Submission to the Australian Energy Regulator (AER)
Annual Information Orders 2024-25 to 2027-28

From Data Collection to Decision: Enhancing Observability in the Annual Information Orders 2024-25 to 2027-28

Response to the AER Draft Update to Annual Information Orders 2026-28 – Electricity Networks

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Submission context

This submission provides targeted technical and policy feedback on the Australian Energy Regulator's draft update to the Annual Information Orders for electricity networks for the 2026-27 and 2027-28 reporting years. It forms part of a broader CSPER (Deakin University) research focus on how electricity-system outcomes are shaped not only by assets, expenditure, and installed capacity, but by the conditions under which system behaviour is observed, reported, interpreted, and regulated.

In this submission, that perspective is applied to the Annual Information Orders as a data-governance instrument. The central argument is that reporting structures do not merely collect information; they shape which aspects of network performance, operating context, and emerging system behaviour are visible within regulatory processes. As electricity networks become increasingly influenced by inverter-based resources, consumer energy resources, storage, export services, curtailment, and flexible demand, the interpretability of reported data becomes increasingly important.

The submission supports the AER's objective of improving clarity, consistency, comparability, and auditability in annual network information. It recommends targeted refinements to definitions, metadata, and condition-linked reporting fields so that the Annual Information Orders continue to support transparent, decision-useful, and future-ready regulatory assessment under changing electricity system conditions.

1. Opening Statement

This submission provides targeted feedback on the Australian Energy Regulator's draft update to the Annual Information Orders for electricity networks for the 2026-27 and 2027-28 reporting years. We support the AER's objective of improving the clarity, consistency, and usability of annual network information. As outlined in the AER's explanatory statement, the proposed update is intended to clarify ambiguous requirements, correct information specification issues, update definitions, address matters that required exemptions under the current Orders, and streamline future reporting by reducing the need for additional guidance. The AER has also indicated that these Orders impose annual reporting obligations on regulated distribution networks, transmission networks, and interconnectors under its information-gathering powers [1-4].

This issue is becoming more important as the electricity system becomes more dynamic and increasingly shaped by inverter-based resources, consumer energy resources, storage, export services, and flexible demand. AEMO's 2025 Inputs, Assumptions and Scenarios Report is used for forecasting and planning activities, including the Integrated System Plan, demonstrating that system-wide planning increasingly depends on structured datasets and explicit assumptions [5]. Similarly, AEMO's Enhanced Locational Information framework provides locational metrics and indicators designed to inform regulatory, investment, and transmission augmentation decisions [6]. Together, these developments highlight a broader trend: energy-sector decisions increasingly depend on whether the right system characteristics are made visible through structured data.

For this reason, our comments are not directed at replacing the AER's reporting framework or creating unnecessary reporting burden. Rather, we suggest that targeted refinements to definitions, metadata, and supporting explanations could improve the interpretability of reported information. This is particularly relevant where traditional expenditure, asset, and reliability categories may not fully explain the conditions under which network outcomes occur. Greater visibility of operating context, including demand conditions, export constraints, curtailment exposure, DER interactions, and other condition-dependent factors, would help distinguish between differences caused by network efficiency and differences caused by the underlying operating environment [5-7].

This distinction is important since technical performance in modern electricity systems is often condition-dependent. Established photovoltaic and inverter performance models demonstrate that delivered output and conversion efficiency vary with operating conditions such as load level, temperature, voltage, and power factor [8-10]. International standards for inverter performance measurement similarly recognise that efficiency must be evaluated across operating ranges rather than as a single fixed value [11, 12]. In practice, factors such as inverter loading ratio, curtailment, and non-unity power factor operation can affect realised energy yield and system performance [13-15]. These effects are typically modest at the device level but become relevant when aggregated across large systems.

The AER has invited stakeholders to provide feedback on the draft Orders and suggest additional changes to improve its information requirements [1]. This submission responds to that invitation by focusing on how reported data can better support transparent, comparable, and decision-useful regulatory analysis in a rapidly changing electricity system. The central point is straightforward: if an important system condition is not visible in the reporting framework, it becomes difficult to account for it later in benchmarking, expenditure assessment, performance interpretation, or future regulatory review.

To clarify the focus of this submission, Table 1 summarises the main Annual Information Order (AIO) issues addressed below and the corresponding refinements suggested. The emphasis is not on changing the overall reporting framework, but on improving how reported data can be interpreted as electricity-system behaviour becomes more dynamic and condition-dependent.

Table 1. Summary of submission focus for the Annual Information Orders

AIO issue	Submission response	Suggested refinement
Clarity and consistency of reporting requirements	Supported. Clearer definitions and instructions improve the quality and comparability of reported data.	Continue refining definitions, validation rules, and Basis of Preparation requirements.
Standardised annual reporting	Supported. Standardisation is essential for comparability across distributors, TNSPs, and interconnectors.	Preserve standardised reporting while allowing targeted contextual fields where operating conditions materially affect interpretation.
Aggregated expenditure, asset, and performance data	Supported, but aggregation can reduce visibility of operational context.	Add metadata or explanatory fields to identify material drivers such as curtailment, export constraints, PF duty, temperature effects, and loading conditions.
Data used for benchmarking and regulatory assessment	Supported. However, benchmarking depends on whether reported data captures relevant system conditions.	Improve observability of condition-dependent factors so performance differences are not misread as efficiency differences.
Future information requirements	Supported. The 2026-28 update is an opportunity to prepare reporting frameworks for a more dynamic electricity system.	Consider a staged pathway toward condition-aware reporting, beginning with low-burden metadata and targeted fields.

2. The Role of Annual Information Orders in Regulatory Visibility

The Annual Information Orders play a central role in determining what the AER can observe, compare, and interpret across regulated electricity networks. Although they are presented as reporting instruments, their practical role is broader than data collection. They establish the information architecture through which network expenditure, asset condition, service performance, operating environment, and customer outcomes are made visible to the regulator. In effect, the Orders help define what becomes measurable within annual regulatory reporting, and what remains outside routine observation [2-4].

This role matters because regulatory decisions are only as strong as the information base that supports them. The AER's draft update recognises this directly by seeking to clarify ambiguous requirements, correct information specification issues, update definitions, and improve future reporting processes [1]. These changes are important because unclear definitions or inconsistent reporting structures can affect the comparability and interpretation of network data.

The AIO framework already reflects a strong concern for consistency and auditability. For example, the distributor instructions require financial information to be derived from audited statutory accounts, be verifiable, and be supported by appropriate regulatory accounting principles. Similar requirements apply across transmission and interconnector reporting, ensuring consistency in cost allocation and service classification [1-4].

However, as the electricity system changes, the scope of regulatory visibility also needs to evolve. Traditional reporting categories were largely designed around expenditure, asset classes, and reliability outcomes. While these remain necessary, they may not fully capture the operating context behind reported outcomes in a system increasingly shaped by inverter-based generation, consumer energy resources, storage, and flexible demand. AEMO's planning frameworks, including the 2025 Inputs, Assumptions and Scenarios Report and Enhanced Locational Information work, show that system assessment increasingly depends on locational, operational, and condition-based data rather than static asset descriptors alone [5, 6].

This does not imply that the Annual Information Orders should become detailed engineering models. Rather, annual reporting should preserve sufficient operating context to make observed outcomes interpretable. For example, two networks may report similar expenditure or reliability outcomes while operating under materially different conditions of DER penetration, export constraints, demand variability, or curtailment exposure. Without contextual information, observed differences may be interpreted as differences in efficiency or performance when they may partly reflect differences in operating environment [5, 7].

This issue becomes more important as system performance increasingly reflects condition-dependent behaviour. Established technical literature on photovoltaic and inverter performance demonstrates that energy output and efficiency vary with operating conditions such as load level, temperature, voltage, and power factor [8-12]. Empirical studies further show that curtailment, inverter loading ratio, and non-unity power factor operation can affect realised energy yield and system performance [13-15]. These effects are individually modest but systematic, and therefore relevant when interpreting aggregated system outcomes.

In this context, the Annual Information Orders function as a boundary-setting mechanism for regulatory visibility. If an operating condition is captured within the reporting framework, it can be observed, compared, and incorporated into regulatory assessment. If it is not captured, it may only appear indirectly through expenditure patterns or performance outcomes, making interpretation more uncertain [1, 5, 7].

The key point is not that every technical variable should be reported annually. Rather, the reporting framework should remain capable of identifying where operating context materially affects interpretation. A reporting system that is clear, consistent, and auditable is necessary. A reporting system that also preserves sufficient visibility of evolving system conditions will be more effective in supporting robust and transparent regulatory decisions [1, 5, 7].

3. From Data Collection to Regulatory Outcome

The Annual Information Orders form the starting point of a broader regulatory information pathway that extends from data collection through to decision-making. While the Orders are primarily framed as reporting requirements, their practical role is to define the inputs into a sequence of analytical and regulatory processes. In simplified terms, this pathway can be understood via the schematic presentation in figure 1.

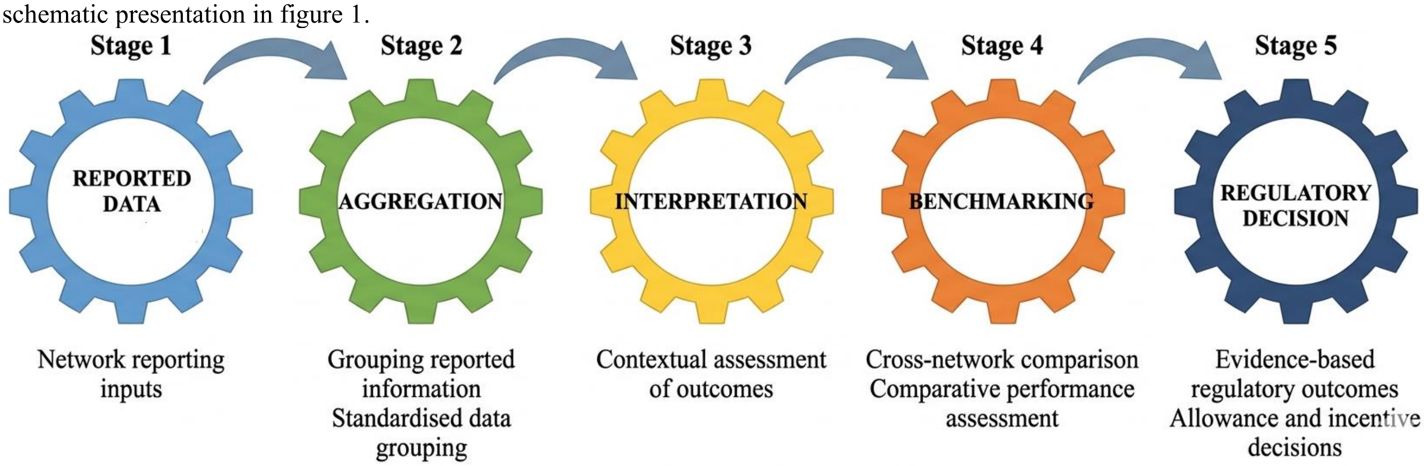

Figure 1. Data-to-decision pathway

At each stage, the structure and content of reported data influence how information is processed, compared, and ultimately used in regulatory assessment. This means that the design of reporting requirements is not neutral. It shapes how network performance is understood and how regulatory conclusions are formed.

The first stage of this pathway is the collection of reported data through the Annual Information Orders. The AER requires that this information be consistent, verifiable, and aligned with audited financial records, supported by defined cost allocation methods and explanatory documentation. This ensures that the data entering the regulatory process is internally consistent and comparable across networks. However, consistency at the reporting stage does not guarantee completeness in terms of system representation [1-4].

The second stage involves aggregation. Reported data is organised into standardised categories, service classifications, and time-based structures. While aggregation is necessary to make large datasets usable, it also reduces detail. In particular, aggregation can mask differences in operating conditions, temporal variability, and regional characteristics. For example, similar expenditure or performance metrics may reflect very different underlying system conditions when averaged across time, assets, or locations.

The third stage is interpretation. At this point, aggregated data is analysed to draw conclusions about network performance, efficiency, and service delivery. Interpretation often relies on implicit assumptions about comparability across networks and stability of operating conditions. AEMO's planning and forecasting frameworks, including the Inputs, Assumptions and Scenarios Report and related datasets, demonstrate that system-level interpretation increasingly depends on understanding the conditions under which data is generated, not just the reported values themselves [5, 6].

The fourth stage is benchmarking. The AER uses reported and interpreted data to compare networks, assess efficiency, and evaluate expenditure proposals. Benchmarking assumes that differences in reported outcomes reflect differences in performance or efficiency. However, where operating conditions are not fully visible in the underlying data, observed differences may partially reflect differences in environment rather than differences in network management or efficiency [1-4].

The final stage is decision-making. Regulatory outcomes, including expenditure allowances, performance assessments, and incentive mechanisms, are informed by the outputs of the previous stages. At this point, the original structure of the reported data has already shaped the range of possible interpretations. If a relevant system condition has not been captured earlier in the pathway, it becomes difficult to introduce it at the decision stage without additional assumptions or ad hoc adjustments [1-4].

This leads to a central observation: the reporting stage defines the informational boundary of the entire regulatory process. If an aspect of system behaviour is not captured in the reported data, it is unlikely to be systematically accounted for in aggregation, interpretation, benchmarking, or decision-making. Later stages may attempt to infer or approximate missing information, but such corrections are inherently limited and may introduce additional uncertainty.

This issue is particularly relevant in the context of a rapidly evolving electricity system. As discussed in Section 2, system behaviour is increasingly influenced by condition-dependent factors associated with inverter-based resources, distributed energy resources, curtailment, and dynamic operating conditions. Established technical literature shows that system performance is not constant, but varies with operating conditions such as loading, temperature, voltage, and power factor [8-12]. Where these conditions are not visible in reported datasets, their effects may be embedded in aggregated outcomes without being explicitly recognised.

The implication is not that the AER's reporting framework is deficient. Rather, it highlights the importance of ensuring that the data entering the regulatory pathway retains sufficient contextual information to support meaningful interpretation. A reporting system that captures only outcomes without sufficient visibility of operating conditions may lead to interpretations that are internally consistent but incomplete [1].

Accordingly, the design of the Annual Information Orders should be considered not only in terms of reporting efficiency and consistency, but also in terms of how well they support the full data-to-decision pathway. Ensuring that relevant system characteristics are visible at the reporting stage will strengthen the robustness of all subsequent stages of analysis and improve confidence in regulatory outcomes.

4. Where Current AIO Structures Are Strong

The current Annual Information Order framework provides a strong foundation for consistent and reliable regulatory reporting. Its primary strengths lie in standardisation, comparability, and auditability, which together support the effective use of reported data across regulatory processes [1].

First, the AIOs establish a high level of standardisation in how information is defined, structured, and submitted. The use of prescribed templates, detailed instructions, and validation rules ensures that data is collected in a consistent format across all regulated entities. The AER's updates to clarify definitions, correct information specification issues, and streamline reporting requirements further reinforce this objective. This standardisation reduces ambiguity and supports more efficient data handling and analysis [2-4].

Second, the framework enables comparability across networks. By requiring consistent classification of expenditure, services, and asset categories, the AIOs allow the AER to compare performance and costs across distribution and transmission businesses on a like-for-like basis. This is essential for benchmarking, expenditure assessment, and broader regulatory evaluation. The use of common reporting structures and aligned cost allocation approaches supports this comparability across different networks and jurisdictions [1-4].

Third, the AIOs are designed to ensure auditability and data integrity. Reporting requirements are linked to audited statutory accounts, supported by regulatory accounting principles, and accompanied by explanatory documentation such as the Basis of Preparation. These requirements provide confidence that reported data is verifiable, traceable, and suitable for regulatory use. They also support transparency in how reported values are derived and interpreted [2-4].

Collectively, these features make the current AIO framework robust as a data collection and reporting system. They ensure that the information entering the regulatory process is consistent, comparable, and reliable. The observations in this submission build on this foundation, with the aim of strengthening how reported data can be interpreted in the context of an evolving electricity system.

5. Loss of Operational Granularity in Current Reporting Structures

While the current Annual Information Order framework provides strong consistency and comparability, it necessarily simplifies complex system behaviour in order to produce standardised and manageable datasets. This simplification is not a flaw in itself. It is a practical requirement of large-scale reporting. However, as system conditions evolve, the extent and nature of this simplification become increasingly important for how reported data is interpreted.

5.1 What gets simplified

Several types of simplification are embedded within standard reporting structures. First, reported values are often time-averaged. Annual reporting consolidates performance, utilisation, and cost data over extended periods. While this is appropriate for high-level assessment, it reduces visibility of intra-day, seasonal, and event-driven variability, which are becoming more relevant in systems with high renewable penetration.

Second, reporting relies on aggregated metrics. Data is grouped across assets, locations, and service categories to ensure comparability and usability. This aggregation process is necessary, but it can obscure differences in operating conditions between regions, asset classes, or time periods. For example, similar aggregate outcomes may reflect very different patterns of utilisation, constraint, or system interaction.

Third, system performance is often implicitly interpreted through static or averaged parameters, particularly where detailed operational characteristics are not explicitly reported. This includes assumptions about stable performance across time and conditions, which are embedded in how aggregated outcomes are understood rather than how they are explicitly reported.

These simplifications are consistent with the AER's emphasis on standardisation and comparability. However, their implications become more significant as system behaviour becomes more dynamic and condition-dependent [1-4].

5.2 What gets lost

The consequence of these simplifications is a reduction in visibility of certain operating conditions that increasingly influence system performance.

In particular, condition-dependent behaviour of inverter-based resources is not directly visible in standard reporting structures. Established technical models and standards demonstrate that inverter performance varies with operating conditions such as load level, temperature, voltage, and power factor [8-12]. When reporting structures rely on aggregated outcomes, these variations are embedded within reported values without being explicitly identified.

Similarly, curtailment exposure is not always clearly distinguishable from other performance drivers when data is aggregated. Studies show that curtailment and export constraints can materially affect realised energy output and utilisation patterns, particularly in high-renewable systems [14]. Without explicit visibility, its effects may appear indirectly through reduced utilisation or altered cost metrics.

Thermal derating effects also contribute to differences between nominal and realised performance. Empirical studies indicate that elevated temperatures can reduce photovoltaic and inverter output, particularly in regions with high ambient temperatures [16]. These effects are typically absorbed into aggregated performance data rather than explicitly reported.

In addition, power factor–related losses and operational requirements are becoming more relevant as inverter-based resources provide voltage support and other grid services. Non-unity power factor operation introduces additional losses and affects real power delivery, as demonstrated in experimental and modelling studies [15]. These effects are not directly observable in standard expenditure or reliability categories.

At a broader level, these factors contribute to regional variability in system performance, particularly across Renewable Energy Zones (REZs). Differences in temperature profiles, curtailment frequency, network constraints, and operating conditions mean that similar technologies can produce different outcomes in different locations. AEMO's planning and locational analysis frameworks highlight the increasing importance of these regional characteristics in system assessment [5, 6].

The key point is not that these effects are unknown. They are well understood in technical literature and increasingly recognised in planning processes. The issue is that they are not systematically visible within standard reporting datasets. As a result, their influence may be embedded within aggregated outcomes without being explicitly identified, making it more difficult to distinguish between differences in network performance and differences in operating environment.

6. Consequence: Partial Observability of Inverter-Dominated System Behaviour

The preceding discussion highlights a shift in the nature of the issue. The challenge is not that system behaviour is unknown or poorly understood. On the contrary, a substantial body of technical literature, operational experience, and planning analysis demonstrates that modern electricity systems exhibit condition-dependent behaviour, particularly in relation to inverter-based resources, distributed energy, and network constraints. The issue is that these behaviours are not always systematically captured within regulatory data frameworks [1-4].

In this context, the concept of partial observability becomes relevant. Regulatory processes rely on structured datasets to represent system performance, cost, and utilisation. Where key operating conditions are not explicitly captured, they remain only indirectly observable through aggregated outcomes. This does not eliminate their influence. Instead, it embeds that influence within reported metrics without clearly identifying its source. This relationship is illustrated in Figure 2, where commonly reported AIO data, such as aggregated expenditure, reliability metrics, utilisation indicators, and asset categories, sits above operating conditions that may materially shape those outcomes but remain inferred rather than explicitly visible [2-4].

As outlined in Section 5, several factors contribute to this effect, including condition-dependent inverter performance, curtailment exposure, thermal derating, and power factor–related losses. These factors are well established in both modelling and empirical studies [8-12]. However, when reporting structures rely on aggregated, time-averaged, and categorised data, their effects are absorbed into high-level indicators such as expenditure, utilisation, or reliability outcomes.

This creates a situation where system behaviour is visible in aggregate but not identifiable in structure. For example, differences in utilisation or performance across networks may reflect variations in curtailment exposure, thermal conditions, or operating requirements. Without explicit visibility of these conditions, it becomes difficult to distinguish whether observed differences arise from network efficiency, asset condition, or underlying operating environment.

This limitation becomes more significant as the system transitions toward higher shares of inverter-based resources. AEMO's planning and forecasting frameworks increasingly recognise that system outcomes depend on locational, temporal, and

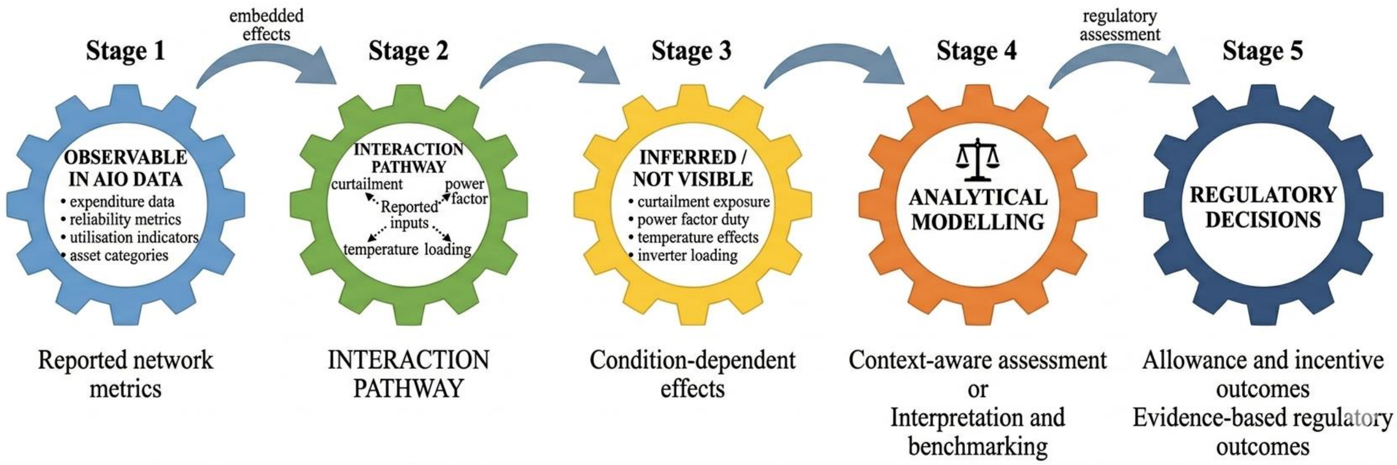

Figure 2. Regulatory visibility gap

operational factors, including network constraints, resource variability, and operating conditions [5, 6]. In such a system, performance is not solely determined by installed capacity or asset configuration, but by how those assets operate under varying conditions.

From a regulatory perspective, partial observability introduces interpretative risk. Benchmarking, expenditure assessment, and performance evaluation rely on the assumption that reported data adequately represents underlying system behaviour. Where relevant conditions are not captured, there is a risk that:

- differences in operating environment are interpreted as differences in efficiency,
- aggregated outcomes are treated as directly comparable when underlying conditions differ, and
- observed performance metrics reflect a combination of structural and contextual factors that are not separately identifiable.

This does not imply that current regulatory assessments are incorrect. Rather, it highlights that the informational basis of those assessments may be incomplete in specific, systematic ways.

The key implication is that improving observability does not require eliminating aggregation or standardisation but ensuring that the reporting framework retains sufficient information to interpret aggregated outcomes correctly. This may include, for example, providing additional context through metadata, explanatory fields, or targeted reporting elements that indicate when operating conditions materially influence reported results [1-4].

In summary, the transition to an inverter-dominated system does not introduce unknown behaviour. It introduces behaviour that is known but not always visible in structured reporting data. Addressing this gap is not a question of adding complexity for its own sake, but of ensuring that regulatory datasets remain capable of supporting accurate interpretation as system conditions evolve.

7. Evidence from Recent Research and Submissions

This section draws together relevant evidence from technical literature, system planning work, and recent submissions to illustrate that the issues identified in Sections 5 and 6 are not theoretical. They are already well documented across multiple layers of the electricity system. The purpose here is not to introduce new arguments, but to show that condition-dependent behaviour, regional variability, and system-level dynamics are established realities, even if they are not always visible within standard reporting structures.

7.1 Device-level behaviour: efficiency surfaces, not constants

At the device level, photovoltaic and inverter performance is widely recognised as multi-dimensional rather than constant. Established models such as the Sandia PV performance model, PVWatts, and the System Advisor Model represent system output as a function of irradiance, temperature, voltage, and operating conditions, rather than fixed efficiency values [8-10]. International standards similarly define inverter efficiency across operating ranges, capturing variation with load and operating point rather than a single nominal value [11, 12].

Empirical and modelling studies further show that performance depends on factors such as inverter loading ratio, curtailment, and non-unity power factor operation. For example, deviations from optimal loading conditions can introduce measurable bias in energy estimates [13], while curtailment and off-maximum-power-point operation reduce realised output [14]. Power factor requirements for voltage support introduce additional losses and affect real power delivery [15].

The consistent finding across this literature is that efficiency behaves as a surface across operating conditions, not as a fixed parameter. When reporting frameworks rely on aggregated or averaged representations, these variations are embedded within reported outcomes without being explicitly identified.

7.2 Regional variation: differences across REZs

At the regional level, system performance is influenced by spatial variation in operating conditions. REZs differ in temperature profiles, network constraints, curtailment exposure, and system strength requirements. As a result, identical technologies can produce materially different outcomes depending on location.

AEMO's planning frameworks, including the Inputs, Assumptions and Scenarios Report and Enhanced Locational Information analysis, highlight the importance of locational factors in determining system performance, utilisation, and investment value [5, 6]. These frameworks increasingly recognise that installed capacity is not a sufficient proxy for deliverable system capability, particularly in high-renewable scenarios.

This aligns with findings from REZ-related analysis and prior submissions, where regional differences in curtailment, thermal conditions, and network constraints have been shown to affect effective energy output and utilisation. In this context, REZs are not electrically equivalent, even when hosting similar generation technologies.

Where reporting structures do not explicitly capture these regional conditions, their effects may be reflected indirectly in aggregated performance or cost metrics, without being clearly attributable to underlying drivers.

7.3 System-level dynamics: solar abundance, curtailment, and flexibility

At the system level, recent developments in the National Electricity Market highlight the increasing importance of dynamic operating conditions. High levels of rooftop and utility-scale solar generation have led to periods of solar abundance, where supply exceeds demand and system operation depends on curtailment, export management, and demand-side flexibility.

AEMO's operational reporting and planning documents show that curtailment, congestion, and flexibility are becoming structural features of system operation rather than occasional events [5, 6]. Similarly, studies of PV curtailment demonstrate that changing grid conditions can significantly affect realised energy output and system utilisation [14].

These dynamics introduce variability in how assets are used and valued. Performance is increasingly shaped by system conditions such as network constraints, demand patterns, and the availability of flexible resources. As a result, system outcomes cannot be fully understood without reference to the conditions under which they occur.

When reporting frameworks capture only aggregated outcomes, these dynamics may be embedded within the data without being explicitly visible.

7.4 Distribution and access layer: the gap between generation and utilisation

Beyond generation and transmission, recent research highlights the importance of the distribution and access layer in determining how energy is delivered and used. Studies of multi-occupancy buildings, distributed energy systems, and shared infrastructure show that the value of energy depends not only on generation, but on access, allocation, and integration within local networks.

Research on apartment-scale energy systems and shared solar demonstrates that technical capability does not guarantee effective utilisation. Outcomes depend on factors such as infrastructure constraints, governance arrangements, and the ability of users to access and coordinate energy resources [17, 18]. This creates a distinction between available energy and accessible energy, which is not always visible in aggregate system metrics.

At a broader level, this reflects a recurring pattern: system performance is shaped by interactions between technology, network conditions, and user behaviour. Where reporting structures focus primarily on aggregate outputs, these interactions may not be explicitly represented.

Overall implication of evidence

Across device-level behaviour, regional variation, system dynamics, and distribution-level access, a consistent conclusion emerges:

- system behaviour is condition-dependent,
- performance varies across location and time, and
- outcomes depend on operating context, not only installed capacity or asset classification.

These findings are well established in technical literature and system planning practice. The issue is not a lack of understanding, but a gap between what is known and what is systematically captured in reporting frameworks.

This reinforces the central argument of this submission: where relevant system characteristics are not visible in reported data, their influence may still be present, but it becomes more difficult to interpret, compare, and incorporate into regulatory decision-making.

8. Why This Matters Specifically for Annual Information Orders

The preceding sections have established that system behaviour is increasingly condition-dependent and not always fully visible in aggregated datasets. This section focuses on why that matters specifically for the Annual Information Orders (AIOs).

Unlike broader planning or incentive frameworks, the AIOs define the structure of the data that underpins regulatory assessment. As such, any limitation in what is captured at this stage directly affects all subsequent stages of analysis.

The issue is not whether the AER's analytical frameworks are robust. The issue is whether the data entering those frameworks contains sufficient information to support accurate interpretation.

8.1 Data comparability risk

A key objective of the AIO framework is to enable comparability across networks. Standardised reporting structures, common definitions, and consistent cost allocation rules are designed to support like-for-like comparison of expenditure, performance, and service outcomes.

However, comparability at the data structure level does not necessarily imply comparability at the system level. Networks may appear comparable based on reported metrics while operating under materially different conditions. These conditions include variations in:

- DER penetration and export constraints,
- curtailment exposure and network congestion,
- temperature profiles and environmental conditions, and
- operational requirements such as voltage support and reactive power provision.

Evidence from system planning and locational analysis shows that these factors vary significantly across regions and influence realised performance and utilisation [5, 6]. As a result, networks that appear similar in reported data may not be directly comparable in underlying operating context.

Where such conditions are not visible in the reported data, differences in outcomes may be interpreted as differences in network efficiency rather than differences in operating environment.

8.2 Benchmark distortion

Benchmarking relies on the assumption that observed differences in performance or cost reflect differences in efficiency or management. This assumption is valid only if the underlying data captures the key drivers of performance. Where operating conditions are not explicitly represented, there is a risk of benchmark distortion, where:

- efficiency differences are conflated with environmental or operational differences, and
- networks operating under more challenging conditions appear less efficient than those operating under more favourable conditions.

This issue becomes more pronounced in systems with high shares of inverter-based resources. As shown in technical and empirical studies, factors such as curtailment, inverter loading, temperature, and power factor requirements can affect realised output and utilisation [13-15]. These effects are often embedded within aggregated metrics rather than explicitly reported.

The result is that benchmarking outcomes may reflect a combination of efficiency and operating conditions, without a clear way to distinguish between them.

8.3 Misinterpretation risk

A further consequence is the risk of misinterpreting reported outcomes. When data lacks sufficient contextual information, there is a tendency to interpret observed values as direct indicators of performance. However, in the presence of unobserved operating conditions, reported metrics may represent a combination of:

- underlying network performance, and
- external or system-driven factors not captured in the dataset.

This creates the risk that performance differences are interpreted as intrinsic characteristics of the network, when they may partly reflect reporting artefacts arising from aggregation or missing context.

For example, reduced utilisation or altered cost profiles may be attributed to inefficiency, when they are influenced by curtailment, demand variability, or system constraints. Similarly, reliability or service outcomes may reflect operational conditions that are not explicitly visible in standard reporting categories.

Overall implication for AIOs

These risks, comparability, benchmarking distortion, and misinterpretation are not independent. They arise from a common source: the gap between observed data and underlying system conditions.

Because the Annual Information Orders define the structure of reported data, they also define the limits of what can be systematically observed and compared. If relevant operating conditions are not captured at this stage [1-4]:

- comparability may be overstated,
- benchmarking may be partially distorted, and
- interpretation may rely on incomplete information.

The implication is not that the AIO framework is inadequate. Rather, it highlights the importance of ensuring that reporting structures evolve alongside system complexity. Maintaining comparability and auditability remains essential. However, these objectives should be complemented by sufficient visibility of operating context to support accurate interpretation.

9. Practical Gaps in the Current AIO Framework

The previous sections have outlined the broader issue of partial observability and its implications for comparability and interpretation. This section identifies a small number of practical gaps where current reporting structures may not fully capture operating context that is increasingly relevant to system performance.

These observations are not intended as criticisms of the existing framework. The Annual Information Orders are designed to balance completeness with practicality, and their emphasis on standardisation and auditability is appropriate. The purpose here is to highlight specific areas where targeted additions or clarifications could improve the interpretability of reported data without materially increasing reporting burden.

9.1 Curtailment exposure

Current reporting structures do not consistently provide explicit visibility of curtailment exposure at the network or asset level. While the effects of curtailment may be reflected indirectly in utilisation or output-related metrics, they are not always identifiable as a distinct driver.

This is increasingly relevant in systems with high renewable penetration, where curtailment and export constraints are becoming structural features of operation rather than exceptional events. System-level analysis and operational reporting indicate that curtailment can materially affect realised output and network utilisation [5, 14].

Where curtailment exposure is not explicitly captured, its effects may be embedded within aggregated outcomes, making it more difficult to distinguish between differences in performance and differences in operating conditions.

9.2 Operating power factor distributions

The current framework does not explicitly capture operating power factor (PF) distributions or the extent to which assets are required to operate away from unity power factor.

This is becoming more relevant as inverter-based resources are increasingly used to provide voltage support and other grid services. Operation at non-unity power factor can affect real power delivery and introduce additional losses, as demonstrated in experimental and modelling studies [15].

Without visibility of PF operating ranges or duty, these effects may be reflected indirectly in performance or cost metrics, without being clearly attributable to underlying operational requirements.

9.3 Temperature-related performance effects

There is limited visibility of temperature-related performance variation within standard reporting categories. Environmental conditions, particularly ambient temperature, influence both generation output and network performance.

Empirical studies show that photovoltaic system output and inverter efficiency are sensitive to temperature, with higher operating temperatures generally reducing performance [16]. In regions with significant temperature variation, this can contribute to differences in realised system outcomes.

Where temperature effects are not explicitly represented, they are absorbed into aggregated performance indicators, making it difficult to assess whether differences in outcomes reflect asset performance or environmental conditions.

9.4 Inverter loading and operating conditions

The framework does not explicitly capture inverter loading conditions or related operating parameters, such as inverter loading ratio or utilisation relative to capacity.

Technical studies indicate that inverter loading conditions can influence realised energy output and introduce systematic differences between nominal and actual performance [13]. These effects are particularly relevant in systems where oversizing or operational constraints affect utilisation.

In the absence of explicit reporting, these factors are incorporated into aggregated outcomes without being directly observable.

Overall observation

These examples illustrate a consistent pattern: certain operating conditions that materially influence system performance are not explicitly represented in current reporting structures. Their effects are not absent but embedded within broader metrics.

The implication is not that these variables must be always reported in detail. Rather, the reporting framework could benefit from selective mechanisms to indicate when such factors are material, whether through additional fields, metadata, or explanatory guidance.

Addressing these gaps would support more accurate interpretation of reported data, particularly in contexts where differences in operating conditions are significant. It would also strengthen the ability of the AER and stakeholders to distinguish between differences in network performance and differences arising from system context.

10. Recommendations

The following recommendations focus on data structure and observability, rather than modelling detail or methodological change. The objective is to enhance how reported data can be interpreted, while preserving the AER's existing strengths in standardisation, comparability, and auditability. These recommendations are intentionally targeted and scalable, recognising the need to balance improved visibility with practical reporting requirements.

10.1 Improve observability through condition-linked fields

A practical step toward improving interpretability is to introduce limited, condition-linked reporting fields that indicate when operating context materially influences outcomes.

These fields would not require detailed engineering data. Instead, they would provide structured indicators of conditions known to affect system performance, such as:

- curtailment exposure (e.g. presence, frequency, or indicative magnitude),
- operating power factor ranges or duty,
- indicative temperature or environmental operating bands, and
- generalised utilisation or loading conditions for key asset classes.

The purpose of such fields is not to describe system behaviour in full detail, but to ensure that key drivers of variation are visible and distinguishable within reported datasets. This concept is illustrated in Figure 3, where a reported metric such as utilisation or expenditure is paired with contextual metadata, including curtailment exposure, temperature conditions, power factor duty, and loading, resulting in improved interpretability of observed outcomes.

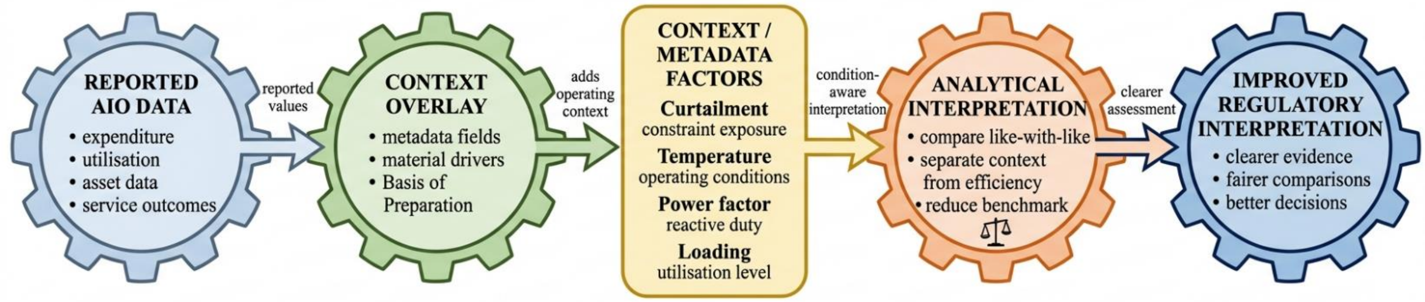

Figure 3. Condition-linked reporting concept

This approach aligns with established technical understanding that system performance varies with operating conditions rather than remaining constant [8-10], while maintaining a reporting structure suitable for annual regulatory use.

10.2 Strengthen metadata transparency

The interpretability of reported data can be significantly improved through enhanced metadata and explanatory requirements, building on existing Basis of Preparation documentation.

In particular, reporting frameworks could more explicitly require:

- identification of key assumptions embedded in reported values,
- clarification of whether values reflect averaged, modelled, or measured data, and
- indication of conditions under which reported values may vary or be constrained.

The AER's current emphasis on verifiability, audited accounts, and explanatory documentation provides a strong foundation for this approach. Strengthening metadata transparency would extend this foundation by improving the ability of users to interpret reported values in context, without altering the core data structure [2-4].

10.3 Introduce tiered reporting pathways

To balance improved observability with reporting burden, a tiered reporting structure could be considered.

Under this approach:

- a baseline reporting layer would retain the current standardised structure, ensuring consistency and comparability across all networks, and
- an enhanced reporting layer would allow for additional contextual information where relevant or where data is already available.

This structure reflects approaches used in system planning and data frameworks, where different levels of detail are provided depending on purpose and availability [5, 6].

A tiered approach allows the framework to evolve without imposing uniform complexity across all participants. It also enables gradual improvement in data quality and visibility as system needs change.

10.4 Futureproofing through staged development

Finally, the AIO framework would benefit from a staged approach to incorporating condition-aware reporting elements. Rather than introducing comprehensive changes in a single step, a phased pathway could:

- identify priority areas where operating context has the greatest impact on interpretation,
- introduce targeted reporting elements or metadata in those areas, and

- review and refine requirements over time as data availability and system complexity evolve.

This approach is consistent with the broader evolution of energy system analysis, where increasing shares of inverter-based resources and distributed energy have required progressive enhancement of data frameworks and planning methodologies [5, 6, 19].

Overall recommendation

Taken together, these recommendations aim to ensure that the Annual Information Orders continue to provide:

- consistent and comparable data,
- transparent and auditable reporting, and
- sufficient visibility of operating context to support accurate interpretation.

The intent is not to increase reporting complexity for its own sake, but to ensure that the structure of reported data remains aligned with the realities of an evolving electricity system.

11. Closing Reflection

As the electricity system continues to evolve, its defining characteristics are shifting away from static asset performance toward dynamic, condition-dependent behaviour. In this context, the effectiveness of regulatory frameworks will depend not only on how decisions are made, but on the quality and structure of the information that informs those decisions.

The Annual Information Orders already provide a strong foundation for consistent, comparable, and auditable reporting. The observations in this submission are intended to build on that foundation by highlighting the importance of regulatory visibility. As system behaviour becomes more influenced by operating conditions, such as variability in demand, network constraints, and the growing role of inverter-based and distributed resources, ensuring that these conditions are sufficiently visible in reported data becomes increasingly important.

The central point is not that the system is becoming more complex. That is already well understood in planning and operational contexts [5, 6]. The more relevant question is whether the data structures used in regulatory processes are evolving at a similar pace. Where important system characteristics are not visible in reporting frameworks, their influence may still be present, but more difficult to interpret, compare, and incorporate into decision-making.

In this sense, the Annual Information Orders serve not only as a reporting mechanism, but as part of the broader infrastructure of regulatory understanding. They shape the boundary between what can be systematically observed and what must be inferred. Maintaining clarity, consistency, and auditability remain essential. Complementing these strengths with sufficient visibility of operating context will help ensure that regulatory assessments remain robust as system conditions change.

In summary, as the electricity system becomes increasingly defined by dynamic and condition-dependent behaviour, the effectiveness of regulatory frameworks will depend not only on how decisions are made, but on which system characteristics are made visible through data.

References

1. Australian Energy Regulator. (2026). *Draft update to annual information orders 2026–28 – Electricity networks: Explanatory statement*. https://www.aer.gov.au/system/files/2026-03/Explanatory%20statement%20-%20Draft%20-%20Update%20to%20Annual%20Information%20Orders%20-%20Electricity%20networks%20-%20March%202026.pdf
2. Australian Energy Regulator. (2026). *Draft annual information order 2026–28 – Electricity distributors: Appendix A – Instructions*. https://www.aer.gov.au/documents/draft-annual-order-2026-28-appendix-instructions
3. Australian Energy Regulator. (2026). *Draft annual order 2026–28 – Electricity TNSPs: Appendix A – Data submission workbook instructions*. https://www.aer.gov.au/system/files/2026-03/DRAFT%20Annual%20Order%202026-28%20%E2%80%93%20Electricity%20transmission%20%E2%80%93%20Appendix%20A%20%E2%80%93%20Instructions.pdf
4. Australian Energy Regulator. (2026). *Draft annual information order 2026–28 – Interconnectors: Appendix A – Instructions*. https://www.aer.gov.au/documents/draft-annual-order-2026-28-appendix-instructions
5. Australian Energy Market Operator. (2025). *2025 inputs, assumptions and scenarios report*. https://www.aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2024/2025-iasr-scenarios/final-docs/2025-inputs-assumptions-and-scenarios-report.pdf
6. Australian Energy Market Operator. (2025). *2025 enhanced locational information report*. https://www.aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/enhanced-locational-information/2025/2025-enhanced-locational-information-report.pdf
7. Australian Energy Market Operator. (2024). *Integrated system plan 2024*. https://www.aemo.com.au/-/media/files/major-publications/isp/2024/2024-integrated-system-plan-isp.pdf
8. King, D. L., Boyson, W. E., & Kratochvil, J. A. (2004). *Photovoltaic array performance model.* Sandia National Laboratories, Sand2004-3535
9. Dobos, A. P. (2014). *PVWatts Version 5 Manual.* National Renewable Energy Laboratory (NREL/TP-6A20-62641). https://research-hub.nrel.gov/en/publications/pvwatts-version-5-manual/
10. Marion, B., Deline, C., & Perez, R. (2018). *System Advisor Model (SAM) photovoltaic performance model.* National Renewable Energy Laboratory, Golden, CO. https://sam.nrel.gov/photovoltaic/pv-publications.html
11. European Committee for Electrotechnical Standardization (CENELEC). (2010). *EN 50530: Overall efficiency of grid-connected photovoltaic inverters.* Brussels, Belgium.https://www.evs.ee/en/evs-en-50530-2010#:~:text=This%20European%20Standard%20provides%20a,MPPT%20efficiency%20is%20indicated%20separately.
12. International Electrotechnical Commission (IEC). (1999). *IEC 61683: Photovoltaic systems – Power conditioners - Procedure for measuring efficiency.* Geneva: IEC.
13. Anderson, K. S., Hobbs, W. B., Holmgren, W. F., Perry, K. R., Mikofski, M. A., & Kharait, R. A. (2022). *The Effect of Inverter Loading Ratio on Energy Estimate Bias.* NREL Technical Report. https://docs.nrel.gov/docs/fy22osti/82812.pdf
14. O'Shaughnessy, E., Cutler, D., Ardani, K., & Margolis, R. (2021). *Solar PV Curtailment in Changing Grid and Technological Contexts.* NREL Report No. NREL/TP-6A20-74176. https://docs.nrel.gov/docs/fy21osti/74176.pdf

15. Gonzalez, S., Neely, J. C., & Ropp, M. (2014). *Effect of Non-Unity Power Factor Operation in Photovoltaic Inverters Employing Grid Support Functions.* Sandia National Laboratories / IEEE PVSC. https://doi.org/10.1109/PVSC.2014.6925199
16. Skoplaki, E., & Palyvos, J. A. (2009). Operating temperature of photovoltaic modules: A survey of pertinent correlations. *Renewable Energy*, 34, 23-29. https://doi.org/10.1016/j.renene.2008.04.009
17. Roberts, M. B., Bruce, A., & MacGill, I. (2019). *Opportunities and barriers for photovoltaics on multi-unit residential buildings: Reviewing the Australian experience*. Applied Energy, 254, 113689. https://doi.org/10.1016/j.rser.2018.12.013
18. Syed, M. M., Hansen, P., & Morrison, G. M. (2020). Performance of a shared solar and battery storage system in an Australian apartment building. *Energy and Buildings, 225*, 110321. https://doi.org/10.1016/j.enbuild.2020.110321
19. Australian Energy Market Operator. (2022). *Integrated system plan 2022*. https://www.aemo.com.au/-/media/files/major-publications/isp/2022/2022-documents/2022-integrated-system-plan-isp.pdf