equipment with 40-year lifespans poorly fit software requiring continuous updates. The result is a regulatory environment that inadvertently creates barriers to the very digitalisation that smart grid performance indicators are meant to encourage.

This creates a paradox. Regulators mandate smart grid indicators to drive performance improvement, but the regulatory frameworks governing cost recovery and incentives make it financially unattractive for operators to pursue the digital investments that would improve performance on those indicators. Operators face a choice between maximising financial returns

under existing regulatory frameworks by focusing on traditional infrastructure or pursuing smart grid solutions that improve functionality performance but receive less favourable regulatory treatment.

Breaking this paradox requires fundamental regulatory reform toward frameworks that create technology neutrality between traditional and digital solutions. This means shifting from pure CAPEX models to TOTEX approaches that value operating expenditure equally with capital expenditure when both deliver equivalent grid functionality improvements. It means expanding regulatory asset bases to include intangible assets like software platforms, data systems, and digital capabilities. It means developing depreciation and cost recovery mechanisms appropriate for digital investments with shorter physical lifespans but ongoing value delivery through updates and improvements.

A few European countries have begun experimenting with such approaches¹⁴. Yet these remain exceptions rather than the rule. Developing robust incentive mechanisms requires an essential foundation-building. This includes building reliable baselines, observing indicator behaviour across different operating contexts, understanding what genuinely drives performance variation, and distinguishing between results stemming from operational excellence versus inherited infrastructure advantages or favourable geography. Operators and regulators alike must develop shared understanding of what good performance looks like and how quickly improvement can reasonably occur, creating the evidence base needed for incentive mechanisms that drive genuine transformation rather than unintended consequences.

ACER explicitly recognises this challenge in recommending a two-to-three-year transition period to establish data collection, modelling, and reporting processes before linking indicators to financial consequences. This transition period serves multiple purposes. It allows operators to build the data infrastructure and analytical capabilities needed to populate indicators reliably. It enables regulators to observe indicator behaviour across different operators and operating conditions, understanding normal variation versus genuine performance differences. It provides time for stakeholder consultation to ensure indicators are technically robust, practically relevant, and perceived as fair by those being measured.

¹⁴ United Kingdom: RIIO framework explicitly considers both CAPEX and OPEX in assessing network company efficiency and includes innovation funding mechanisms to support novel approaches.

Portugal's comprehensive indicator framework includes both input and output measures, creating visibility into both technology deployment and performance outcomes.

Finland's introduction of dynamic line rating indicators for the TSO Fingrid includes specific metrics on both the extent of deployment and the performance improvement achieved, creating a foundation for future incentive mechanisms.

During this transition period, indicators serve primarily as monitoring and transparency tools rather than incentive mechanisms¹⁵. Operators report performance, regulators publish results, stakeholders analyse trends, and all parties learn what the indicators reveal about grid performance and where improvement opportunities exist. This learning phase is essential for building confidence in the indicators and creating the foundation for eventual incentive linkage.

At the same time such a transition period also creates risks. Without financial consequences, indicators may receive insufficient attention and resources. Operators focused on metrics that affect their revenues may treat monitoring-only indicators as compliance exercises rather than strategic priorities. The very learning that the transition period is meant to enable may be undermined by inadequate data quality or incomplete implementation.

Managing this tension requires regulatory leadership that maintains pressure for serious indicator implementation during the transition period while resisting premature incentive linkage. This might include regular public reporting of indicator results to create reputational incentives, stakeholder forums to discuss performance and share best practices, regulatory expectations for improvement over time even without formal penalties, and clear communication that incentive linkage will follow once baselines are established. The message must be clear: the transition period is not a grace period for inaction, but a learning phase for building the foundation of future accountability.

Looking beyond the transition period, the design of incentive mechanisms must account for the fundamental challenge of comparability. Grid topologies, customer density, geographical conditions, legacy infrastructure, and local regulatory requirements vary dramatically between operators, making simple cross-operator benchmarking potentially misleading. An operator serving a dense urban area with modern infrastructure faces fundamentally different challenges than one serving dispersed rural areas with aging equipment. Comparing their absolute performance on functionality indicators, without accounting for these contextual differences, risks penalising operators for circumstances beyond their control.

Where direct comparability is impossible or inappropriate, regulators should emphasise improvement over time as the benchmark. Each operator competes against its own historical performance, demonstrating year-on-year progress in observability, controllability, automation, data management, or other functionality dimensions. This approach rewards genuine performance improvement regardless of starting point, creates incentives for continuous

¹⁵ The [German Federal Network Agency's draft](#) outlines the initial establishment of indicators for transparency and monitoring, with the strategic aim of building a comprehensive data basis. This initial phase is not considered a long-term solution. These new indicators ought to be embedded within the prevailing, ideally reformed, financial framework.

enhancement, and avoids fairness concerns that plague cross-operator benchmarking in heterogeneous systems.

The increased harmonisation of grid and Network Codes across Europe is also a factor. While 100% harmonisation is unrealistic, given that many TSOs and DSOs must manage legacy infrastructure dating back 80 years, an 80% harmonisation target will make a difference. To achieve this, grid codes should be reviewed in collaboration with the T&D Europe industry. Our experts possess the deep knowledge of power generation and demand-side needs required to ensure the system benefits 'One Europe', rather than being fragmented by the individual preferences.

Ultimately, the goal is not merely to create indicators or even incentives but to transform the culture and practice of grid operation toward continuous performance improvement, data-driven decision-making, effective trade-off management, and relentless focus on delivering balanced value to users. Indicators and incentives are tools toward this end, not ends in themselves. Their design should reflect this understanding, balancing accountability with fairness, ambition with realism, and standardisation with flexibility for local context.

The Path Forward: Political Leadership for Functionality-Based Grid Management

1. Implement harmonised smart grid performance indicators

Technical frameworks for smart grid performance indicators are starting to be developed. Driving implementation with urgency and comprehensiveness requires action at multiple levels, beginning with the Member States taking ownership of their obligations under Article 59(1)(l) of the Electricity Directive (EU) 2019/944. The NRAs should move beyond conceptual discussions to concrete implementation, establishing indicators that capture grid functionalities rather than merely technology deployment or isolated performance metrics. These indicators should be adjusted for system-wide utilisation and ideally harmonised across the EU. Results should be reported publicly every two years as the Directive requires, creating transparency that enables stakeholder scrutiny and cross-country learning.

2. Build the data infrastructure for functionality-based regulation

Indicators alone are insufficient without the data infrastructure to populate them meaningfully. The Member States should therefore mandate harmonised data management systems across TSOs and DSOs, breaking down the organisational silos that prevent integrated operational visibility. They should require interoperability standards for cross-border data exchange, ensuring that the European grid can be monitored and managed as an interconnected system rather than a patchwork of national networks. Member States should also invest in measurement

technologies and sensors at all voltage levels, particularly in distribution networks, where visibility currently lags far behind that of transmission systems.

3. Align regulatory incentives with grid performance

Most critically, Member States should consider creating financial incentives for digital investment that level the playing field between traditional infrastructure and smart grid solutions. This means shifting regulatory frameworks from pure CAPEX models towards TOTEX approaches that value operating expenditure alongside capital expenditure when both deliver equivalent functionality improvements. It means linking output-based performance indicators to bonus-penalty systems after an appropriate transition period for establishing baseline and consulting stakeholders. It also means ensuring technology neutrality throughout regulatory frameworks, so that operators choose solutions based on the functionality they deliver and their cost-effectiveness rather than regulatory treatment.

4. Strengthen European coordination and harmonisation

At the European level, the Commission, ACER, and CEER should drive the harmonisation of indicator frameworks across Member States while respecting legitimate differences in local context. European institutions should establish common reporting templates coordinated by ENTSO-E and the EU DSO Entity, ensuring that data is collected consistently and remains meaningful and comparable. They should facilitate knowledge sharing and the exchange of best practices through regular forums, publications, and technical assistance to Member States still developing their approaches. They should also monitor implementation rigorously, identifying laggards and supporting them in catching up with leading Member States.

5. Use EU digitalisation initiatives to accelerate deployment

The Commission's Strategic Roadmap for Digitalisation and AI in the Energy Sector uses the critical opportunity to embed smart grid indicators within a broader vision for digital transformation. The Technopedia platform¹⁶ showcasing best practices in grid-enhancing technologies should be expanded to include case studies of successful smart grid indicators implementation, demonstrating not just what technologies work, but how regulatory frameworks can drive their deployment. And European funding mechanisms should prioritise projects that demonstrate measurable improvements in grid utilisation, creating financial support for the transition from traditional to optimised grid operation.

6. Monitor progress and promote accountability

Finally, European institutions should track and report progress transparently. ACER and CEER should deliver coordinated annual reports on smart grid indicator implementation,

¹⁶ [Technopedia | TSO-DSO Cooperation Platform](#)

documenting which the Member States have established which indicators, what results are being achieved, how trade-offs are being managed, and where implementation gaps persist. These reports should quantify functionality improvements delivered through digital solutions, providing concrete evidence of enhanced observability, controllability, automation, and coordination. And they should assess how effectively different regulatory approaches balance the competing objectives of affordability, security, and sustainability, identifying frameworks that achieve superior outcomes across multiple dimensions rather than excelling in one at the expense of others.

Implementing these measures will require sustained commitment, institutional coordination, and continued investment in capabilities whose benefits accrue over the longer term. As with any regulatory and technological transition, implementation is likely to be gradual and iterative. Performance indicators will evolve as experience is gained, data quality improves, and best practices emerge across Member States. Maintaining flexibility while fostering consistency will therefore be an important part of the process.

Europe has already established many of the essential building blocks for this transition: the legislative frameworks are in place, digital technologies continue to mature, and experience is accumulating across a growing number of projects and national initiatives. The next phase is to translate these foundations into more consistent implementation by strengthening harmonised performance assessment, supporting technology-neutral regulatory approaches, and encouraging balanced, functionality-based grid management. Taken together, these steps can help ensure that Europe's electricity networks are well equipped to deliver a secure, affordable, and sustainable energy system for everyone in the years ahead.