

Infrastructure Quality in the Energy Sector

Why Energy Infrastructure Must be Understood as a Whole

IQI IES1

Revision 1.3 - Updated October 2026

INFRASTRUCTURE QUALITY INITIATIVE

1. Introduction: Why the Energy Sector Reveals the Infrastructure Quality Problem

Energy reaches people through connected infrastructure. Production zones, processing facilities, pipelines, storage systems, power stations, transmission networks, and distribution systems must work together under changing conditions. A problem in one place may affect functions, organizations, communities, or systems far beyond the component where it began.

This is why energy infrastructure reveals an important quality question. Individual parts may satisfy their specifications, inspections may be completed, and required documents may exist, while the assembled infrastructure still fails to deliver its intended function reliably or safely. The issue is not always one defective part. It may arise from the way many compliant parts, activities, responsibilities, and operating conditions interact.

Different engineering disciplines, standards, authorities, contracts, and operating organizations govern different parts of the energy sector. This specialization is necessary, but it does not automatically provide one conclusion about the quality of the whole infrastructure object. To reach such a conclusion, the object itself, its Scale, functions, Boundaries, Interfaces, lifecycle conditions, and supporting Evidence must be made visible.

The Infrastructure Quality Initiative (IQI) calls the defined subject of this examination an Infrastructure Quality Object. Depending on the question, the object may be a component, facility, network, production zone, asset population, or a connected system-of-systems. Declaring the object and its Scale prevents a favorable result for one part from being treated as proof of quality for a larger system without adequate justification.

Energy infrastructure changes over time. A concept becomes a design, construction produces a physical system, operating conditions evolve, equipment ages, and repairs or modifications alter its configuration. Responsibilities may move, and Evidence may become incomplete or outdated. Earlier Findings do not automatically establish the current Quality State when the object or its conditions materially change.

This article uses energy infrastructure to explain the common IQI approach for readers encountering it for the first time and for academic and professional readers. The same Core applies to buildings, bridges, data centers, water systems, and other infrastructure. The energy examples illustrate object definition, Scale, Interfaces, life-cycle change, Evidence, and the limits of Quality Claims. The Infrastructure Standard - Core (IQI_IQC1) establishes the general requirements; WQI_VOC1 and IQI_VOC1 govern terminology.

Readers may consult Why Infrastructure Needs Its Own Quality Standards (IQI_WIS1) for the general introduction, the Factors and Indicators Justification articles for the supporting research, and IQI_IQC1 for the common requirements. Context Guides provide application detail and Quality Outcome Criteria where needed. Their availability and revision status should be checked on the IQI

Standards page. These documents serve different purposes; one compulsory reading order is not required.

2. From Components to Defined Infrastructure Quality Objects

Traditional engineering and technical standards appropriately focus on parts, materials, methods, and activities, such as:

- material and equipment specifications
- design calculations, margins, and technical requirements
- fabrication, construction, installation, and commissioning practices
- inspection, testing, conformity assessment, and acceptance methods
- operating, monitoring, maintenance, repair, and transition requirements

These standards are indispensable. They establish or support specialized requirements for design, materials, equipment, methods, and activities. Evidence from their application may support a broader determination. A specification states what is required; an inspection or test may help show whether it was achieved. Neither the specification nor a favorable finding about one part automatically establishes the Quality of the assembled object.

When compliant components and activities are combined, system-level conditions emerge. They may include:

- integrated structural and functional integrity, containment, and isolation behavior
- operational stability, controllability, reliability, and recovery capability
- interaction among degradation, abnormal conditions, and external threats
- maintainability, inspectability, monitoring visibility, and information continuity
- interaction of Failure-Mode Families across subsystems and Interfaces
- propagation of consequences across organizational, environmental, community, and downstream Boundaries

These conditions cannot be guaranteed by component conformity alone. They become visible only when the declared object, its composition, functions, Interfaces, lifecycle and operating conditions, and supporting Evidence are interpreted together.

The Infrastructure Quality Object is the declared subject of the examination. In this article it may be an energy-infrastructure component, facility, network, zone, life-cycle program, interface condition, asset population, or system-of-systems. Its Scale, internal and external Boundaries, Interfaces, and conditions must be clear. Its external Boundary separates what is included from external objects and conditions; it does not separate the infrastructure from a documentary Reference Layer.

3. Scale and System-of-Systems Relationships

As the Scale of a technical object changes, the relevant quality question also changes. Methods suitable for a manufactured product do not automatically address the behavior of a facility, network, production zone, asset population, or infrastructure system-of-systems.

The same fourteen Core Quality Factors and eighty-three Core Quality Indicators apply across relevant Scales. A component, facility, or network may each require examination of integrity, reliability, human interaction, environmental interaction, and other applicable dimensions. Their technical details and dependencies differ. Methodological Resolution identifies the depth and detail needed to examine the declared object; increasing detail does not, by itself, create a new Factor or Indicator.

Useful questions at different Scales include:

- component Quality: whether the declared component realizes its Intended Functions and Intended Results against applicable requirements and criteria;
- facility or network Quality: whether the integrated object realizes its own Intended Functions and Intended Results, including the effects of Interfaces, dependencies, and combined behavior.

A constituent activity or Result may also be examined as its own Quality Object, with its own Intended Functions, Intended Results, requirements, criteria, and Evidence. This is Fractal Quality Determination and applies across all Factors and Indicators. Satisfactory constituent Findings do not establish satisfactory Quality of the whole; a satisfactory whole-object Finding does not automatically establish the Quality of every separately examined constituent.

4. Lifecycle Reality, Structural Checkpoints, and the Work-Result-Outcome Relationship

The relevant life-cycle stages depend on the declared object and intended determination. They may include:

- conceptual development, feasibility studies, investigations, requirements, and design;
 - construction and installation;
 - inspection, testing, commissioning, and authorization;
 - operation and monitoring;
 - maintenance;
 - repair, modification, and reconstruction;
 - decommissioning, removal, recultivation, and continuing records or other Results.
- This is an illustrative list, not a mandatory sequence. The object may change from a conceptual or virtual form to a physical system and later cease to exist physically while relevant Results continue.

The Infrastructure Quality Object Description makes the subject of the examination clear: its Scale, composition, Intended Functions and Intended Results, configuration, operating medium and conditions, Boundaries, Interfaces, responsibilities, Applicable Basis, assumptions, uncertainty, and Evidence needs. Structural Checkpoints are supporting checks on whether that description is sufficiently complete.

They are not additional Factors, Indicators, technical inspections, or a determination of the object's Quality.

Infrastructure Work is what is performed. Infrastructure Result is what is actually produced, maintained, changed, or made available. Infrastructure Outcome is their bounded combination: Infrastructure Work + Infrastructure Result = Infrastructure Outcome. Completed Work does not establish that the required Result was achieved, and a satisfactory Result does not establish that all Work was satisfactory. At the design stage, Findings concern design Work and Results and what they support about the proposed infrastructure; they do not establish future operating performance.

5. Brownfield Systems and Loss of Alignment

Much of the energy infrastructure in service is brownfield infrastructure: existing objects that are repaired, modified, expanded, repurposed, or operated under legacy constraints and changing external conditions.

In brownfield environments:

- original assumptions, models, or design bases may no longer remain valid
- records and configuration information may be incomplete, fragmented, or inconsistent
- operating practices and actual conditions may drift from intended functions and results
- temporary restrictions, workarounds, or provisional Boundaries may become persistent
- Critical Infrastructure Conditions and Failure-Mode Families may change without adequate re-evaluation

Consider an onshore natural gas production zone undergoing incremental modification:

- legacy reservoir or collector information continues to govern later decisions without sufficient revalidation
- earlier integrity assumptions or corrosion allowances are reused after configuration or operating conditions change
- inspection, monitoring, or subsurface visibility remains limited by access or Evidence constraints
- temporary operating limits or transfer conditions become routine without an updated determination
- necessary repair, modification, or interface work is deferred under schedule, production, or budget pressure

No individual decision necessarily proves nonconformity or failure. Together, however, they may change well integrity, surface-system capacity, monitoring visibility, downstream transfer compatibility, environmental protection, or the demonstrated operating envelope.

The central issue is loss of alignment: the declared Infrastructure Quality Object, its intended functions and intended results, actual configuration, Boundaries, Interfaces, operating conditions, Assumptions, Evidence, Critical Conditions, and claim limits no longer describe the same reality. A responsible determination must then be revised, restricted, qualified, or withdrawn.

6. Boundaries, Interfaces, and Operating Conditions

Energy infrastructure operates through networks of quality-relevant Internal and External Interfaces, including:

- physical and functional Interfaces among subsystems and adjacent infrastructure objects
- responsibility, organizational, contractual, and contractor Interfaces
- regulatory and jurisdictional connections affecting applicable obligations and responsibilities;
- commercial, custody-transfer, customer, and service Interfaces
- informational, monitoring, environmental, community, and emergency-response Interfaces

A problem may develop at an Interface where function, information, responsibility, operating conditions, transfer requirements, or Evidence is incomplete or misaligned. Boundary Transparency and Interface Transparency make the included and excluded contributions, dependencies, transfers, and limitations visible. Their examination must follow the object's Intended Functions and Intended Results rather than assuming that ownership, organizational, contractual, and physical boundaries are the same.

Essential Work and Results must be accounted for within the declared scope or through identified Interfaces, whether provided internally or externally. Outsourcing does not justify excluding an essential contribution, and including it does not make the entire external organization part of the object. A connected system or contributing activity may remain a separate Quality Object. Its contribution and integration still require examination in determining the receiving infrastructure's Quality.

Relevant connections may involve materials, energy, information, people, responsibilities, environmental interactions, and other dependencies. These connections and the conditions at them may change during normal operation, startup, shutdown, abnormal or degraded operation, emergencies, repair, and transition. A Quality Claim about one object must not imply a determination of a neighboring object.

7. Uncertainty, Failure-Mode Families, and Critical Infrastructure Conditions

Energy infrastructure operates with inherent Uncertainty arising from conditions such as:

- geological, subsurface, environmental, and external-hazard variability
- configuration, boundary, interface, and operating-condition uncertainty
- aging, degradation, damage, and incomplete monitoring visibility
- human interaction, organizational responsibility, and contextual pressure
- changing demand, supply, downstream conditions, and system-of-systems behavior

Models, observations, standards, and professional judgment help examine conditions, but knowledge may remain incomplete. Material assumptions, uncertainty, and unresolved conditions must remain visible where they affect requirements, criteria, Evidence, decisions, or claim validity. Uncertainty concerns what can be known or established; it does not mean that the object has no actual Quality State.

Failure-Mode Families help identify how Intended Functions or Intended Results could fail to be realized. A Critical Infrastructure Condition is one whose absence, failure, violation, or unresolved

status prevents a responsible Positive Conclusion or otherwise materially constrains the permissible conclusion or claim. Its criticality must be justified through Function Realization, the Applicable Basis, and applicable criteria. Not every adverse or unresolved Finding is automatically critical. Favorable Findings elsewhere cannot offset a condition where the justified basis prohibits compensation.

8. The Reference Layer and the Application of Existing Requirements and Standards

Laws, regulations, permits, engineering codes, technical standards, contracts, design bases, procedures, scientific knowledge, and professional guidance may provide relevant sources for energy infrastructure. The Applicable Basis establishes which requirements and conditions govern the declared examination. The Reference Layer provides sources used to establish or justify requirements, technical provisions, criteria, and expected states or results. Their roles must be clear; a cited source does not automatically make every provision binding.

The common Core connects these sources to the declared object, its Intended Functions and Intended Results, relevant life-cycle stages, Boundaries, Interfaces, and conditions. Context-specific detail and Quality Outcome Criteria preserve the meanings of the invariant Factors and Indicators. Requirements state what must be fulfilled; criteria state the expected states or results against which fulfillment is examined.

A Context Guide may detail the General Core Requirement under an Indicator and establish one or more Quality Outcome Criteria. Its Reference Layer may identify sources relevant to several Factors and Indicators. Where no guide is needed, criteria may be established directly under the General Core Requirements. The same methodological requirements apply through either route.

Reference Layer sources may be organized by Factor, infrastructure type, jurisdiction, or another suitable structure. What matters is that their applicability, authority, scope, editions, technical meaning, conflicts, and use remain traceable. Changes to a source must be examined for their effects on requirements, criteria, and earlier Findings; a separate source document does not automatically insulate the Core or a guide from review.

Many existing sources are component-, product-, method-, activity-, phase-, discipline-, organization-, or jurisdiction-specific. Their results may provide mandatory requirements, technical criteria, Conformity Findings, or Evidence, but they do not automatically establish the Infrastructure Quality State of a larger assembled object. Compliance with one source, or even several sources, therefore shall not be substituted for the bounded object-level determination required by IQI.

The Reference Layer supplies supporting sources; it is not the external physical environment or a collection of connected infrastructure objects. Its relationship to the Applicable Basis, requirements, Quality Outcome Criteria, and Evidence must remain traceable. WQI Foundational Article 10 explains the methodology for Quality Outcome Criteria.

9. Determining the Infrastructure Quality State

Infrastructure Quality concerns the degree to which the declared object realizes its Intended Functions and Intended Results within its Boundaries and Interfaces in relation to applicable Quality Outcome Criteria. Its actual Quality State exists independently of any examination. Evidence and Evidence Quality constrain what can responsibly be established about that state; they do not create it.

The determination is object-relative, function-based, bounded, lifecycle-aware, context-dependent, and evidence-supported. It does not arise from one document, one inspection, one compliance statement, one score, or the absence of observed failure.

The examination brings together:

realization of the declared object's Intended Functions and Intended Results;

- its actual Work, Results, configuration, and relevant life-cycle and operating conditions;
- Evidence-Supported Findings under applicable requirements and criteria, together with their relationships, Critical Conditions, and material uncertainty.

Quality Determination establishes what the Evidence supports about the object's actual Quality State within a stated scope and period. "Indeterminate" describes the determination's limits; it is not a third actual Quality State. A lack of Evidence supporting a Positive Conclusion does not, by itself, establish a Negative Conclusion.

The examination identifies the object and intended determination; establishes the applicable requirements and Quality Outcome Criteria; examines Evidence; develops Findings under the Indicators and Factors; and considers those Findings together through a Synthesis of Material Findings. The synthesis preserves Critical Conditions, Non-Compensability, material Interfaces, dependencies, and uncertainty. It supports the conclusion, if any, and the information communicated in a Quality Claim.

This is a relationship among the elements of an examination, not one compulsory one-pass sequence. New Evidence or changed conditions may require earlier steps to be revisited. Traceability preserves the basis for the Findings and any conclusion without extending them beyond the declared object, Scale, conditions, or period.

10. Evidence, Findings, and Bounded Claims

WQI_EQC1 governs Evidence Quality through Evidence Sufficiency, Evidence Trustworthiness, and Evidence Applicability: is there enough of the necessary Evidence, can it be relied upon for what it represents, and can it support this particular Finding and determination? Large quantities of data, formal records, and precise measurements do not answer these questions by themselves.

Energy-infrastructure Evidence may include:

- records of actual design Work and Results, verified configuration, models and their validation, and evidence of fulfillment of functional and technical requirements;
- construction, commissioning, inspection, testing, monitoring, and performance information
- operating, maintenance, repair, modification, incident, anomaly, and lifecycle-transition records
- conformity, compliance, environmental, worker, community, and interface information
- assumption, uncertainty, unresolved-condition, and decision-traceability records
- Evidence concerning Critical Infrastructure Conditions and conditions of continued validity

Evidence-Supported Findings state what the Evidence supports about applicable requirements or criteria. Findings under each Indicator and Factor must preserve contrary Evidence, material assumptions, uncertainty, and unresolved conditions. Synthesis of Material Findings considers their meaning and relationships rather than simply counting or averaging favorable results. Reporting the resulting conclusion in a claim is not a second synthesis.

Evidence in the energy sector is often fragmented across disciplines, organizations, systems, and lifecycle stages. IQI organizes it around the declared object and the determination dependency rather than treating document volume as proof of quality.

An Infrastructure Quality Claim Statement may communicate selected Findings or, where supported, an overall Positive, Conditionally Positive, or Negative Conclusion. Where no conclusion can responsibly be expressed, a Refusal to Express a Conclusion explains the reasons. The claim must identify its claimant, intended recipient or use, declared object, scope, basis, relevant period and conditions, and material limitations and uncertainty. A Conditionally Positive Conclusion does not establish fulfillment of future conditions and cannot replace a currently justified Negative Conclusion merely because correction may be possible. WQI_QCC1 governs the Quality of the claim as a separate Quality Object.

11. Conclusion

The energy sector illustrates a fundamental truth: technical excellence and conformity at the component level do not automatically establish the Quality State of an assembled Infrastructure Quality Object.

Actual infrastructure Quality concerns the realization of the declared object's Intended Functions and Intended Results through its Work, Results, constituents, and relationships. Evidence and uncertainty concern what can be established about that actual condition. Existing standards and regulations remain essential, but their application does not by itself establish the Quality of the integrated whole.

IQI provides a common architecture of fourteen Factors and eighty-three Indicators, with General Core Requirements and context-specific Quality Outcome Criteria. The examination accounts for essential external contributions, examines constituents and the whole, establishes Evidence-Supported Findings, and synthesizes material Findings while preserving Critical Conditions, Non-Compensability, and uncertainty. Any determination or claim remains within what the Evidence supports.

The energy examples demonstrate an application of the infrastructure-wide Core. The infrastructure, an organization, its Management System, the Evidence, and a Quality Claim may each be separately examined as Quality Objects. WQI_QOC1, WQI_QMS1, WQI_EQC1, and WQI_QCC1 govern their respective subjects where applicable. Their Findings may inform the infrastructure examination without replacing it.

Figures and Image References

Conceptual Illustrations of Infrastructure Quality in the Energy Sector

The figures below illustrate energy infrastructure at different Scales and lifecycle conditions. They are not engineering specifications, complete Infrastructure Quality Object descriptions, or Quality State determinations. Their purpose is to help visualize system-of-systems relationships, object Boundaries, Interfaces, Uncertainty, lifecycle evolution, operating pressures, and the updated IQI determination architecture.

Set A - System-Level Energy-Flow Context

(Macro-Scale system-of-systems perspective)

Source: Lawrence Livermore National Laboratory (LLNL) energy flow charts.

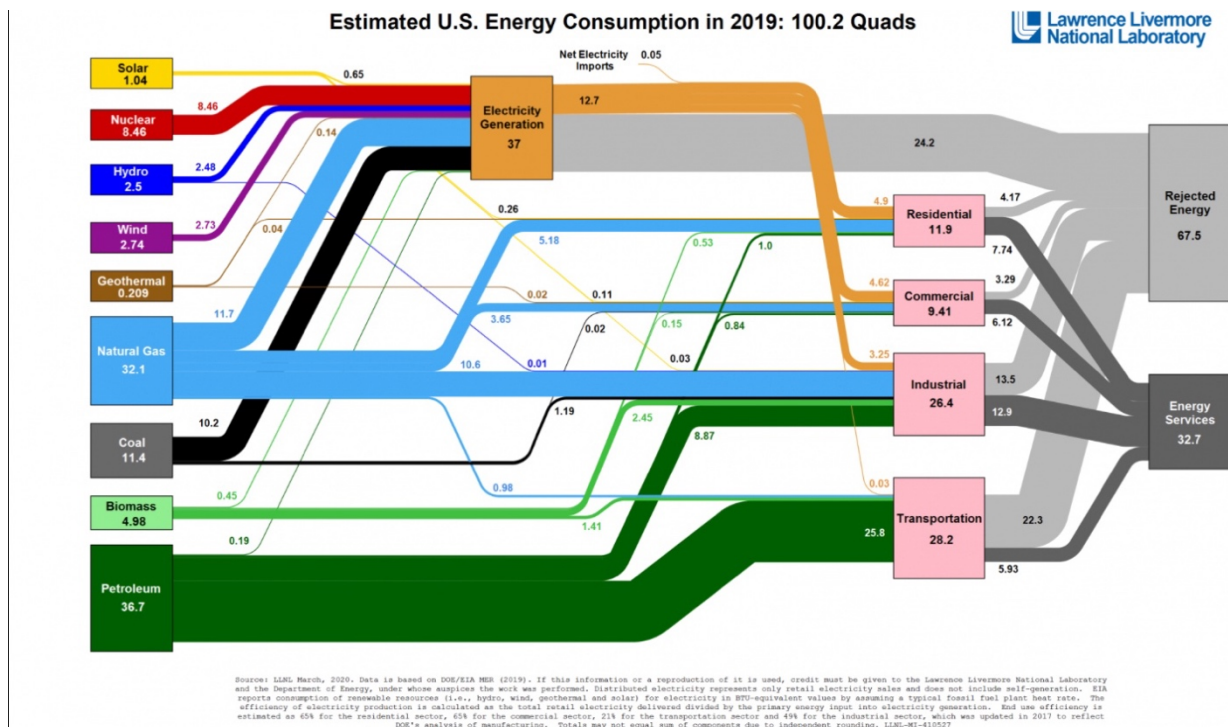


Figure A-1. U.S. Energy System Structure and Losses (LLNL, 2019)

This Sankey diagram presents the U.S. energy system as a macro-Scale system-of-systems. Primary energy sources pass through conversion and end-use sectors to produce delivered energy services and rejected energy.

In the IQI framework, the figure illustrates that:

- an Infrastructure Quality Object may be declared at a broad system-of-systems Scale when its purpose, composition, Boundaries, Interfaces, and Evidence basis are sufficiently defined;
- system-level results emerge from relationships among multiple infrastructure objects and conversion Interfaces;
- losses, constraints, risks, and consequences may accumulate across Interfaces and operating contexts.

The figure is a macro-Scale context illustration. It does not imply that one Quality State determination for an individual facility automatically determines the Quality State of the national energy system, or vice versa.

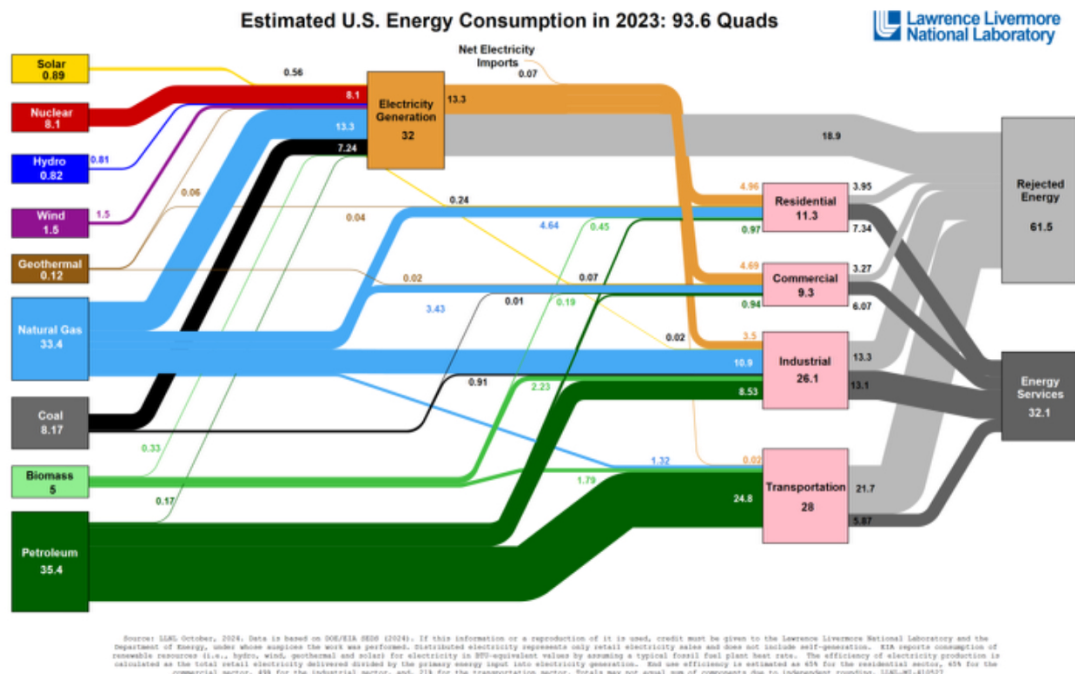


Figure A-2. U.S. Energy System Structure and Evolution (LLNL, 2023)

This later energy-flow chart enables comparison of the structure and context of the U.S. energy system across time.

In the IQI framework, comparison of Figures A-1 and A-2 illustrates:

- changes in system composition, operating context, and infrastructure relationships;
- changes in relevant Boundaries, Interfaces, conversion pathways, and external dependencies;
- changes that may alter Quality Outcome Criteria, Evidence needs, Critical Conditions, and claim validity.

The comparison reinforces that infrastructure context is dynamic. Earlier Findings and claims must be reviewed when the declared object, Scale, configuration, conditions, requirements, or Evidence materially change. A change in knowledge may change the determination without itself changing the underlying Quality State.

Set B - Natural Gas Infrastructure as a System-of-Systems

(Functional topology, object Boundaries, and Interfaces)

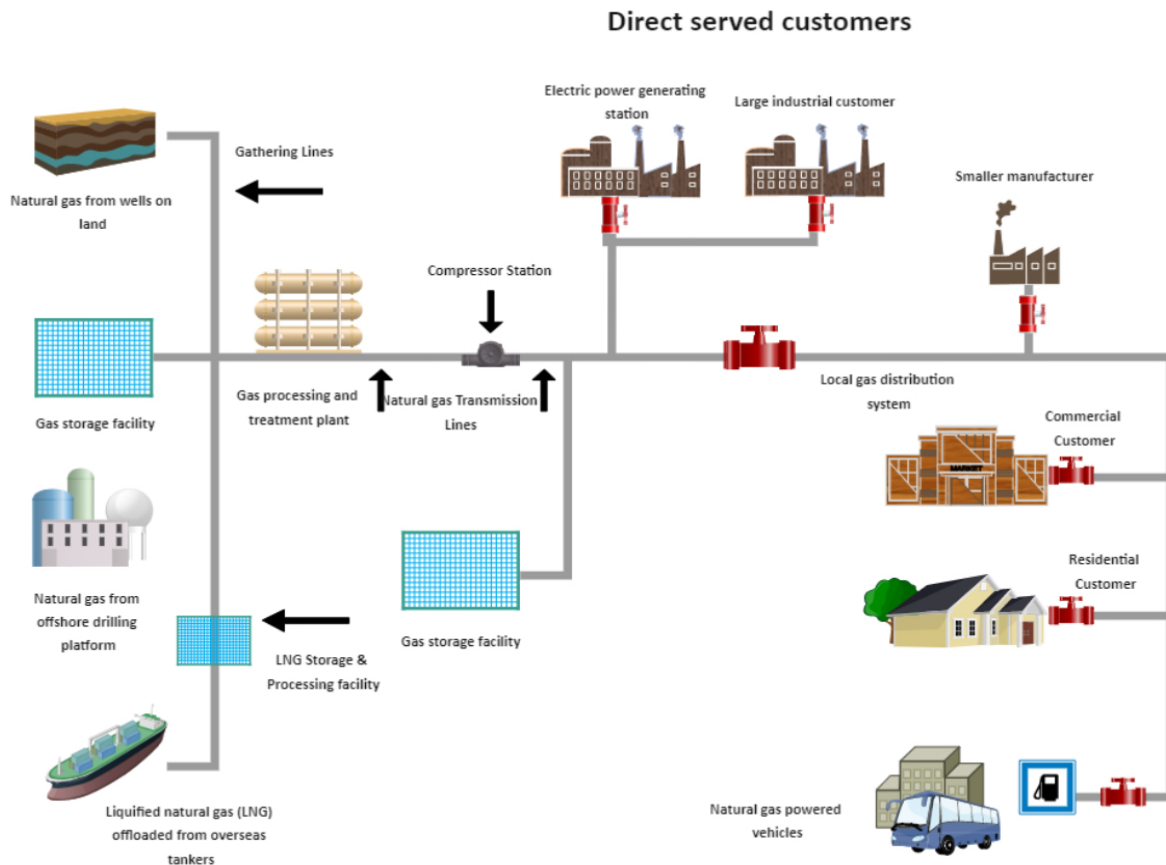


Figure B-1. Functional Delivery Chain of Natural Gas Infrastructure

This diagram presents a simplified functional chain connecting natural-gas production, processing, transportation, storage, distribution, and end use.

production -> processing -> transportation -> storage or conversion -> distribution or direct delivery -> end use.

In the IQI framework, the figure illustrates:

- a natural-gas chain may be interpreted as a system-of-systems composed of separately declared Infrastructure Quality Objects;
- quality-relevant Interfaces concentrate transfer conditions, responsibilities, information, custody, operating constraints, and Evidence;
- physical subsystems and functional roles must be distinguished when Boundaries and claims are established.

Infrastructure Quality may be determined for one bounded object or for a broader declared system-of-systems. The Scale and claim Boundary must be explicit, and a claim about one segment shall not imply the Quality State of adjacent segments.

Natural Gas Energy Supply Infrasrtucture

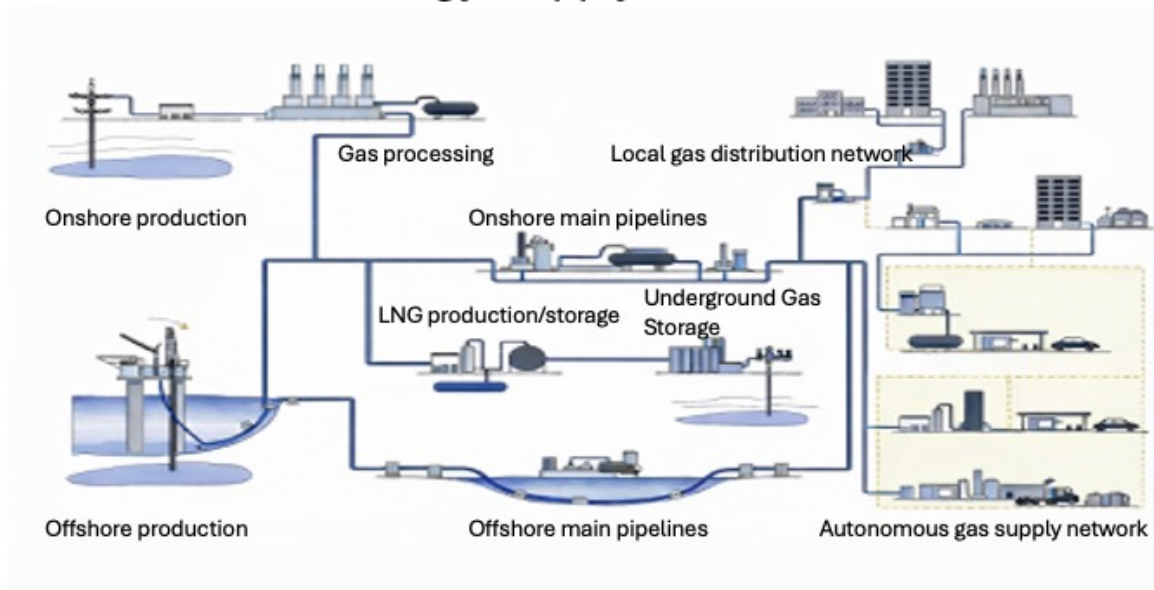


Figure B-2. Structural Topology of Natural Gas Infrastructure

This topology illustrates onshore and offshore production, natural gas processing, onshore and offshore main pipeline transportation, LNG, underground storage, local distribution, and autonomous supply as connected but separately bounded infrastructure contexts.

In the IQI framework, the topology illustrates:

- each infrastructure context requires its own declared object, Scale, Boundaries, Interfaces, operating conditions, and Evidence basis;
- the system-of-systems relationship does not erase the quality identity of each bounded object;
- responsibility and Quality Claim Boundaries must be visible across transfer Interfaces.

Infrastructure Boundaries are declared functional and methodological limits supported by physical, operational, informational, environmental, responsibility, Evidence, and claim conditions - not merely lines around equipment.

IQI Context Guides apply the common Core to particular infrastructure types and conditions. They may detail General Core Requirements and establish context-specific Quality Outcome Criteria, using relevant Reference Layer sources. Their use preserves the invariant Factors and Indicators. Users should identify the applicable edition and revision status of any guide before relying on it.

Set C - Infrastructure Quality as a System Condition

(Scale, Uncertainty, and lifecycle interaction)

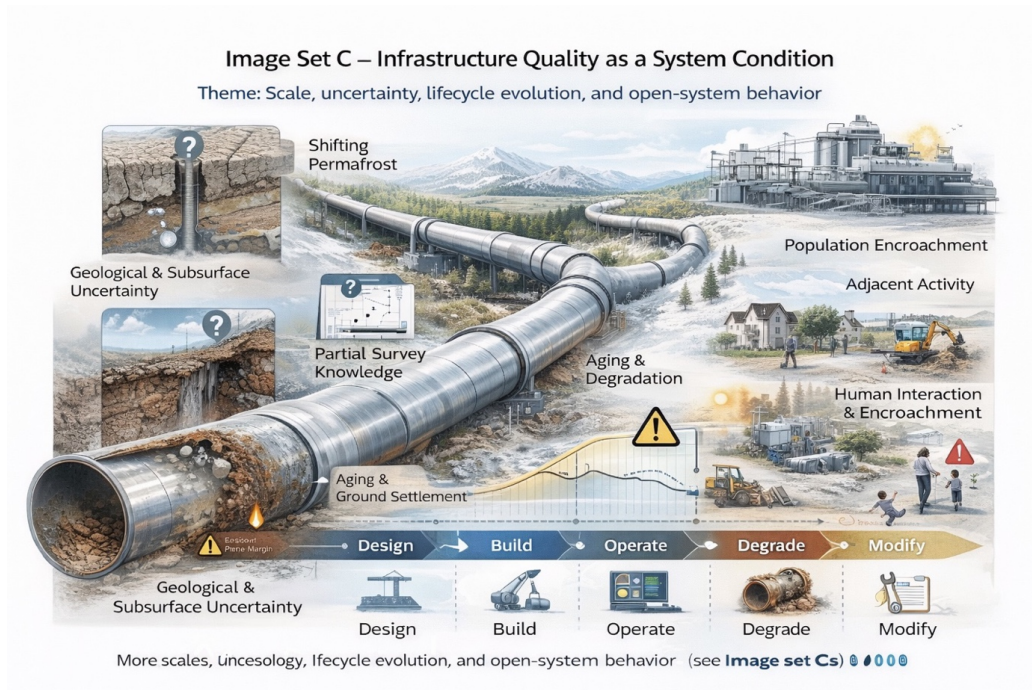


Figure C-1. Infrastructure Behavior Across Scale, Uncertainty, and Lifecycle

This conceptual illustration presents Infrastructure Quality as an object-level and system condition rather than a property of a single component.

It illustrates that the quality question changes with Scale:

- component Scale: technical specification, product behavior, and conformity of a defined part;
- facility, network, zone, or asset-population Scale: interaction among subsystems, functions, Boundaries, and Interfaces;
- system-of-systems Scale: interdependence, changing Context, Uncertainty, external interaction, and consequence propagation.

Key concepts illustrated include:

- partial knowledge and Uncertainty in geological, environmental, and operating conditions;
- cumulative degradation, aging, modification, and loss of alignment;
- propagation of local conditions through connected Interfaces and broader systems;
- interaction among infrastructure, workers, communities, environmental media, and adjacent activity.

The figure supports the distinction between product quality and Infrastructure Quality while emphasizing that any determination must begin with a declared Infrastructure Quality Object and Scale.

Set D - Market Pressure and Infrastructure Quality Reality

(Economic and schedule drivers versus Function Realization)



Figure D-1. Construction Under Schedule and Cost Pressure

This figure illustrates how schedule, cost, resource, and delivery pressures can influence Infrastructure Work and the realization of the intended object.

In the IQI framework, the figure demonstrates that:

- market and project pressures may change decisions without directly appearing as technical defects;
- completed Construction Work does not prove that the intended Infrastructure Result was realized;
- early trade-offs may reduce margins, create Unresolved Conditions, or establish later Critical Infrastructure Conditions.



Figure D-2. Brownfield Infrastructure Under Operational Pressure

This figure depicts a brownfield object operating under accumulated constraints, including:

- spatial congestion and complex physical Interfaces;
- limited access for inspection, monitoring, Maintenance, and Repair/Modification;
- legacy configuration, documentation, and design limitations;
- concentrated or interacting Failure-Mode Families and Critical Conditions.

In the IQI framework, the figure illustrates that:

- brownfield infrastructure is a principal energy-sector reality;
- degradation and loss of alignment may be incremental and difficult to observe;
- system-level risk may emerge from cumulative decisions rather than one isolated failure.

(Temporal realization and continued validity)



The design is itself a Quality Object whose Work and Results may be examined. Structural Checkpoints help confirm that its description is sufficiently complete. Findings may establish what the design demonstrates about the proposed facility, but do not establish actual operating performance before that performance occurs.



Figure E-2. Construction Phase - Translation of Intent into the Realized Object

This figure illustrates Construction as Infrastructure Work through which intended requirements, Boundaries, Interfaces, and functions are translated into a physical and functional object.

The determination must distinguish completed Work from the actual Infrastructure Result. Construction records and conformity findings may provide Evidence, but they do not by themselves establish the Quality State of the commissioned or operating object.



Figure E-3. Operation and Modification - Lifecycle Change and Claim Validity

This figure depicts the long-term evolution of an Infrastructure Quality Object under Operation, aging, degradation, Maintenance, Repair/Modification, modernization, and adaptation.

Infrastructure Quality is not fixed at commissioning. Material changes in configuration, operating conditions, Interfaces, requirements, or degradation may require renewed examination. Changes in Evidence or knowledge may also change what can be determined or claimed without themselves changing the actual infrastructure condition.

Set F - Shared Language and Determination Architecture

(Updated IQI object-level framework)

Determining Infrastructure Quality

One common Core across infrastructure types, life-cycle stages, scales, and examination detail

14 Core Quality Factors

83 Core Quality Indicators

- 1 Functional Requirements
- 2 Technical Requirements
- 3 Conformity Assessment
- 4 Structural and Functional Integrity
- 5 Harm, Risk, and Safety
- 6 Infrastructure and Environment
- 7 Operational Reliability
- 8 Human and Infrastructure Interaction
- 9 Competence of Personnel
- 10 Regulatory and Standards Compliance
- 11 Infrastructure and Stakeholders
- 12 Infrastructure Monitoring
- 13 Documentation and Traceability
- 14 Infrastructure Adaptability

Factor 14 has one Indicator: capability to accommodate required changes.

Quality Determination

- 1 Identify the infrastructure object
Intended Functions and Intended Results; essential Work and Results; life-cycle stage; Boundaries and Interfaces.
- 2 Establish what applies
General Core Requirements; context-specific detail and Quality Outcome Criteria; the Applicable Basis and Reference Layer.
- 3 Examine Evidence
Evidence Sufficiency • Evidence Trustworthiness • Evidence Applicability
Governed by WQI_EQC1.
- 4 Establish Findings
What does the Evidence support under each applicable Indicator and Factor? Preserve limitations and unresolved matters.
- 5 Synthesize material Findings
Consider relationships, Critical Conditions, Non-Compensability, and material uncertainty. Preserve distinct Findings.
- 6 Record the determination
State what can be established about Quality within the declared scope. Explain when no conclusion can responsibly be expressed.

Actual Quality State

The object's actual Quality-relevant condition exists independently of its examination or any claim.

Observations and records provide Evidence about actual conditions.

Parts and the whole

Account for essential external contributions. Examine Interfaces, dependencies, and combined behavior. Satisfactory parts do not establish a satisfactory whole.

Quality Claim

Communicate supported Findings or a conclusion for an intended recipient. Make the scope, basis, conditions, limitations, and uncertainty clear.
The claim is a separate Quality Object, examined under WQI_QCC1.

Infrastructure Quality Initiative (IQI)

Illustrative overview • October 2026 • Application may be iterative

Quality State ≠ determination status

"Indeterminate" describes the determination.

Figure F-1. Determining Infrastructure Quality

This infrastructure-wide overview also applies to the energy examples in this article. It distinguishes:

- the fourteen Core Quality Factors and eighty-three Core Quality Indicators;
- General Core Requirements, context-specific detail, Quality Outcome Criteria, Applicable Basis, and Reference Layer;
- the declared object, essential Work and Results, life-cycle stages, Boundaries, Interfaces, and external contributions;
- Evidence Quality under WQI_EQC1 and Evidence-Supported Findings;
- Synthesis of Material Findings, Critical Conditions, Non-Compensability, and material uncertainty;
- the actual Quality State from what can be established through Quality Determination;
- the Quality Claim as a separate Quality Object under WQI_QCC1.

In the IQI framework, the figure demonstrates that:

- the infrastructure has an actual Quality State independently of the examination and claim;
 - technical, organizational, regulatory, worker, community, and other interested parties require shared reference points;
 - IQI connects applicable requirements, criteria, sources, Evidence, Findings, and their synthesis without replacing engineering, regulation, professional judgment, or organizational management systems. The overview is illustrative; IQI_IQC1 and the governing vocabularies provide the requirements and meanings.
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