Liquefied Natural Gas Infrastructure

IQI Context Guide LNG1

(Informative)

Infrastructure Quality Standard — Core

IQI CONTEXT GUIDE LNG1

First Draft Edition — Updated July 2026

Interprets IQI_IQC1 Second Draft Edition — Updated July 2026 using WQI_VOC1 and IQI_VOC1

INFRASTRUCTURE QUALITY INITIATIVE

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0. Introduction

0.1 Status and Position of This Context Guide

This document is an informative IQI Context Guide for interpreting and applying the Infrastructure Quality Standard — Core (IQI_IQC1) to liquefied natural gas infrastructure. It provides context-specific interpretation and does not create an alternative Core Standard.

Within the Whole Quality document architecture, WQI_VOC1 defines Root Concepts, IQI_VOC1 defines energy-infrastructure Applied Concepts, IQI_IQC1 establishes invariant Core requirements, and LNG1 interprets those requirements within the bounded liquefied natural gas infrastructure context.

LNG1 addresses liquefied natural gas infrastructure as a midstream segment of the natural gas infrastructure chain. It is distinct from the upstream production segment addressed by PZN1 and from the downstream local-distribution and end-use segments. Automotive LNG fuel stations are excluded from LNG1 and are treated as a separate downstream infrastructure context under LNGFS1. LNG1 shall not redefine Root or Applied Concepts, create alternative Core Quality Factors, replace Core Quality Indicators, or expand an Infrastructure Quality Claim Statement beyond its supporting Infrastructure Quality State determination.

0.2 Governing Documents and One Authoritative Definition

This Guide shall be read with the current controlled editions of WQI_VOC1 — Whole Quality Root Vocabulary Standard, IQI_VOC1 — Infrastructure Quality Applied Vocabulary Standard, and IQI_IQC1 — Infrastructure Quality Standard — Core.

Each Whole Quality concept has one authoritative definition at the document layer appropriate to that concept. Where a Root, Applied, or Core-specific term appears in this Guide, the governing definition in WQI_VOC1, IQI_VOC1, or IQI_IQC1 applies.

LNG1 may explain LNG-specific meaning and identify context-specific terms, conditions, failure modes, criteria, and Evidence sources. Such interpretation shall not alter the authoritative meaning of the governing vocabulary or the invariant Core architecture.

0.3 What This Guide Supports

This Guide supports interpretation of energy infrastructure quality for LNG infrastructure as a midstream conversion, cryogenic storage, transfer, terminal, and regasification segment. Depending on the declared Infrastructure Quality Object, LNG1 may receive natural gas, condition and liquefy it, contain and preserve LNG at cryogenic conditions, manage boil-off gas, transfer or load and unload LNG, receive imported LNG, regasify LNG, and transfer regasified gas to connected infrastructure.

LNG1 commonly interfaces with MNT1 main pipeline transportation infrastructure. Feed gas may pass from an MNT1 object into LNG1 for liquefaction, and regasified gas may pass from LNG1 into an MNT1 object for onward transportation. LNG1 may also interface with natural gas processing infrastructure, marine LNG transportation, other LNG systems, underground storage, local distribution, industrial users, and power-generation infrastructure. The terms inlet, outlet, import, export, receipt, and send-out describe transfer direction or Interface position; they do not classify LNG1 itself as upstream or downstream.

Automotive LNG fueling and retail vehicle-dispensing infrastructure are not LNG1 realization pathways. They form a separately bounded downstream LNG fuel-station object governed by LNGFS1, including its own storage, conditioning, dispensing, vehicle, public, and retail Interfaces.

The Guide supports identification of the Infrastructure Quality Object, Infrastructure Quality Object Description, Structural Checkpoints, Boundaries, Interfaces, Infrastructure Lifecycle Stages, Infrastructure Operating Conditions, Infrastructure Realization Pathways, Failure-Mode Families, Context-Specific Quality Outcome Criteria, Evidence sources, Critical Infrastructure Conditions, Uncertainty, Infrastructure Quality State determination, and Infrastructure Quality Claim Boundaries.

0.4 What This Guide Does Not Do

This Guide does not prescribe LNG site selection, process selection, liquefaction technology, cryogenic equipment or storage-tank design, pressure and thermal management, boil-off gas management, marine or land transfer design, regasification technology, send-out conditions, inspection methods, integrity-management methods, operating procedures, emergency-response arrangements, compliance programs, audits, or certification methods.

It does not replace applicable laws, regulations, permits, engineering codes, technical standards, contracts, operating procedures, maritime and transportation requirements, environmental and safety requirements, professional judgment, or organizational management systems. These sources may form part of the Reference Layer for a declared LNG1 Infrastructure Quality Object.

Compliance, component conformity, activity completion, documentation, nominal liquefaction or regasification capacity, storage capacity, cargo transfer, continued operation, LNG production, import or export volume, or absence of observed failure is not by itself equivalent to a demonstrated positive Infrastructure Quality State.

0.5 Infrastructure Quality Object and System-Level Anchoring

Every application of LNG1 begins with a declared and sufficiently described Infrastructure Quality Object. The object may be a whole integrated LNG facility or terminal, or a bounded liquefaction train, cryogenic storage system, tank population, boil-off gas system, transfer or loading system, marine terminal Interface, unloading system, regasification system, send-out system, peak-shaving or satellite LNG system where within the midstream scope, floating LNG or floating storage and regasification system, lifecycle program, asset population, Interface condition, or connected LNG system-of-systems.

LNG1 quality interpretation connects the declared gas-receipt or LNG-receipt Interfaces; conditioning, liquefaction, phase-transformation, cryogenic containment, storage, boil-off gas, transfer, loading and unloading, regasification, send-out, monitoring, safety, environmental-protection, utility, control, and information systems; and the declared transfer Interfaces with MNT1, marine transportation, or other connected objects.

The object shall be interpreted at its declared Scale and Boundary. Individual tanks, process trains, heat exchangers, transfer arms, pumps, vaporizers, components, tests, documents, operating records, cargo movements, or compliance findings may provide Evidence, but they do not by themselves determine the Infrastructure Quality State of a broader assembled LNG object.

The declared object architecture shall also distinguish Infrastructure Work, Infrastructure Result, and Infrastructure Outcome. Completion of Design, Construction, testing, cooldown, Commissioning, liquefaction, storage, transfer, loading, unloading, regasification, send-out, monitoring, Maintenance, repair, or other Work does not by itself establish that the intended Result or a satisfactory Infrastructure Outcome has been realized.

0.6 Structural Checkpoints and Core Dependency

Before detailed Factor interpretation begins, Structural Checkpoints confirm that the declared Infrastructure Quality Object and its description are sufficiently developed. Structural Checkpoints are a completeness step; they are not a Core Quality Factor, Core Quality Indicator, Quality Outcome Criterion, technical inspection, assessment, or Infrastructure Quality State determination.

Where the object, Scale, LNG realization pathway, composition, Boundaries, Interfaces, Infrastructure Intended Functions, Infrastructure Intended Results, lifecycle and operating conditions, responsibilities, Context, Uncertainty, or Evidence basis is insufficiently described, the scope or proposed claim shall be refined, restricted, or qualified before interpretation proceeds.

Infrastructure Quality Object and Infrastructure Quality Object Description -> Structural Checkpoints -> Boundaries and Interfaces -> Infrastructure Intended Functions and Infrastructure Intended Results -> Failure-Mode Families -> Core Quality Factors -> Core Quality Indicators -> Context-Specific Quality Outcome Criteria -> Evidence-Supported Findings -> Quality Factor Interpretation -> Critical-Condition and Non-Compensability Review -> Infrastructure Quality State -> Infrastructure Quality Claim Statement

0.7 Reference Layer, Critical Infrastructure Conditions, Infrastructure Quality State, and Claims

Applicable laws, regulations, permits, codes, standards, contracts, process and design bases, operating procedures, maritime and transportation requirements, scientific knowledge, and professional guidance form the Reference Layer. They support context interpretation but do not redefine WQI Root Concepts, IQI Applied Concepts, or the IQC1 Core architecture.

LNG1 may identify Critical Infrastructure Conditions where failure, prohibition, unresolved status, insufficient Evidence, or loss of visibility would prevent a responsible positive Infrastructure Quality State determination or Infrastructure Quality Claim Statement.

An Infrastructure Quality Claim Statement shall be derived from a bounded Infrastructure Quality State determination and shall not exceed it. Use of this Guide does not imply IQI certification, approval, endorsement, accreditation, legal compliance, engineering acceptance, regulatory approval, or performance of a conformity assessment by IQI.

1. Purpose, Scope, and Context Guide Architecture

1.1 General Purpose

The purpose of LNG1 is to support consistent application of IQI_IQC1 to liquefied natural gas infrastructure without creating requirements independent of the Core Standard.

The Guide provides a controlled context interpretation of the invariant Core Intended Function architecture, the 14 Core Quality Factors, the Core Quality Indicators, and the Infrastructure Quality State determination and Infrastructure Quality Claim Statement requirements established in IQI_IQC1.

1.2 Scope of Application

LNG1 applies to liquefied natural gas infrastructure as a midstream segment. Its possible functions include natural-gas receipt and conditioning; liquefaction and phase transformation; cryogenic storage; boil-off gas management; LNG transfer, loading, unloading, import, and export; regasification and send-out; peak-shaving, satellite, floating, or integrated LNG operation where the declared object performs midstream conversion, storage, balancing, transfer, terminal, or send-out functions; and the supporting systems required for those functions.

The Infrastructure Quality Object may include, where relevant to the declared Boundary:

- feed-gas receipt, measurement, conditioning, pretreatment, compression, and transfer systems where included within the LNG object;
- liquefaction trains, refrigeration and heat-exchange systems, cryogenic process equipment, pressure-control and relief systems, and supporting process systems;
- full-containment, membrane, spherical, underground, or other LNG storage systems; tank foundations and containment systems; pumps, piping, insulation, impoundment, and boil-off gas systems;
- LNG loading and unloading systems, jetties, berths, transfer arms or hoses, manifolds, marine and land transportation Interfaces, metering, custody-transfer, isolation, emergency-shutdown, communication, and control systems;
- LNG import and export terminals, regasification systems, vaporizers, send-out compression and measurement systems, floating LNG and floating storage and regasification systems where included, and peak-shaving or satellite systems within the declared midstream scope; and
- utilities, power, instrument air, cooling, fire and gas detection, firefighting, drainage, environmental-protection, security, monitoring, automation, communication, emergency, Documentation, Evidence, and other supporting systems.

Quality-relevant Interfaces may include MNT1 main pipeline transportation, natural gas processing, other LNG facilities, marine LNG carriers and port systems, underground gas storage, local distribution, industrial and power-generation users, electric-power and communication systems, environmental media, workers, contractors, communities, emergency responders, and public authorities. Their relevance does not automatically place the surrounding object or organization inside the LNG1 Boundary.

Automotive LNG fuel stations, retail dispensing systems, vehicle fueling areas, and vehicle-side fueling Interfaces are excluded from LNG1 and belong to the separate downstream LNGFS1 context. A satellite or peak-shaving LNG facility is included in LNG1 only when its declared object and intended function concern midstream storage, balancing, regasification, or send-out rather than automotive retail fueling.

1.3 Infrastructure Quality Object and Object Description

The declared LNG1 Infrastructure Quality Object shall identify its Scale, LNG realization pathway, composition, included and excluded process, cryogenic storage, transfer, marine-interface, regasification, send-out, utility, safety, monitoring, control, information, support, and transfer systems, and relevant system-of-systems relationships.

The Infrastructure Quality Object Description shall identify the Infrastructure Intended Functions and Infrastructure Intended Results; relevant Infrastructure Configuration; Infrastructure Operating Medium and Infrastructure Operating Conditions; applicable Infrastructure Lifecycle Stage or transition; Boundaries and Interfaces; responsibilities; Context; Assumptions; Uncertainty; Evidence basis; and the intended scope of the Infrastructure Quality State determination or claim.

A component, activity, document set, process train, storage tank or tank population, transfer system, marine Interface, regasification train, send-out system, floating facility, or lifecycle program may be declared as a narrower Infrastructure Quality Object, but its Infrastructure Quality State shall not automatically determine the Infrastructure Quality State of the broader LNG facility, terminal, or system-of-systems.

1.4 Structural Checkpoints

Before detailed context interpretation proceeds, the following Structural Checkpoints shall be addressed:

- the Infrastructure Quality Object, Scale, LNG realization pathway, and purpose of the determination are declared;
- the process, phase-transformation, cryogenic storage, transfer, regasification, monitoring, protection, utility, information, support, and external-transfer composition of the object is sufficiently described;
- the Infrastructure Intended Functions, Infrastructure Intended Results, and relevant Infrastructure Work-Result-Outcome relationships are identified;
- the feed-gas, LNG-cargo, regasified-gas, MNT1, marine, and other material Interfaces; internal cryogenic and process Interfaces; Boundaries; Infrastructure Lifecycle Stage; Infrastructure Operating Medium; Infrastructure Operating Conditions; responsibilities; Context; Assumptions; Uncertainty; and Evidence basis are sufficiently visible; and
- the proposed Infrastructure Quality Claim Boundary does not exceed the described object or the intended determination.

An unsatisfied Structural Checkpoint requires refinement, restriction, or qualification of the object description or proposed claim. It does not itself constitute a negative Infrastructure Quality State determination.

1.5 Boundaries of Applicability

The LNG1 inlet-side Boundary depends on the declared realization pathway. For liquefaction, it is commonly the transfer Interface at which natural gas and associated information, control, custody, responsibility, and Evidence enter LNG1 from an MNT1 main pipeline transportation system or another separately bounded gas-supply or processing object. For an import or unloading object, it may be the LNG cargo-transfer Interface between a marine carrier or another transportation object and the receiving LNG terminal.

The LNG1 outlet-side Boundary also depends on the declared realization pathway. It may be the LNG loading or export Interface at which LNG passes to a separately bounded marine or land transportation object, or the regasified-gas send-out Interface at which gas and associated information, control, custody, responsibility, and Evidence pass from LNG1 to an MNT1 main pipeline transportation system or another separately bounded receiving object.

LNG1 is a midstream segment regardless of whether the object is described as liquefaction, export, storage, import, unloading, regasification, or send-out infrastructure. The expressions inlet-side, outlet-side, import-side, export-side, receipt-side, and send-out-side are positional and operational terms for the Interfaces bounding the object; they do not classify LNG1 as upstream or downstream.

Unless expressly included within the declared object and Infrastructure Quality Claim Boundary, LNG1 excludes external production-zone, processing, main pipeline, underground storage, local distribution, marine-carrier, industrial-use, power-generation, and unrelated infrastructure objects. Automotive LNG fuel-station infrastructure is expressly excluded and shall be addressed as the downstream LNGFS1 object.

Cryogenic natural-gas processing or natural-gas-liquids recovery infrastructure remains within GPP1 when its declared intended function is gas processing or product recovery rather than LNG production, cryogenic LNG storage, LNG terminal transfer, or regasification. The use of cryogenic technology alone does not place a processing facility inside LNG1.

1.6 System-of-Systems and Scale Interpretation

Liquefied natural gas infrastructure shall be interpreted as an assembled Infrastructure Quality Object or system-of-systems rather than as an unconnected collection of process trains, tanks, transfer equipment, cargo movements, regasification units, records, or activities.

Infrastructure Quality depends on the interaction of received natural gas or LNG, pretreatment and conditioning, liquefaction and refrigeration, heat exchange, phase transformation, cryogenic containment and insulation, storage tanks, boil-off gas management, pumps and piping, transfer and loading or unloading systems, marine and transportation Interfaces, regasification and send-out systems, utilities, power and communication, monitoring and control, safety and emergency systems, environmental and community conditions, responsibilities, records, and connected MNT1 or other external Interfaces.

The selected Scale shall be explicit. Findings at a component, process train, tank, transfer arm, berth, vaporizer, send-out station, floating unit, cargo-transfer event, or individual lifecycle-activity Scale may support but shall not automatically determine a claim at facility, terminal, tank-population, integrated-system, or system-of-systems Scale.

1.7 Lifecycle Scope and Infrastructure Operating Conditions

LNG1 applies across the principal IQI lifecycle sequence:

Design -> Construction -> Commissioning -> Operation -> Maintenance -> Repair/Modification -> Decommissioning/Transition

Context-specific sub-stages may include site and marine-interface planning; process selection and Design; procurement and fabrication; tank, process-train, pipeline, jetty, berth, utility, and support-system Construction; pressure testing, drying, inerting, cooldown, initial fill, Commissioning, and startup; liquefaction, storage, loading, unloading, cargo receipt, regasification, send-out, boil-off gas management, monitoring, inspection, Maintenance, repair, modification, expansion, conversion, recommissioning, temporary shutdown, conservation, repurposing, closure, decommissioning, and Evidence retention.

Infrastructure Operating Conditions may include normal feed-gas receipt, liquefaction, storage, loading, unloading, regasification, and send-out; startup and shutdown; cooldown and warmup; tank filling and emptying; cargo transfer; pressure, temperature, level, flow, composition, or phase transients; boil-off gas variation; weather and marine conditions; abnormal, degraded, non-routine, emergency, isolation, depressurization, venting, reduced-capacity, outage, Maintenance, repair, recommissioning, and Decommissioning/Transition conditions, as applicable to the declared object and determination.

1.8 Infrastructure Realization Pathways

LNG1 may be realized through different Infrastructure Realization Pathways, including base-load or smaller-scale liquefaction; export or import terminal operation; integrated liquefaction, storage, and loading; integrated unloading, storage, regasification, and send-out; peak-shaving or satellite storage and regasification within the midstream scope; floating LNG; floating storage and regasification; differing tank and containment concepts; marine, truck, rail, or pipeline transfer Interfaces where included; and differing refrigeration, boil-off gas, utility, monitoring, safety, and control arrangements.

An Infrastructure Realization Pathway describes how the declared Infrastructure Quality Object is configured and brought into service. It is not an engineering preference ranking and does not by itself establish Infrastructure Quality. Each pathway remains subject to the invariant Core Quality Factors, Core Quality Indicators, applicable Context-Specific Quality Outcome Criteria, Evidence requirements, Critical Infrastructure Conditions, and bounded Infrastructure Quality State determination.

1.9 Boundary and Interface Evolution and Lifecycle Verification

In LNG infrastructure, designed, contractual, regulatory, organizational, marine, transportation, process, cryogenic, and physical Boundaries and Interfaces may initially be intended or provisional. They become verified quality-relevant conditions only when Evidence demonstrates that the relevant receipt, phase-transformation, containment, storage, transfer, loading or unloading, regasification, send-out, control, protection, responsibility, or information relationship has been realized and remains compatible with Infrastructure Intended Functions and Infrastructure Intended Results under the declared lifecycle and operating conditions.

This principle applies to MNT1-to-LNG1 feed-gas Interfaces; LNG1-to-MNT1 regasified-gas send-out Interfaces; marine carrier-to-terminal and terminal-to-carrier LNG transfer Interfaces; process-train, tank, boil-off gas, transfer, regasification, utility, power, communication, control, safety, and environmental Interfaces; operator and contractor responsibility transfers; and Interfaces created or changed by expansion, debottlenecking, repair, conversion, floating-unit change, repurposing, temporary shutdown, recommissioning, or Decommissioning/Transition.

A specified, constructed, tested, accepted, cooled down, commissioned, documented, compliant, producing, storing, transferring, regasifying, or operating condition does not by itself demonstrate that the intended Boundary or Interface has been realized and remains valid.

1.10 Relationship to the Reference Layer

Applicable regulatory systems and standards addressing LNG siting, process safety, cryogenic equipment and materials, storage tanks and containment, pressure systems, liquefaction, refrigeration, boil-off gas, transfer and loading or unloading, marine and port Interfaces, regasification and send-out, pipelines and gas quality, fire and explosion protection, emergency response, worker safety, environmental protection, emissions, security, transportation, facility conversion, closure, and decommissioning may form part of the Reference Layer.

Reference Layer sources may support Infrastructure Intended Functions and Infrastructure Intended Results, Quality Outcome Criteria, technical interpretation, Evidence, responsibilities, Critical Infrastructure Conditions, and claim limitations. Compliance with those sources does not by itself establish a positive Infrastructure Quality State.

1.11 Relationship to Quality Outcome Criteria, Infrastructure Quality State Determination, and Claims

LNG1 supports identification of Context-Specific Quality Outcome Criteria for interpreting the invariant Core Quality Indicators. Such criteria may express an expected condition, result, relationship, threshold, prohibited condition, tolerance, or Evidence-supported state connected to the applicable Reference Layer.

Evidence-Supported Findings are interpreted at the Core Quality Factor level, followed by Critical-Condition and Non-Compensability Review, before the Infrastructure Quality State is determined.

An Infrastructure Quality Claim Statement shall identify the declared Infrastructure Quality Object, Scale, LNG realization pathway, Infrastructure Quality Claim Boundary, lifecycle and operating conditions, applicable Quality Outcome Criteria, Evidence basis and Evidence Sufficiency, Assumptions, Uncertainty, Unresolved Conditions, Critical Infrastructure Conditions, included and excluded Interfaces, limitations, and conditions of continued validity.

1.12 Relationship to Other Context Guides

LNG1 is one bounded context within the wider natural gas and energy-infrastructure Context Guide architecture. PZN1 addresses the upstream onshore natural gas production-zone object; GPP1 addresses natural gas processing; MNT1 addresses the midstream main pipeline transportation object; UGS1 addresses the midstream underground storage object; LNG1 addresses the separate midstream LNG conversion, cryogenic storage, terminal, transfer, regasification, and send-out object; LDN1 addresses downstream local distribution; and LNGFS1 addresses downstream automotive LNG fuel-station infrastructure.

LNG1 and MNT1 are both midstream segments, but they are not interchangeable. MNT1 transports natural gas through a main pipeline system. LNG1 changes phase where applicable, stores LNG under cryogenic conditions, manages boil-off gas, supports terminal transfer and marine cargo Interfaces, and may regasify LNG for send-out. Their shared Interfaces may include feed-gas receipt from MNT1 and regasified-gas transfer back to MNT1, with measurement, pressure, flow, gas-quality, isolation, operational coordination, custody, responsibility, records, and Evidence conditions.

LNGFS1 is not a subsection or realization pathway of LNG1. It is a separately bounded downstream object whose intended function concerns receipt and storage of LNG for vehicle fueling, conditioning and dispensing, vehicle Interfaces, retail and public-space interaction, and associated downstream operating conditions.

Where a connected production, processing, main pipeline, underground storage, marine transportation, local distribution, fuel-station, power-generation, industrial-use, or other infrastructure system is declared as a separate Infrastructure Quality Object, the applicable Context Guide should govern that separate object and its Infrastructure Quality Claim Boundary. Every adjacent Context Guide interprets the same IQC1 Core architecture but establishes its own object description, Boundaries, Interfaces, lifecycle and Infrastructure Operating Conditions, Failure-Mode Families, Context-Specific Quality Outcome Criteria, Evidence sources, Critical Infrastructure Conditions, Uncertainty, and Infrastructure Quality Claim Boundaries.

2. Infrastructure Quality Object Description and Context Characteristics of Liquefied Natural Gas Infrastructure

2.1 Purpose of Object and Context Description

This Section establishes the LNG1 Infrastructure Quality Object architecture that shall be visible before the invariant Core Quality Factors and Core Quality Indicators are interpreted. It connects the declared LNG object to its Infrastructure Intended Functions and Infrastructure Intended Results, Infrastructure

Work-Result-Outcome relationships, Scale, composition, Infrastructure Configuration, Infrastructure Operating Medium, Infrastructure Operating Conditions, Infrastructure Realization Pathways, lifecycle transitions, Boundaries, Interfaces, Assumptions, Uncertainty, and Evidence basis.

The description supports context interpretation and completion of the Structural Checkpoints. It does not by itself establish a positive Infrastructure Quality State, conformity, technical acceptance, regulatory approval, operating authorization, or an Infrastructure Quality Claim Statement.

2.2 Declared LNG1 Infrastructure Quality Object

The LNG1 Infrastructure Quality Object is a declared and bounded midstream energy-infrastructure object used to receive natural gas or LNG, transform natural gas into LNG where liquefaction is included, preserve LNG under cryogenic conditions, store and manage LNG inventory, manage boil-off gas, transfer and load or unload LNG, transform LNG back to gaseous natural gas where regasification is included, and transfer gas or LNG to another separately bounded Infrastructure Quality Object.

The declared object may be a whole integrated LNG terminal or facility, an export or import terminal, a liquefaction facility, a cryogenic storage system, a tank or tank population, a boil-off gas system, a loading or unloading system, a marine-terminal Interface, a regasification and send-out system, a peak-shaving or satellite LNG system within the midstream scope, a floating LNG facility, a floating storage and regasification unit, an Interface condition, a lifecycle program, an asset population, or another bounded LNG system-of-systems.

The selected Scale and Boundary shall be explicit. A component, process train, tank, jetty, berth, transfer arm, vaporizer, control system, cargo-transfer event, activity, document set, or operating record may be declared as a narrower Infrastructure Quality Object, but its Quality State shall not automatically determine the Quality State of the broader LNG facility or terminal.

Automotive LNG fuel-station infrastructure is not included in the LNG1 Infrastructure Quality Object unless an adjacent bulk-supply Interface is being described solely to bound LNG1. Receipt, storage, conditioning, dispensing, vehicle interaction, retail operation, and public-space conditions for vehicle fueling belong to the separately bounded downstream LNGFS1 object.

2.3 LNG1 as a Midstream Segment and Its Relationship to MNT1

LNG1 is the midstream LNG conversion, cryogenic storage, terminal-transfer, regasification, and send-out segment of the natural gas infrastructure chain. It is neither the upstream production segment nor the downstream local-distribution, automotive-fueling, or gas-consumption segment.

LNG1 commonly interfaces with MNT1 main pipeline transportation infrastructure. Feed gas may pass from MNT1 to LNG1 for conditioning and liquefaction, and regasified gas may pass from LNG1 to MNT1 for onward main-pipeline transportation. These are midstream-to-midstream Interfaces between separately bounded Infrastructure Quality Objects with different intended functions.

An LNG1 object may also receive gas from a processing or another supply object, receive LNG from marine or land transportation, transfer LNG to a carrier or bulk receiving object, or send regasified gas directly to a separately bounded downstream distribution, industrial, or power-generation object where the actual infrastructure arrangement so provides. Such variations shall be declared without reclassifying LNG1 itself as upstream or downstream.

The terms feed-gas inlet, LNG receipt, loading, unloading, import, export, regasified-gas outlet, and send-out describe operating direction and relative Interface position. They do not determine the segment classification of LNG1.

2.4 Infrastructure Intended Functions and Infrastructure Intended Results

LNG1 interprets the invariant IQC1 Intended Function architecture through LNG-specific subfunctions and Intended Results. It does not create a competing Core Intended Function.

Primary context functions may include receiving natural gas or LNG at declared transfer conditions; measuring and controlling receipt; conditioning feed gas where included; removing heat and transforming natural gas into LNG; preserving LNG within a declared cryogenic, pressure, level, composition, and inventory envelope; storing LNG; managing boil-off gas and vapor return; transferring, loading, unloading, or receiving LNG; regasifying LNG where included; controlling pressure, flow, temperature, composition, and phase; and transferring LNG or gaseous natural gas, information, custody, responsibility, and Evidence at declared external Interfaces.

Supporting and protective functions may include cryogenic containment; insulation and thermal management; refrigeration and heat exchange; storage-tank integrity; pressure relief, vent, flare, reliquefaction, fuel-gas, or recovery functions where included; pumping and compression; utility, power, water, firewater, communication, monitoring, automation, shutdown, isolation, emergency, security, environmental-protection, marine-support, and information-retention functions.

Lifecycle functions may include site and Interface planning; Design and Construction; fabrication, transport, erection, testing, drying, inerting, cooldown, initial fill, Commissioning, and startup; controlled Operation; Maintenance, inspection, Repair/Modification, expansion, debottlenecking, conversion, floating-unit replacement or relocation where relevant, temporary shutdown, conservation, recommissioning, repurposing, closure, Decommissioning/Transition, residual-condition management, and Evidence retention.

Context-specific Infrastructure Intended Results may include feed gas received within declared conditions; natural gas liquefied and LNG produced within the declared process and quality envelope; LNG contained and preserved without unacceptable loss, release, pressure excursion, thermal instability, or degradation; boil-off gas managed within the declared arrangement; LNG transferred safely and compatibly; LNG regasified and sent out within declared MNT1 or other receiving-system conditions; and an Evidence basis sufficient for the bounded determination or claim.

2.5 Infrastructure Work, Infrastructure Result, and Infrastructure Outcome

Infrastructure Work in LNG1 may include planning, siting support, Design, procurement, fabrication, Construction, installation, pressure testing, drying, inerting, cooldown, Commissioning, initial fill, startup, feed-gas conditioning, liquefaction, refrigeration, heat exchange, storage, inventory management, boil-off gas management, transfer, loading, unloading, regasification, send-out, monitoring, inspection, Maintenance, repair, replacement, modification, expansion, conversion, recommissioning, temporary shutdown, conservation, decommissioning, restoration, and Documentation.

An Infrastructure Result is what is actually produced, maintained, changed, protected, stored, transferred, or made available through that Work. Examples include a functioning liquefaction train, established cryogenic containment, an LNG inventory, managed tank pressure, a completed cargo transfer, a functioning boil-off gas system, regasified gas at a declared transfer condition, an isolated system, a verified repair, monitoring information, or retained lifecycle Evidence.

Infrastructure Work + Infrastructure Result = Infrastructure Outcome

An LNG1 Infrastructure Outcome may take the form of an LNG conversion, storage, transfer, import, export, regasification, or send-out service; LNG or gaseous natural gas transferred to another object; a maintained cryogenic or isolated condition; or an available capability. Completion of Work does not prove that the intended Result was realized, and an observed Result does not by itself validate all Work or establish a satisfactory Infrastructure Quality State.

2.6 Scale, Composition, and System-of-Systems Relationships

The declared Scale may range from an individual component, tank, process train, loading arm, vaporizer, control loop, transfer event, or Interface condition to an integrated terminal, tank population, multi-train facility, floating facility, lifecycle program, asset population, or LNG system-of-systems.

Depending on the declared Boundary, LNG1 composition may include feed-gas receipt and conditioning; liquefaction and refrigeration trains; heat exchangers; separators, pumps, compressors, piping, valves, pressure-control and relief systems; cryogenic storage tanks and containment; boil-off gas and vapor-return systems; loading and unloading jetties, berths, arms, hoses, couplings, manifolds, and emergency release systems; regasification and send-out systems; marine-support systems; utilities, power, water, firewater, drainage, vent, flare, fuel-gas, nitrogen, air, communication, security, monitoring, automation, control, emergency, environmental-protection, and information systems.

Infrastructure Quality depends on the interaction of these elements rather than on isolated conformity. Findings at a component, process-train, tank, berth, transfer, or subsystem Scale may support but shall not automatically determine a claim at facility, terminal, tank-population, integrated-system, or system-of-systems Scale.

Connected MNT1, marine transportation, processing, UGS1, LDN1, industrial, power-generation, port, emergency-response, water, electricity, communication, and environmental systems remain outside LNG1 unless expressly included. Their Interfaces may nevertheless be essential to Function Realization and claim validity.

2.7 Infrastructure Configuration, Operating Medium, and Operating Conditions

Infrastructure Configuration may be onshore or floating; export, import, or integrated; liquefaction-focused, storage-focused, transfer-focused, regasification-focused, peak-shaving, satellite, or multi-function; single-train or multi-train; single-tank or tank-population; and based on differing refrigeration, containment, transfer, vapor-handling, regasification, utility, marine, monitoring, control, and safety arrangements.

The Infrastructure Operating Medium may include natural gas, LNG, flash gas, boil-off gas, vapor return, refrigerants, fuel gas, nitrogen or other inert gas, water, steam, heat-transfer fluids, firewater, treatment chemicals, condensate, liquids, and other materials where they affect the declared object. Composition, phase, pressure, temperature, moisture, contaminants, density, heating value, and compatibility may change across the object and across lifecycle or operating conditions.

Infrastructure Operating Conditions may include normal feed-gas receipt, conditioning, liquefaction, storage, loading, unloading, LNG receipt, regasification, and send-out; startup and shutdown; drying, inerting, cooldown, warmup, initial fill, tank filling and emptying, heel conditions, cargo transfer, pressure and temperature transients, boil-off gas variation, reduced-rate operation, equipment outage, maintenance, abnormal, degraded, non-routine, emergency, isolation, depressurization, venting, flaring, severe weather, marine or metocean conditions, and Decommissioning/Transition conditions.

The object description shall identify the operating envelope and the conditions included in the intended determination. A claim based on one operating mode, season, cargo condition, feed-gas composition, tank state, transfer arrangement, or lifecycle stage shall not be generalized to another without supporting Evidence.

2.8 Infrastructure Realization Pathways and Lifecycle Transitions

LNG1 may be realized through base-load or smaller-scale liquefaction; export-terminal liquefaction, storage, and loading; import-terminal unloading, storage, regasification, and send-out; integrated export and import operation; storage and transshipment; peak-shaving or satellite storage and regasification within the midstream scope; floating LNG; floating storage and regasification; differing tank and containment concepts; and differing refrigeration, heat-exchange, boil-off gas, utility, monitoring, safety, and control arrangements.

An Infrastructure Realization Pathway describes how the declared object is configured and brought into service. It is not an engineering preference ranking and does not by itself establish Infrastructure Quality.

Lifecycle transitions may change the validity of the pathway and its assumptions. Transitions include Design to Construction, Construction to Commissioning, drying and inerting to cooldown, cooldown to first LNG introduction, initial fill to Operation, Operation to modification or expansion, temporary shutdown to recommissioning, conversion between export and import or other operating roles, floating-unit change, repurposing, and Decommissioning/Transition.

Automotive LNG dispensing is not an LNG1 realization pathway. A bulk LNG terminal or storage object may transfer LNG toward an LNGFS1 supply chain, but the downstream fuel-station object and vehicle-dispensing function remain separately bounded.

2.9 Feed-Gas Receipt, Conditioning, and Liquefaction

Where liquefaction is included, the LNG1 object receives gaseous natural gas through a declared transfer Interface, commonly from MNT1, and may condition the gas before phase transformation. Quality-relevant conditions may include pressure, flow, temperature, composition, moisture, contaminants, heavy hydrocarbons, mercury or other constituents where applicable, measurement, control, isolation, custody, responsibility, and Evidence transfer.

Liquefaction depends on coordinated refrigeration, heat exchange, compression, expansion, separation, control, utility, power, and protection systems. Successful production of LNG does not by itself demonstrate stable phase transformation, adequate thermal margin, process safety, environmental protection, reliability, or compatibility with storage and transfer systems.

A change in feed-gas composition or MNT1 transfer conditions may affect pretreatment, refrigeration duty, heat-exchanger behavior, LNG composition, storage behavior, boil-off gas generation, regasification, send-out compatibility, Evidence interpretation, and claim validity.

2.10 Cryogenic Phase Transformation and Thermal Regime

LNG infrastructure involves controlled transformation between gaseous and liquid phases and sustained operation at cryogenic temperatures. These are quality-relevant conditions affecting material behavior, thermal stress, insulation, containment, process stability, equipment performance, instrumentation, monitoring, and lifecycle behavior.

Quality interpretation shall consider cooldown and warmup rates, thermal gradients, heat ingress, cold spots, differential movement, contraction and expansion, insulation condition, vapor generation, pressure response, and compatibility of materials and connections with the actual temperature and phase conditions.

Phase transformation and cryogenic operation shall remain visible across functional and technical requirements, conformity, integrity, process safety, environmental protection, reliability, workplace interaction, competence, monitoring, Documentation, Evidence, and bounded claims.

2.11 Cryogenic Storage, Inventory, and Containment

Cryogenic storage may be a principal function or an intermediate function within an integrated LNG1 object. Storage quality depends on continued primary and secondary containment where applicable, tank and foundation behavior, insulation, pressure and level control, inventory understanding, boil-off gas management, monitoring, emergency protection, environmental compatibility, and transfer readiness.

Storage capacity, nominal tank volume, or presence of LNG does not by itself establish a satisfactory Infrastructure Quality State. The determination shall consider actual inventory, heel and operating range, stratification and mixing conditions, rollover-related concerns where applicable, pressure behavior, temperature distribution, fill and withdrawal patterns, instrumentation, settlement or movement where relevant, and Evidence limitations.

The storage Boundary includes the physical containment system and the functional conditions required to preserve LNG without unacceptable leakage, release, vapor accumulation, overpressure, thermal instability, structural degradation, or loss of visibility.

2.12 Boil-Off Gas, Vapor, Pressure, and Relief Management

Boil-off gas is a normal physical consequence of LNG storage, transfer, and heat ingress. Its generation, collection, compression, recovery, reliquefaction, use, return, transfer, venting, or flaring where applicable is therefore part of the LNG1 context rather than an incidental activity.

Boil-off gas management affects storage pressure, process stability, emissions, energy use, equipment loading, transfer operations, emergency response, and compatibility with connected systems. The declared object shall identify the intended vapor-management pathway and the conditions under which it remains available.

Pressure relief, vent, flare, emergency depressurization, vapor return, and isolation functions shall be interpreted as interacting protective pathways. The existence of relief capacity or operating records does not by itself demonstrate that the combined vapor and pressure-management architecture remains effective under the declared normal, transient, degraded, and emergency conditions.

2.13 LNG Transfer, Loading, Unloading, and Custody Transition

LNG transfer includes the quality-relevant interaction among the terminal or facility, transfer piping, pumps, loading arms or hoses, couplings, manifolds, vapor return, receiving or delivering system, measurement, communication, shutdown, emergency release, containment, environmental protection, personnel, custody, responsibility, records, and Evidence.

Transfer may occur between shore and marine carrier, between facilities, through truck, rail, ISO-container, or other bulk-transfer arrangements, or within an integrated terminal. The connected transportation object is outside LNG1 unless expressly included, but the transfer Interface may be within the LNG1 determination because it affects Function Realization and consequences.

A completed cargo movement or measured transferred quantity does not by itself demonstrate compatibility, containment, correct sequencing, emergency readiness, evidence continuity, or a satisfactory Quality State of the terminal, carrier, or combined Interface.

2.14 Regasification and Send-Out

Where regasification is included, LNG1 transforms LNG into gaseous natural gas and transfers it through a declared send-out Interface. Quality-relevant conditions may include LNG composition and inventory, pumping, vaporization, heat-source and heat-exchange behavior, pressure and temperature control, gas quality, flow stability, measurement, odorization status where applicable to the receiving arrangement, isolation, custody, responsibility, and Evidence.

The predominant send-out arrangement connects LNG1 to MNT1. The LNG1-to-MNT1 Interface is a midstream-to-midstream transfer, and the MNT1 receiving conditions shall remain visible in the LNG1 object description and Evidence basis.

A direct connection to LDN1, an industrial facility, or a power-generation object may create a midstream-to-downstream Interface. Such an arrangement shall be declared according to the actual Boundary and shall not transform the LNG1 object itself into a downstream segment.

Regasification capacity or send-out flow alone does not establish Infrastructure Quality. The determination shall consider the whole path from stored LNG through regasification and transfer to the receiving object under the declared lifecycle, operating, gas-quality, environmental, monitoring, and Evidence conditions.

2.15 Floating LNG and FSRU Context

Where the declared object is floating LNG infrastructure or a floating storage and regasification unit, the LNG1 context includes the relevant process, storage, transfer, regasification, send-out, marine-support, mooring, stationkeeping, metocean, hull or structural, utility, power, control, emergency, access, evacuation, responsibility, and Evidence conditions within the declared Boundary.

Marine-vessel classification, port, flag-state, coastal-state, and other requirements may form part of the Reference Layer, but they do not by themselves determine the Infrastructure Quality State of the LNG1 object.

Shared boundaries between vessel, terminal, pipeline, port, marine service, and operator responsibilities shall be explicit. A floating unit, berth, mooring, or transfer arrangement shall not be generalized beyond the environmental and operating conditions supported by Evidence.

2.16 Utility, Power, Control, Safety, Emergency, and Security Dependencies

LNG Function Realization depends on supporting systems that may include electricity generation or supply, refrigeration, cooling or heating media, water, steam, fuel gas, nitrogen, instrument air, firewater, drainage, communication, automation, control, alarm, shutdown, isolation, fire and gas detection, spill and vapor control, emergency response, access, security, and cyber-dependent monitoring or control where relevant.

These systems may be internal to LNG1 or external Interfaces. Their classification shall follow the declared object, but their loss, degradation, mismatch, or limited Evidence may materially affect liquefaction, containment, transfer, regasification, environmental protection, public consequence, and claim validity.

A redundancy statement, installed backup, successful test, or management arrangement does not by itself demonstrate continuing availability or coordinated performance under the actual operating and emergency conditions.

2.17 Operating-Medium Compatibility and Product Quality

LNG1 shall distinguish the gas and LNG conditions at each quality-relevant point: feed-gas receipt, conditioned gas, liquefaction, LNG storage, LNG transfer, boil-off gas, regasification, and gaseous send-out. Material composition and phase changes shall be connected to the declared Intended Results and receiving-system requirements.

Compatibility may be affected by moisture, contaminants, heavy hydrocarbons, nitrogen, carbon dioxide, mercury or other constituents where relevant, refrigerant or process interactions, tank mixing, cargo blending, boil-off gas composition, vapor return, and regasification behavior.

A contractual specification or isolated sample does not automatically demonstrate compatibility across the entire object, inventory, cargo, time period, or operating condition. Evidence shall be bounded by sampling, measurement, model, uncertainty, and representativeness limits.

2.18 Environmental, Community, Public-Consequence, and Infrastructure-Protection Context

LNG1 may interact with marine and coastal environments, rivers, ports, industrial sites, land, soil, groundwater, surface water, air, ecosystems, communities, workers, roads, utilities, nearby facilities, and emergency-response systems. Relevant pathways may include methane or refrigerant releases, venting or flaring, combustion emissions, water intake and outfall, thermal discharge, treatment chemicals, firewater or emergency runoff, spills, vapor dispersion, noise, light, traffic, and marine or port activity.

These interactions are quality-relevant because they affect operating assumptions, degradation, monitoring, emergency preparedness, environmental protection, stakeholder commitments, public consequence, and claim meaning. Compliance or permitting status alone does not establish the condition or behavior of the declared Infrastructure Quality Object.

Infrastructure-protection conditions may include unauthorized access, interference, collision, dropped objects, marine impact, vehicle impact, external fire, loss of utilities or communications, security events, and other external conditions capable of affecting essential LNG functions or Evidence continuity.

2.19 Monitoring, Visibility, Models, and Uncertainty

LNG1 quality determination depends on visibility of cryogenic temperature, pressure, level, flow, composition, inventory, containment, thermal behavior, boil-off gas, transfer conditions, gas and fire detection, equipment condition, environmental interaction, emergency-system readiness, Interface performance, and lifecycle change.

Monitoring information may be incomplete, delayed, non-representative, inaccessible, or dependent on automation, calibration, algorithms, models, or inferred relationships. Data volume and absence of alarms shall not substitute for Evidence Sufficiency or understanding of material limitations.

Models may support refrigeration, heat transfer, tank behavior, vapor generation, dispersion, structural behavior, marine conditions, process dynamics, inventory, or risk interpretation. Their phenomena, geometry, inputs, assumptions, calibration, validation, time basis, uncertainty, and applicable operating range shall be visible.

Material Uncertainty may arise from hidden degradation, limited inspection access, tank or insulation condition, changing cargo or feed composition, unobserved transient behavior, incomplete transfer records, changing environmental conditions, aging, modification, multi-operator arrangements, and incomplete responsibility or Evidence transfer.

2.20 LNG1 Failure-Mode Families

Failure-Mode Families support development of context-specific Quality Outcome Criteria and Evidence-Supported Findings. They do not replace the invariant Core Quality Factors or Core Quality Indicators.

Illustrative LNG1 Failure-Mode Families include:

- object, Scale, realization-pathway, Boundary, or Interface mismatch;
- feed-gas, LNG, boil-off gas, refrigerant, vapor-return, or send-out medium incompatibility;
- loss of liquefaction, refrigeration, heat-exchange, or phase-transformation control;
- cryogenic material, thermal-barrier, insulation, connection, or containment degradation;
- storage-tank, foundation, primary or secondary containment, pressure, level, inventory, stratification, or rollover-related loss of control where applicable;
- boil-off gas, vapor, pressure-relief, vent, flare, recovery, reliquefaction, or fuel-gas pathway failure;
- transfer, loading, unloading, coupling, loading-arm, hose, manifold, vapor-return, custody, communication, emergency-release, shutdown, or isolation failure;
- regasification, vaporization, heat-source, pumping, pressure, temperature, gas-quality, measurement, or send-out mismatch;
- utility, power, control, automation, alarm, communication, monitoring, security, or cyber-dependent function loss where relevant;
- fire, explosion, vapor dispersion, spill, emergency response, evacuation, access, or public-consequence control failure;
- environmental-release, emission, discharge, water-intake, outfall, thermal-effect, marine, coastal, or cumulative-impact failure;
- floating-unit, mooring, stationkeeping, metocean, berth, jetty, or marine-interface failure where applicable;
- lifecycle transition, cooldown, first fill, startup, shutdown, recommissioning, conversion, repurposing, or decommissioning loss of alignment;
- organizational, contractor, carrier, port, operator, MNT1, emergency-response, custody, responsibility, or Evidence-transfer failure;
- monitoring, inspection, model, Documentation, traceability, or Evidence Sufficiency failure; and
- scope substitution in which downstream automotive LNG fueling is incorrectly included within LNG1 or represented by an LNG1 claim.

2.21 Critical Infrastructure Conditions

A Critical Infrastructure Condition is a context-specific condition whose failure, prohibition, unresolved status, insufficient Evidence, or loss of visibility may prevent a responsible positive Infrastructure Quality State determination or Infrastructure Quality Claim Statement. Criticality depends on effect, not on equipment naming alone.

Illustrative LNG1 Critical Infrastructure Conditions may include inability to demonstrate cryogenic containment; unresolved tank, foundation, insulation, or thermal-integrity concerns; uncontrolled or inadequately visible pressure, boil-off gas, vapor, relief, vent, flare, or emergency-isolation behavior; material incompatibility at a feed-gas, cargo-transfer, regasification, or MNT1 send-out Interface; unavailable essential power, utility, control, fire and gas detection, shutdown, or emergency functions;

unresolved stratification or rollover-related conditions where applicable; unacceptable environmental or public-consequence exposure; unverified floating-unit or marine-interface limits; unclear responsibility at a shared Interface; material Evidence gaps; or a lifecycle transition that invalidates prior assumptions.

A condition may also be critical where the proposed claim crosses into a separately bounded MNT1, marine transportation, LNGFS1, LDN1, industrial, power-generation, or other object without a corresponding determination and Evidence basis.

Critical Infrastructure Conditions shall be carried into Factor interpretation, Critical-Condition and Non-Compensability Review, Infrastructure Quality State determination, and the bounded Infrastructure Quality Claim Statement.

3. LNG1 Boundaries, Interfaces, Operating Conditions, and Lifecycle Transitions

3.1 Purpose of Boundary and Lifecycle Interpretation

This Section establishes how LNG1 Boundaries, Interfaces, Infrastructure Operating Conditions, and lifecycle transitions are declared, verified, and carried into Core Factor interpretation, Evidence-Supported Findings, Infrastructure Quality State determination, and Infrastructure Quality Claim Statements.

A Boundary identifies the declared extent of the Infrastructure Quality Object or determination. An Interface is the quality-relevant interaction across or within a Boundary. A lifecycle transition is an Interface between conditions in time. These elements shall not be treated only as drawings, ownership lines, contractual points, permits, or organizational assignments.

3.2 Boundary, Interface, and Related Terms

LNG1 uses the governing WQI and IQI definitions for Boundary, Interface, Infrastructure Quality Object, Infrastructure Configuration, Infrastructure Operating Medium, Infrastructure Operating Conditions, Infrastructure Lifecycle Stage, Infrastructure Quality Claim Boundary, Evidence, Uncertainty, and related concepts.

Context-specific expressions include feed-gas receipt Interface, LNG receipt Interface, liquefaction path, cryogenic containment Boundary, storage-tank Boundary, boil-off gas and vapor Interface, loading or unloading Interface, marine transfer Interface, regasification path, send-out Interface, utility and support Interface, and LNGFS1 supply Interface.

The terms inlet-side, outlet-side, import-side, export-side, receipt-side, loading-side, unloading-side, and send-out-side are positional or operational descriptions. They do not classify LNG1 itself as upstream or downstream.

3.3 Outer Boundary of the LNG1 Infrastructure Quality Object

The outer LNG1 Boundary shall identify the included physical, functional, process, cryogenic, storage, transfer, regasification, control, protection, utility, monitoring, information, organizational, environmental, and lifecycle elements and the points at which responsibility, custody, operating control, information, and Evidence pass to another object.

The outer Boundary may encompass an integrated terminal or a narrower facility, train, storage system, transfer system, regasification system, floating unit, Interface condition, or lifecycle program. It shall state included and excluded systems and shall not be inferred solely from property, fence, permit, ownership, contract, or operating-organization boundaries.

Where the object combines multiple realization pathways, the determination shall identify whether each pathway and connecting internal Interface is included. A claim concerning one train, tank, berth, or lifecycle condition shall not imply the Quality State of the whole terminal.

3.4 Feed-Gas Receipt and MNT1-to-LNG1 Transfer Boundary

Where LNG1 receives feed gas from MNT1, the external feed-gas Boundary is the declared midstream-to-midstream transfer Interface at which gas and associated measurement, pressure, flow, temperature, composition, control, isolation, custody, responsibility, records, and Evidence pass from the MNT1 object to the LNG1 object.

The Interface may include metering, regulation, filtration, separation, conditioning, isolation, communication, control, and quality-verification functions according to the declared Boundary. The presence of a connecting pipeline or contractual delivery point does not by itself establish compatibility or Evidence Sufficiency.

Where feed gas comes from another processing, storage, LNG, or supply object, the actual adjacent object shall be declared. Use of feed-gas or inlet terminology does not change the midstream status of LNG1.

3.5 Liquefaction, Refrigeration, and Internal Phase-Transformation Boundaries

The liquefaction Boundary identifies the included path from feed-gas receipt and conditioning through refrigeration, heat exchange, phase transformation, separation, pressure and temperature control, LNG rundown, and transfer to storage or loading.

Internal Interfaces may connect pretreatment, refrigeration cycles, refrigerants, compressors, drivers, heat exchangers, separators, pumps, piping, controls, utilities, flare or vent, fuel gas, and storage systems. Their interaction shall be interpreted at the declared Scale and operating condition.

A train boundary, package boundary, or vendor scope shall not obscure system-level dependencies. Successful operation of an individual process package does not establish satisfactory Function Realization across the complete liquefaction path.

3.6 Cryogenic Storage and Containment Boundaries

The cryogenic storage Boundary includes the declared storage tank or containment system, foundation, primary and secondary containment where applicable, insulation, roof or cover, penetrations, piping connections, pumps, instruments, pressure and level control, relief, vapor, spill, drainage, monitoring, and associated protection systems.

Functional containment extends beyond the nominal tank shell where dikes, impoundment, secondary containment, vapor control, separation distances, spill control, emergency isolation, environmental pathways, or adjacent-system consequences affect the declared object.

Storage Boundaries shall identify tank population, inventory range, heel condition, operating envelope, excluded tanks or systems, and the Evidence basis for temperature, pressure, level, inventory, thermal, structural, foundation, containment, and monitoring interpretations.

3.7 Boil-Off Gas, Vapor-Return, Pressure-Relief, Vent, and Flare Interfaces

The boil-off gas and vapor Boundary connects storage, transfer, loading, unloading, process, regasification, compression, recovery, reliquefaction, fuel-gas, vapor-return, relief, vent, flare, and emergency-depressurization functions where included.

The determination shall identify normal and abnormal vapor pathways, capacity and availability assumptions, pressure interactions, receiving-system compatibility, emission pathways, control and shutdown relationships, and Evidence limitations.

Where vapor or boil-off gas passes to an external object, the transfer Boundary shall identify the receiving object and responsibility. A nominally available route shall not be treated as effective under all operating conditions without Evidence.

3.8 LNG Loading and Export Transfer Boundary

The loading or export Boundary is the declared Interface at which LNG, vapor return where applicable, information, control, custody, responsibility, records, and Evidence pass from LNG1 to a marine carrier or another bulk transportation or receiving object.

The Interface may include pumps, piping, manifolds, loading arms or hoses, couplings, emergency release, shutdown and isolation, measurement, communication, mooring or berth conditions, spill and vapor control, and coordinated procedures. The marine carrier or land transportation object remains separate unless expressly included.

Export describes cargo direction; it does not make LNG1 an upstream object. A completed loading event does not determine the Quality State of the carrier or of future cargo transfers.

3.9 LNG Unloading and Import Transfer Boundary

The unloading or import Boundary is the declared Interface at which LNG, vapor return where applicable, information, control, custody, responsibility, records, and Evidence pass from a marine carrier or another bulk transportation object into LNG1.

Quality interpretation shall address compatibility of cargo, pressure, temperature, composition, unloading rate, vapor management, tank allocation, communication, shutdown, emergency release, mooring or berth conditions, custody transfer, and receiving-system readiness.

Import describes cargo direction; it does not make LNG1 a downstream object. Unloaded quantity or cargo acceptance does not by itself demonstrate satisfactory storage, vapor, environmental, or later regasification behavior.

3.10 Marine, Port, Truck, Rail, ISO-Container, and Other Transportation Interfaces

Marine, port, truck, rail, ISO-container, and other transportation systems are generally separate Infrastructure Quality Objects. LNG1 includes only the declared terminal, transfer, support, staging, access, communication, emergency, and Evidence Interfaces needed for the bounded LNG1 object or determination.

Transportation Interfaces may affect scheduling, operating limits, loading and unloading, traffic, custody, responsibility, security, emergency response, environmental exposure, public consequence, and continuity of Evidence. These dependencies shall remain visible even where the transportation object is excluded.

A truck-loading or bulk-distribution Interface does not place downstream automotive dispensing within LNG1. The LNGFS1 Boundary begins at the separately declared downstream fuel-station object, including its receipt, storage, conditioning, dispensing, vehicle, retail, and public-space Interfaces.

3.11 Regasification Path and LNG1-to-MNT1 Send-Out Boundary

The regasification path extends from storage through pumping, vaporization, heat-source and heat-exchange systems, pressure and temperature control, gas conditioning where included, measurement, isolation, and transfer to the declared send-out Interface.

Where send-out enters MNT1, the external Boundary is the midstream-to-midstream Interface at which regasified natural gas, information, control, custody, responsibility, records, and Evidence pass from LNG1 to MNT1. MNT1 pressure, flow, temperature, gas-quality, measurement, control, isolation, and operational-coordination conditions shall be explicit.

A material mismatch at the send-out Interface may invalidate an LNG1 claim even where regasification equipment continues to operate. A separate MNT1 determination is required for claims about the receiving main-pipeline object beyond the Interface.

3.12 Direct Downstream Send-Out and Other External Transfer Boundaries

Where LNG1 sends gas directly to LDN1, an industrial user, a power-generation object, or another downstream receiving object, the external transfer is a midstream-to-downstream Interface. The Boundary shall identify the actual receiving object, pressure and flow conditions, gas quality, odorization status where applicable, measurement, control, isolation, custody, responsibility, records, and Evidence.

Where LNG1 transfers LNG to another midstream terminal, storage, or bulk-transport object, the Interface remains between separately bounded midstream objects. Where LNG is transferred toward LNGFS1, LNG1 ends at the declared bulk-supply or transportation Interface; the downstream station remains outside LNG1.

The nature of the adjacent object shall be determined by its intended function and declared Boundary, not solely by physical proximity or direction of flow.

3.13 Operating-Medium, Product, and Gas-Quality Boundaries

Operating-medium Boundaries identify the conditions of feed gas, conditioned gas, refrigerants, LNG, stored inventory, boil-off gas, vapor return, flash gas, regasified gas, send-out gas, utilities, water, and other materials relevant to the declared object.

The determination shall identify composition, phase, pressure, temperature, moisture, contaminants, density, heating value, sampling and measurement basis, variability, blending or mixing, and compatibility with process, storage, transfer, carrier, MNT1, or other receiving-system conditions.

A specification, certificate, isolated sample, cargo document, or model shall not be generalized beyond its supported material, location, time, inventory, and operating condition.

3.14 Utility, Power, Water, Communication, Control, and External-Support Interfaces

LNG1 may depend on external electricity, fuel, water, steam, heat-source or heat-sink, nitrogen, instrument air, communication, data, security, emergency response, port, marine service, roads, and other support systems. These are separate objects unless expressly included.

The Interface shall identify availability, capacity, quality, reliability, control, isolation, communication, responsibility, emergency priority, restoration assumptions, and Evidence relevant to LNG Function Realization.

A contractual service level, installed backup, or prior operating history shall not substitute for a bounded understanding of current dependency and Critical Infrastructure Conditions.

3.15 Environmental, Land, Marine, Community, and Public-Consequence Boundaries

Environmental and public-consequence Boundaries include the interactions of LNG1 with air, water, marine and coastal environments, land, soil, groundwater, ecosystems, nearby buildings and infrastructure, workers, communities, traffic, ports, emergency responders, and authorities.

The Boundary shall identify relevant methane, refrigerant, vent, flare, combustion, spill, vapor-dispersion, water-intake, outfall, thermal-discharge, chemical, firewater, runoff, noise, light, traffic, marine, and cumulative-effect pathways where applicable.

These external environments and communities are not components of LNG1, but their interaction may determine acceptable operating conditions, protective functions, monitoring needs, emergency readiness, stakeholder commitments, Critical Infrastructure Conditions, and claim limitations.

3.16 Human, Organizational, Custody, and Responsibility Boundaries

Human and organizational Boundaries may involve owner, operator, terminal, process, storage, marine, carrier, port, contractor, maintenance, engineering, utility, control-room, emergency-response, environmental, security, regulatory, and other responsible parties.

The determination shall identify responsibility for operations, maintenance, transfer, custody, emergency action, monitoring, change, Evidence retention, and decision authority at shared Interfaces. Multiple organizations or contracts do not remove the need for an integrated understanding of the Infrastructure Quality Object.

Unclear or changing responsibility may become an Unresolved Condition or Critical Infrastructure Condition even when equipment and procedures appear complete.

3.17 Monitoring, Information, Model, and Evidence Boundaries

The monitoring and Evidence Boundary defines what can be observed, measured, tested, inspected, sampled, modeled, verified, or reasonably inferred about the declared LNG1 object. It shall identify coverage by process train, tank, transfer system, berth, floating unit, regasification system, external Interface, lifecycle stage, operating condition, and time.

Relevant Evidence may include Design bases, material and fabrication records, conformity findings, test and inspection records, drying, inerting, cooldown, Commissioning and first-fill records, operating data, tank and foundation information, thermal and insulation information, inventory and gas-quality records, transfer and cargo records, boil-off gas data, relief and shutdown testing, maintenance and modification records, environmental monitoring, incidents, alarms, model results, Interface agreements, responsibility records, and MNT1 transfer information.

A model Boundary shall identify the phenomena, geometry, inputs, assumptions, calibration, validation, time basis, uncertainty, and operating range represented. An Infrastructure Quality Claim Statement shall not extend beyond the Evidence Boundary.

3.18 Lifecycle Boundaries

Lifecycle Boundaries identify the applicable stage or transition for the declared LNG1 object and determination. The principal sequence is Design, Construction, Commissioning, Operation, Maintenance, Repair/Modification, and Decommissioning/Transition, with LNG-specific sub-stages where relevant.

A Design-stage object may be represented by intended configuration and predicted behavior. A Construction-stage object includes realized work and unresolved conformity or completion conditions. A Commissioning-stage object may include drying, inerting, cooldown, initial fill, startup, and verification. An Operation-stage object includes actual cryogenic, process, storage, transfer, regasification, utility, environmental, and Interface behavior.

The claim shall identify the lifecycle condition and shall not roll forward automatically. Evidence and assumptions from one stage shall not be treated as proof of another stage without lifecycle continuity and verification.

3.19 Lifecycle Transition Interfaces

Lifecycle transitions are quality-relevant Interfaces because configuration, responsibility, operating medium, temperature, pressure, inventory, monitoring, Evidence, assumptions, and Critical Infrastructure Conditions may change.

Relevant transitions include concept to Design; Design to Construction; Construction to acceptance; acceptance to drying and inerting; inerting to cooldown; cooldown to first LNG introduction; initial fill to Operation; Operation to Maintenance or Repair/Modification; modification or expansion to recommissioning; export to import or other role conversion; temporary shutdown to conservation; conservation to recommissioning; floating-unit change; repurposing; and Operation to Decommissioning/Transition.

Each transition shall identify transferred and unresolved conditions, changed Boundaries or Interfaces, required verification, responsibility, Evidence continuity, and the effect on prior determinations or claims.

3.20 Acceptance, Commissioning, Drying, Inerting, Cooldown, Initial Fill, and Startup

Acceptance and Commissioning may provide Evidence that planned systems, protective functions, Interfaces, controls, and responsibilities are capable of supporting realized LNG behavior, but completion of activities does not itself establish Infrastructure Quality.

Quality-relevant conditions may include construction completion and deviations, cleanliness, drying, inerting, oxygen and moisture conditions, pressure and leak testing, instrument and control verification, shutdown and isolation testing, utility readiness, controlled cooldown rate, thermal gradients, first LNG introduction, initial tank fill, pressure and boil-off gas behavior, tank allocation and stratification considerations where applicable, transfer readiness, environmental controls, operating procedures, personnel competence, emergency readiness, and Interface compatibility.

Temporary exceptions, deferred work, incomplete Evidence, unverified assumptions, or unresolved findings shall remain visible and shall restrict the determination or claim where material.

3.21 Temporary Shutdown, Conservation, Recommissioning, Conversion, Repurposing, and Decommissioning/Transition

During temporary shutdown or conservation, LNG1 may no longer realize its normal operating pathway but may still require containment, pressure and boil-off gas management, inventory control, isolation, utilities, monitoring, security, environmental protection, emergency readiness, responsibility, and Evidence retention.

Recommissioning shall verify current condition, changed configuration, operating medium, utilities, controls, protective systems, personnel competence, Interfaces, assumptions, and Evidence before prior claims are renewed.

Conversion, expansion, debottlenecking, export-import role change, floating-unit replacement, repurposing, or introduction of a different gas or energy carrier may change the Infrastructure Quality Object and applicable Context Guide. Original assumptions shall not be carried forward without controlled review.

Decommissioning/Transition shall address safe removal or isolation, residual LNG or gas, warming and inerting, pressure and vapor, dismantling, waste and environmental conditions, marine or land restoration, monitoring, responsibility, records, and protection of affected Interfaces and communities.

3.22 Boundary and Interface Verification

Planned, designed, contractual, regulatory, organizational, or drawn Boundaries and Interfaces become verified quality-relevant conditions only where Evidence demonstrates that the intended physical, functional, process, transfer, containment, control, responsibility, information, or protection relationship has been realized under the declared conditions.

Verification may include physical inspection, test and Commissioning results, cooldown and first-fill records, operating behavior, transfer testing, cargo records, boil-off gas performance, tank and containment monitoring, regasification and MNT1 send-out data, emergency shutdown and isolation tests, environmental monitoring, Interface agreements, responsibility matrices, maintenance, change records, and Evidence-transfer records.

Verification depth shall be proportionate to quality significance, lifecycle stage, operating condition, Critical Infrastructure Conditions, Evidence limitations, and the intended claim. Not every Interface requires the same method, but every material Interface requires a defensible basis.

3.23 Boundary and Interface Dependencies, Evolution, and Assumption Drift

Boundaries and Interfaces are interdependent. A change in feed-gas composition, refrigeration configuration, tank operation, cargo type, boil-off gas routing, transfer equipment, regasification heat source, MNT1 conditions, utility supply, marine arrangement, operator responsibility, environmental exposure, or monitoring coverage may affect multiple Factors and claim conditions.

Boundary evolution occurs through construction, modification, expansion, aging, changed operating mode, changing cargo or gas supply, changed transportation or downstream connections, environmental change, new Reference Layer requirements, ownership or operator change, and accumulated experience.

Assumption drift occurs when original assumptions no longer match actual configuration, operating medium, operating conditions, lifecycle stage, Interface behavior, Evidence, or Context. It shall be identified and carried into Quality Outcome Criteria, findings, Critical Infrastructure Conditions, and claim validity.

3.24 Boundary and Interface Uncertainty, Failure, and Degradation

Uncertainty may concern physical extent, process behavior, thermal condition, containment, inventory, gas quality, transfer compatibility, operating limits, responsibility, environmental exposure, lifecycle condition, monitoring coverage, model validity, or Evidence Sufficiency. It shall remain visible rather than being assumed resolved.

Boundary or Interface failure may be physical, functional, informational, organizational, operational, or evidentiary. Examples include containment loss, incompatible transfer conditions, communication breakdown, emergency-isolation mismatch, unclear custody, missing Evidence, changed assumptions, loss of monitoring, or failure of a support dependency.

Continued production, storage, transfer, regasification, or send-out does not demonstrate that all Boundaries and Interfaces remain satisfactory. Material degradation may invalidate a claim before total operational failure occurs.

3.25 Boundary Transparency and Object-Scale Consistency

An LNG1 Infrastructure Quality Claim Statement shall identify the declared object, Scale, realization pathway, claim Boundary, included and excluded systems and Interfaces, lifecycle and operating conditions, operating medium, applicable Quality Outcome Criteria, Evidence basis, Assumptions, Uncertainty, Unresolved Conditions, Critical Infrastructure Conditions, limitations, date, and conditions of continued validity.

A claim concerning LNG1 shall not imply the Quality State of MNT1, a marine carrier, port, LNGFS1, LDN1, an industrial or power-generation object, an emergency-response organization, or another connected object unless each is included within the declared object and supported by the corresponding determination.

Findings at a component, train, tank, berth, transfer-event, regasification, or Interface Scale may support but shall not automatically determine a facility, terminal, fleet, asset-population, or system-of-systems claim. Object, Scale, Boundary, Interface, Evidence, determination, and claim shall remain consistent.

4. Context-Specific Interpretation of Core Quality Factors, Core Quality Indicators, and Quality Outcome Criteria

4.1 General

This Section interprets the invariant IQI_IQC1 Core Quality Factors and Core Quality Indicators for Liquefied Natural Gas Infrastructure. It provides LNG1 Context-Specific Interpretation, illustrative Context-Specific Quality Outcome Criteria, and illustrative Evidence considerations without modifying the normative Core.

The 14 Core Quality Factors and 97 Core Quality Indicator titles, order, and meanings remain governed by IQI_IQC1. LNG1 does not create an additional LNG-specific Factor, replace a Core Quality Indicator, or redefine a governing WQI or IQI concept.

LNG1 shall be interpreted as a declared and bounded midstream Infrastructure Quality Object. It is neither an upstream production segment nor a downstream distribution, consumption, or vehicle-fueling segment. Its feed-gas receipt and regasified-gas send-out Interfaces are commonly connected to the separate MNT1 midstream main-pipeline transportation object.

LNG1 may also include declared bulk LNG transfer Interfaces with marine carriers, road tankers, railcars, or ISO containers. Such bulk transfer does not include automotive vehicle dispensing. Automotive LNG fuel stations and vehicle-fueling functions are separately bounded downstream objects governed through LNGFS1.

The LNG1 object may include feed-gas receipt and conditioning where included; liquefaction and refrigeration; cryogenic storage and containment; boil-off gas, vapor, pressure, relief, vent, and flare management; transfer, loading, and unloading; regasification and send-out; floating LNG or FSRU systems; utilities, controls, safety, emergency, security, environmental-protection, and monitoring systems; and the declared MNT1 and bulk-carrier Interfaces.

Infrastructure Quality is not established merely by installed liquefaction, storage, transfer, or regasification capacity; successful production, cargo transfer, or send-out; current operation; regulatory compliance; documentation volume; component conformity; or Absence of Observed Failure. The relevant question is whether the declared Infrastructure Intended Functions and Infrastructure Intended Results are realized and remain visible within the stated Scale, Boundaries, Interfaces, lifecycle and operating conditions, Assumptions, Uncertainty, and Evidence basis.

The illustrative Context-Specific Quality Outcome Criteria under each Indicator are not independent Core requirements or universal engineering acceptance limits. They identify expected conditions, results, relationships, prohibited conditions, tolerances, or Evidence-supported states that may be refined through the applicable Reference Layer for the declared LNG1 object.

Illustrative Evidence considerations identify possible sources and lines of inquiry. Their existence does not establish Evidence Sufficiency. Evidence shall be evaluated for relevance, credibility, coverage, representativeness, timeliness, traceability, consistency, and adequacy for the object, Scale, lifecycle and operating condition, and claim being examined.

An LNG1 Infrastructure Quality Claim Statement shall remain bounded by the supporting Infrastructure Quality State determination and shall identify the declared midstream LNG object and realization pathway, Scale, Infrastructure Quality Claim Boundary, lifecycle and operating conditions, included and excluded MNT1, marine, road, rail, ISO-container, utility, environmental, community, and other Interfaces, Evidence basis, Assumptions, Uncertainty, Unresolved Conditions, Critical Infrastructure Conditions, limitations, and conditions of continued validity.

4.2 Factor 1 — Functional Specification Quality

Purpose of the Factor

The authoritative IQC1 purpose is:

To ensure that the Infrastructure Intended Functions and Infrastructure Intended Results of the declared Infrastructure Quality Object are explicitly defined, complete, coherent, and traceable across the Lifecycle, forming a valid basis for technical realization, Operation, integrity interpretation, Evidence, and bounded claims.

Core architecture role: Defines the functional reference basis from which all later technical realization, evidence, and claims shall remain traceable.

Definitions and Governing Terms

Governing WQI and IQI terms. Intended Function, Intended Result, Function Realization, Boundary, Interface, Assumption, Uncertainty, Lifecycle, Infrastructure Intended Function, and Infrastructure Intended Result apply with their authoritative WQI_VOC1 and IQI_VOC1 meanings.

IQC1 Factor-specific terms. Functional Specification, Functional Requirement, Functional Intent, Core Function Categories, Operating Envelope, Functional Change, and Traceability apply as defined in IQI_IQC1 and are not redefined in LNG1.

LNG1 context terms and anchors. midstream LNG conversion, storage, terminal-transfer, and regasification role; MNT1-connected feed-gas receipt and regasified-gas send-out Interfaces; liquefaction, cryogenic storage, boil-off gas management, LNG transfer, loading, unloading, regasification, and send-out; bulk marine, road-tanker, rail, and ISO-container transfer Interfaces; exclusion of automotive LNG dispensing and fuel-station operation to the downstream LNGFS1 context; and the primary, supporting, protective, and lifecycle functions identified in Sections 2 and 3. Their technical meaning, values, methods, and acceptance conditions depend on the declared Infrastructure Quality Object, applicable Context-Specific Quality Outcome Criteria, and the Reference Layer.

Context-specific boundary. Asset-specific functions, subfunctions, operating limits, acceptance conditions, and technical values are established through this Guide or the applicable Reference Layer; they are not defined universally by this Factor.

Context-Specific Interpretation

Functional Specification Quality concerns the quality of the stated functional intent for the declared LNG Infrastructure Quality Object.

In the LNG context, functional specification should make clear what the declared Infrastructure Quality Object is intended to do, under what conditions, within what boundaries, across which interfaces, during which lifecycle condition, and with what Assumptions and limitations.

Functional specification quality is not limited to naming a facility type, capacity, process, or operational activity.

For LNG infrastructure, functional specification may concern liquefaction, cryogenic storage, transfer, loading, unloading, transportation support, import, export, regasification, send-out, boil-off gas management, floating LNG operation, FSRU operation, peak-shaving, satellite LNG supply, integrated terminal operation, or other declared LNG-context realization pathways.

Functional requirements should be sufficiently complete and clear to support later technical specification, conformity assessment, integrity interpretation, process-safety interpretation, environmental protection, operational reliability, monitoring, documentation, and bounded Infrastructure Quality Claim Statements.

Functional specification should also identify LNG-specific boundary and interface conditions, including cryogenic containment, phase transformation, thermal behavior, boil-off gas behavior, transfer interfaces, transportation interfaces, regasification and send-out interfaces, environmental interactions, lifecycle transitions, and Critical Infrastructure Conditions where relevant.

For Factor 1, LNG1 shall be interpreted as a midstream Infrastructure Quality Object. Feed-gas receipt from MNT1, LNG transfer to or from a bulk carrier, and regasified-gas send-out to MNT1 are transfer Interfaces between separately bounded objects; they do not reclassify LNG1 as upstream or downstream.

Bulk loading of LNG into a marine carrier, road tanker, railcar, or ISO container may be included where it is part of the declared LNG1 terminal or transfer Boundary. Dispensing LNG as automotive fuel to vehicles is excluded and belongs to the separately bounded downstream LNGFS1 context.

Core Quality Indicators

The following Core Quality Indicator titles are invariant and governed by IQI_IQC1. The clauses under each Indicator provide LNG1 Context-Specific Interpretation, illustrative Context-Specific Quality Outcome Criteria, and Evidence considerations; they do not reproduce or replace the normative Core Indicator Statement.

4.2.1 Indicator 1.1 — Completeness of Functional Requirements

Context-Specific Interpretation

In LNG infrastructure, completeness of functional requirements means that the declared Infrastructure Quality Object has a sufficiently complete statement of what it is intended to accomplish within the LNG context.

Functional requirements should identify the intended LNG-context realization pathway and the principal functions needed to realize it.

Depending on the declared Infrastructure Quality Object, these functions may include gas receipt, treatment or conditioning where included, liquefaction, cryogenic storage, boil-off gas management, LNG transfer, loading, unloading, regasification, send-out, pressure control, thermal control, monitoring, safety functions, emergency functions, environmental protection functions, utility support, and interface functions.

Completeness should be interpreted in relation to the declared boundary.

A functional requirement set for a liquefaction facility will differ from a functional requirement set for a regasification terminal, storage facility, FSRU, satellite LNG facility, peak-shaving facility, or integrated LNG terminal.

Completeness does not require all LNG functions to be included in every declared Infrastructure Quality Object.

It requires that the functions relevant to the declared object, realization pathway, boundary, lifecycle condition, interfaces, Assumptions, and Infrastructure Quality Claim Statement are not omitted or hidden.

Illustrative Context-Specific Quality Outcome Criteria

Functional requirements for the declared LNG Infrastructure Quality Object may be considered complete when they identify, as applicable:

- the declared LNG-context realization pathway;
- the principal intended functions of the Infrastructure Quality Object;
- the operating modes relevant to the claim;
- the lifecycle condition to which the functional requirements apply;
- cryogenic, thermal, pressure, phase-transformation, and storage conditions where relevant;
- transfer, loading, unloading, regasification, send-out, and transportation-interface functions where relevant;
- boil-off gas management functions where relevant;
- monitoring, control, safety, emergency, utility, and supporting functions where relevant;
- environmental protection and public-consequence functions where relevant;
- boundaries and interfaces affecting realization of the intended function;
- Assumptions, exclusions, and limitations relevant to the functional intent;
- Critical Infrastructure Conditions that must remain visible for the functional intent to be credible.

Functional requirements should be sufficient to support development of technical specifications, Evidence interpretation, and bounded Infrastructure Quality Claim Statements.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- functional design basis documents;
- basis-of-design documents;
- functional requirement specifications;
- declared scope and boundary statements;
- operating philosophy documents;
- LNG pathway descriptions;
- process descriptions;
- interface requirement documents;
- safety philosophy documents;
- environmental basis documents;
- emergency-function descriptions;
- lifecycle-stage definitions;
- Assumptions and exclusions registers;
- Critical Infrastructure Conditions registers;
- Infrastructure Quality Claim Boundary statements.

4.2.2 Indicator 1.2 — Clarity and Unambiguity of Functional Intent

Context-Specific Interpretation

In LNG infrastructure, clarity and unambiguity of functional intent means that the intended function of the declared Infrastructure Quality Object is stated in a way that can be understood, traced, interpreted, and evaluated.

The functional intent should not be ambiguous as to whether the claim concerns a liquefaction facility, export terminal, import terminal, storage system, regasification facility, FSRU, floating LNG facility, satellite LNG facility, peak-shaving facility, transfer system, loading or unloading interface, integrated terminal, or another declared LNG Infrastructure Quality Object.

Functional intent should also avoid ambiguity about whether connected infrastructure is included within the declared object or only treated as an external interface.

In the LNG context, unclear functional intent may lead to misunderstanding of the claim boundary, under-recognition of interface conditions, inappropriate transfer of Assumptions, incomplete Evidence, or misleading Infrastructure Quality Claim Statements.

Clarity is especially important where one facility performs multiple functions or where responsibility is shared across operators, contractors, transportation systems, port systems, pipeline systems, emergency-response systems, or other connected infrastructure.

Illustrative Context-Specific Quality Outcome Criteria

Functional intent may be considered clear and unambiguous when:

- the declared Infrastructure Quality Object is named and bounded;
- the LNG-context realization pathway is identified;
- included and excluded functions are distinguishable;
- included and excluded interfaces are distinguishable;
- the lifecycle condition is stated;
- the intended operating modes are identifiable;
- terms such as storage, transfer, liquefaction, regasification, send-out, loading, unloading, and transportation support are used consistently;
- Assumptions about connected infrastructure are stated rather than implied;
- the functional intent can be traced into technical specifications and Evidence;
- the functional intent can support a bounded Infrastructure Quality Claim Statement without implying quality outside the declared boundary.

Functional intent should be sufficiently clear that different users of the Guide would not reasonably interpret the claim boundary or intended LNG function in materially different ways.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- declared Infrastructure Quality Object descriptions;
- functional-intent statements;
- boundary diagrams;
- interface maps;
- process-flow descriptions;
- operating-mode descriptions;
- lifecycle-condition statements;
- responsibility matrices;
- terminology lists;
- project scope documents;
- basis-of-design narratives;
- Infrastructure Quality Claim Statement draft statements;
- records of scope clarification or Assumption resolution.

4.2.3 Indicator 1.3 — Explicit Treatment of Functional Boundaries and Interfaces

Context-Specific Interpretation

In LNG infrastructure, functional boundaries and interfaces are central to understanding whether the intended function can be realized.

Functional boundaries identify what is included in the declared LNG Infrastructure Quality Object and what remains outside it.

Functional interfaces identify quality-relevant interactions across those boundaries.

Such interfaces may include upstream gas supply, gas processing, pipeline connection, cryogenic storage, boil-off gas management, LNG transfer, marine loading or unloading, truck or rail loading, regasification, gas send-out, downstream pipeline systems, local distribution systems, industrial users, electric-power systems, environmental systems, emergency-response systems, port systems, and surrounding communities.

Explicit treatment of functional boundaries and interfaces is necessary because LNG infrastructure often operates as part of a system-of-systems.

An Infrastructure Quality Claim Statement may be misleading if it does not distinguish the declared LNG Infrastructure Quality Object from connected infrastructure that affects its operation but is not included in the claim.

Illustrative Context-Specific Quality Outcome Criteria

Functional boundaries and interfaces may be considered explicitly treated when:

- the declared Infrastructure Quality Object boundary is stated;
- internal and external interfaces are identified where relevant;
- included and excluded interfaces are distinguished;
- functional dependencies on connected systems are identified;
- transportation interfaces are distinguished from transportation systems unless included in the declared object;
- upstream and downstream Assumptions are stated;
- interface responsibility is identifiable;
- lifecycle transition interfaces are recognized;
- interface-related Critical Infrastructure Conditions are identified where relevant;
- the Infrastructure Quality Claim Boundary does not imply unassessed quality beyond the declared boundary.

Functional boundaries and interfaces should be sufficiently clear to support technical specification, conformity assessment, Evidence interpretation, monitoring, documentation, and Infrastructure Quality Claim Statements.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- boundary statements;
- boundary diagrams;
- interface registers;
- interface-control documents;
- battery-limit descriptions;
- custody-transfer descriptions;

- process-interface descriptions;
- marine, truck, rail, or pipeline interface documents;
- responsibility matrices;
- operating agreements;
- emergency-response interface documents;
- environmental-interface documents;
- lifecycle-transition records;
- Infrastructure Quality Claim Statement scope statements.

4.2.4 Indicator 1.4 — Identification and Documentation of Functional Assumptions and Uncertainties

Context-Specific Interpretation

In LNG infrastructure, functional requirements often depend on Assumptions and Uncertainties related to gas supply, gas composition, operating modes, environmental conditions, transportation availability, downstream demand, connected-system behavior, technology configuration, lifecycle stage, and emergency-response capability.

Such Assumptions and Uncertainties should be identified and documented because they may affect whether the declared Infrastructure Quality Object can realize its intended function.

In the LNG context, functional Assumptions may involve inlet gas conditions, liquefaction conditions, storage duration, boil-off gas behavior, transfer frequency, loading or unloading conditions, regasification requirements, send-out pressure, gas-quality compatibility, transportation-interface conditions, environmental exposure, community consequence Assumptions, and availability of supporting utilities or emergency systems.

Uncertainty may also arise where infrastructure is brownfield, aging, modified, expanded, repurposed, floating, multi-operator, or dependent on external systems.

Unidentified Assumptions and Uncertainties may later appear as integrity problems, process-safety gaps, operational unreliability, environmental exposure, Evidence limitations, or invalid Infrastructure Quality Claim Statements.

Illustrative Context-Specific Quality Outcome Criteria

Functional Assumptions and Uncertainties may be considered adequately identified and documented when:

- Assumptions affecting the intended LNG function are stated;
- Uncertainties affecting the intended LNG function are stated;
- Assumptions about gas supply, gas composition, storage, transfer, regasification, send-out, transportation, utilities, environmental conditions, and emergency response are documented where relevant;
- Assumptions about connected infrastructure are distinguished from verified conditions;
- Uncertainties affecting Critical Infrastructure Conditions are identified;
- Assumptions and Uncertainties are traceable into technical specifications, Evidence interpretation, monitoring, and Infrastructure Quality Claim Statements;
- unresolved Assumptions or Uncertainties are not hidden by generalized statements of compliance, completion, capacity, or operational success.

Assumptions and Uncertainties should be maintained in a form that allows them to be revisited when lifecycle conditions, operating modes, boundaries, interfaces, or Infrastructure Quality Claim Statements change.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- Assumptions registers;
- Uncertainty registers;
- design-basis Assumptions;
- process-basis Assumptions;
- gas-composition Assumptions;
- operating-mode Assumptions;
- environmental-basis Assumptions;
- interface Assumptions;
- lifecycle-stage Assumptions;
- brownfield condition assessments;
- change records;
- risk studies;
- technical queries;
- unresolved-issue logs;
- Evidence-gap registers;
- Infrastructure Quality Claim Statement limitation statements.

4.2.5 Indicator 1.5 — Traceability of Functional Requirements Across the Lifecycle

Context-Specific Interpretation

In LNG infrastructure, functional requirements should remain traceable across the lifecycle of the declared Infrastructure Quality Object.

Traceability is important because functional intent may be weakened or lost as infrastructure moves from planning to design, construction, acceptance, commissioning, cooldown, first LNG introduction, operation, maintenance, modification, temporary shutdown, conservation, recommissioning, repurposing, or decommissioning.

Functional requirements should remain connected to technical specifications, conformity assessments, commissioning Evidence, operating Evidence, monitoring records, change records, and Infrastructure Quality Claim Statements.

In the LNG context, lifecycle traceability is especially important where cryogenic behavior, phase transformation, storage behavior, boil-off gas management, transfer conditions, regasification and send-out requirements, environmental interactions, and interface Assumptions become visible only during realized infrastructure behavior.

Loss of functional traceability may allow original Assumptions to drift, Unresolved Conditions to disappear, or Infrastructure Quality Claim Statements to exceed their Evidence basis.

Illustrative Context-Specific Quality Outcome Criteria

Functional requirements may be considered traceable across the lifecycle when:

- functional requirements can be traced from concept and design into technical specifications;
- functional requirements can be traced into construction, acceptance, commissioning, cooldown, operation, maintenance, and change Evidence where relevant;
- functional requirements remain connected to declared boundaries and interfaces;
- functional requirements remain connected to Assumptions and Uncertainties;

- functional requirements remain connected to Critical Infrastructure Conditions;
- lifecycle transitions do not obscure unresolved functional issues;
- changes in operating mode, boundary, interface, or lifecycle condition trigger review of relevant functional requirements;
- Infrastructure Quality Claim Statements identify the lifecycle condition and Evidence basis supporting the stated functional interpretation.

Traceability should be sufficient to show whether the declared LNG Infrastructure Quality Object continues to realize the intended function within the applicable lifecycle condition.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- requirements traceability matrices;
- design-basis-to-specification traceability;
- commissioning traceability records;
- cooldown records;
- first LNG introduction records;
- operating records;
- maintenance and inspection records;
- monitoring records;
- management-of-change records;
- lifecycle transition records;
- unresolved finding logs;
- Assumption tracking records;
- Critical Infrastructure Conditions tracking records;
- Infrastructure Quality Claim Statement Evidence files.

4.2.6 Indicator 1.6 — Functional Changes

Context-Specific Interpretation

Functional Changes concern changes that affect the intended function, functional boundary, realization pathway, operating mode, lifecycle condition, or interface Assumptions of the declared LNG Infrastructure Quality Object.

In LNG infrastructure, functional changes may arise from expansion, debottlenecking, added storage, changed liquefaction operation, changed regasification or send-out requirements, changed transfer mode, added marine or truck loading, changed gas supply, changed gas composition, changed downstream demand, changed boil-off gas strategy, changed operating philosophy, changed environmental Assumptions, changed emergency-response arrangements, or repurposing of infrastructure.

Functional changes may also arise when a facility originally designed for one pathway is later used differently, such as a storage-focused facility becoming part of a broader terminal operation, or an import terminal adding export or reload functions.

Functional changes should be evaluated because they may affect technical specifications, integrity Assumptions, process safety, environmental protection, operational reliability, competence needs, monitoring coverage, documentation, and Infrastructure Quality Claim Statement validity.

Illustrative Context-Specific Quality Outcome Criteria

Functional changes may be considered adequately addressed when:

- functional changes are identified and documented;
- the affected Infrastructure Quality Object boundary is reviewed;
- the affected LNG-context realization pathway is reviewed;
- included and excluded interfaces are reviewed;
- Assumptions and Uncertainties are updated;
- Critical Infrastructure Conditions are reviewed;
- technical specifications and conformity assessments are reviewed where relevant;
- lifecycle condition and Evidence basis are updated;
- monitoring, documentation, competence, and emergency-response implications are considered where relevant;
- Infrastructure Quality Claim Statements are revised, limited, withdrawn, or re-evidenced where the functional change affects claim validity.

Functional changes should not be treated only as administrative, operational, or commercial changes where they alter the realization of the invariant Core intended function.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- management-of-change records;
- functional change requests;
- revised functional requirements;
- scope revision records;
- operating philosophy revisions;
- interface revision records;
- gas-supply or gas-composition change records;
- storage or transfer change records;
- regasification or send-out change records;
- environmental change assessments;
- emergency-response revision records;
- technical specification revisions;
- conformity reassessment records;
- updated Assumptions and Uncertainty registers;
- revised Infrastructure Quality Claim Statements.

4.3 Factor 2 — Technical Specification Quality

Purpose of the Factor

The authoritative IQC1 purpose is:

To ensure that Technical Specifications correctly, completely, and coherently translate Functional Requirements into realizable and examinable Technical Requirements that remain valid across the Lifecycle of the declared Infrastructure Quality Object.

Core architecture role: Examines whether functional intent has been translated into a coherent technical basis suitable for realization and lifecycle use.

Definitions and Governing Terms

Governing terms. Functional Specification, Functional Requirement, Operating Envelope, and Infrastructure Configuration apply with the meanings established under Factor 1 or IQI_VOC1, as applicable.

IQC1 Factor-specific terms. Technical Specification, Technical Requirement, Functional-to-Technical Translation, Technical Basis, and Technical Specification Change apply as defined in IQI_IQC1 and are not redefined in LNG1.

LNG1 context terms and anchors. feed-gas, conditioning, liquefaction, refrigeration, cryogenic material, insulation, storage-tank, containment, boil-off gas, vapor-return, pressure-relief, transfer, loading-arm, hose, berth, regasification, vaporizer, metering, gas-quality, MNT1 receipt and send-out, utility, control, shutdown, fire-and-gas, environmental-protection, and bulk-transport Interface specifications. Their technical meaning, values, methods, and acceptance conditions depend on the declared Infrastructure Quality Object, applicable Context-Specific Quality Outcome Criteria, and the Reference Layer.

Context-specific boundary. Design values, numerical limits, tolerances, safety factors, material requirements, and acceptance criteria depend on the asset, technology, lifecycle condition, and Reference Layer and therefore remain outside the universal Core definitions.

Context-Specific Interpretation

Technical Specification Quality concerns the quality of the translation from functional intent into technical requirements for the declared LNG Infrastructure Quality Object.

In the LNG context, technical specifications should define the technical conditions necessary to realize the declared LNG-context realization pathway within the stated boundary, interfaces, lifecycle condition, Assumptions, limitations, and Critical Infrastructure Conditions.

Technical specifications may address, where relevant, cryogenic containment, materials, insulation, thermal behavior, pressure control, liquefaction systems, storage systems, boil-off gas management, transfer systems, loading and unloading systems, regasification systems, send-out systems, utilities, monitoring, control, safety, emergency systems, environmental protection, and connected-interface conditions.

Technical Specification Quality is not demonstrated merely by the existence of design documents, equipment specifications, drawings, calculations, vendor documentation, or references to codes and standards.

It depends on whether those technical specifications are complete, correct, coherent, traceable to functional requirements, aligned with lifecycle conditions, explicit about Assumptions and Uncertainties, and controlled when technical changes occur.

In LNG infrastructure, technical specification quality is especially important because cryogenic behavior, phase transformation, thermal stress, pressure control, boil-off gas behavior, transfer compatibility, regasification and send-out compatibility, environmental interaction, and emergency isolation may strongly affect infrastructure behavior and Infrastructure Quality Claim Statement validity.

Technical specifications shall distinguish midstream LNG terminal and bulk-transfer functions from downstream automotive LNG dispensing. Requirements for vehicle fueling equipment, retail or fleet dispensing, and public fuel-station operation are outside LNG1 unless only their external transfer Interface is being examined.

Core Quality Indicators

The following Core Quality Indicator titles are invariant and governed by IQI_IQC1. The clauses under each Indicator provide LNG1 Context-Specific Interpretation, illustrative Context-Specific Quality Outcome Criteria, and Evidence considerations; they do not reproduce or replace the normative Core Indicator Statement.

4.3.1 Indicator 2.1 — Completeness of Technical Specifications

Context-Specific Interpretation

In LNG infrastructure, completeness of technical specifications means that the technical requirements necessary to realize the declared functional intent are sufficiently identified for the declared Infrastructure Quality Object.

Technical specifications should address the systems, interfaces, operating conditions, lifecycle conditions, Assumptions, and Critical Infrastructure Conditions relevant to the declared LNG-context realization pathway.

Completeness should be interpreted in relation to the declared boundary.

A technical specification set for a liquefaction facility will differ from one for a regasification terminal, LNG storage facility, FSRU, satellite LNG facility, peak-shaving facility, transfer system, or integrated LNG terminal.

Completeness does not require every possible LNG technical requirement to be included in every case.

It requires that technical requirements relevant to the declared object, realization pathway, lifecycle condition, interfaces, Assumptions, Evidence basis, and Infrastructure Quality Claim Statement are not omitted or obscured.

Illustrative Context-Specific Quality Outcome Criteria

Technical specifications for the declared LNG Infrastructure Quality Object may be considered complete when they address, as applicable:

- the declared LNG-context realization pathway;
- process and system requirements needed to realize the functional intent;
- cryogenic, thermal, pressure, phase-transformation, and containment requirements;
- storage, boil-off gas management, transfer, loading, unloading, regasification, and send-out requirements where relevant;
- material, insulation, equipment, instrumentation, control, monitoring, safety, emergency, utility, and supporting-system requirements where relevant;
- environmental protection and emissions-related technical requirements where relevant;
- internal and external interface requirements;
- lifecycle-stage requirements, including commissioning, cooldown, operation, modification, temporary shutdown, recommissioning, repurposing, or decommissioning where relevant;
- technical Assumptions, exclusions, limitations, and unresolved conditions;
- Critical Infrastructure Conditions that require technical definition or control.

Technical specification completeness should be sufficient to support conformity assessment, integrity interpretation, process-safety interpretation, operational reliability, monitoring, Evidence interpretation, and bounded Infrastructure Quality Claim Statements.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- technical specifications;
- design-basis documents;
- process design documents;
- equipment specifications;
- material specifications;
- piping and instrumentation diagrams;

- process-flow diagrams;
- control and safety-system specifications;
- storage-system specifications;
- boil-off gas management specifications;
- transfer, loading, and unloading specifications;
- regasification and send-out specifications;
- interface-control documents;
- environmental-control specifications;
- monitoring and instrumentation specifications;
- commissioning and cooldown specifications;
- technical Assumptions registers;
- Critical Infrastructure Conditions registers.

4.3.2 Indicator 2.2 — Correctness and Unambiguity of Translation from Functional to Technical Requirements

Context-Specific Interpretation

In LNG infrastructure, technical specifications should correctly and unambiguously translate functional requirements into technical requirements.

The technical requirements should correspond to the declared LNG Infrastructure Quality Object, the declared LNG-context realization pathway, the applicable lifecycle condition, and the intended Infrastructure Quality Claim Boundary.

Incorrect or ambiguous translation may occur where the functional intent is broad but the technical specifications address only selected equipment, selected systems, selected lifecycle stages, or selected interfaces.

It may also occur where LNG-specific conditions such as cryogenic operation, phase transformation, thermal behavior, boil-off gas management, transfer compatibility, emergency isolation, environmental interaction, or downstream send-out compatibility are not clearly translated into technical requirements.

Correct translation does not mean that the Context Guide prescribes specific engineering solutions.

It means that the technical specification set should be demonstrably aligned with the declared functional intent and should not leave material gaps between what the infrastructure is intended to do and what the technical requirements define.

Illustrative Context-Specific Quality Outcome Criteria

Translation from functional to technical requirements may be considered correct and unambiguous when:

- each principal functional requirement has corresponding technical requirements where needed;
- the technical requirements are consistent with the declared Infrastructure Quality Object;
- the technical requirements are consistent with the LNG-context realization pathway;
- technical requirements identify relevant boundaries and interfaces;
- cryogenic, thermal, pressure, phase-transformation, storage, transfer, boil-off gas, regasification, send-out, safety, emergency, and environmental conditions are translated where relevant;
- Assumptions about connected systems are translated into interface requirements where relevant;
- technical terms are used consistently;
- technical requirements can be traced back to functional requirements;

- technical requirements do not imply inclusion of systems outside the declared boundary unless explicitly included;
- technical requirements can support a bounded Infrastructure Quality Claim Statement without ambiguity.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- functional-to-technical traceability matrices;
- design-basis crosswalks;
- requirement allocation records;
- interface requirement allocation records;
- process design narratives;
- technical basis memoranda;
- engineering design reviews;
- technical clarification records;
- design verification records;
- specification review records;
- technical deviation records;
- Assumption resolution records;
- Infrastructure Quality Claim Statement Evidence mapping.

4.3.3 Indicator 2.3 — Internal Consistency and Coherence of Technical Specifications

Context-Specific Interpretation

In LNG infrastructure, technical specifications should be internally consistent and coherent across systems, disciplines, interfaces, lifecycle stages, and Evidence sources.

LNG infrastructure often involves multiple technical domains, including process engineering, cryogenic systems, storage, piping, materials, civil and structural systems, electrical systems, instrumentation and control, safety systems, emergency systems, environmental controls, marine interfaces, transportation interfaces, and downstream gas systems.

Inconsistency between technical specifications may create quality-relevant gaps even when individual specifications appear complete.

For example, inconsistency may occur between process Assumptions and storage design, between gas composition Assumptions and liquefaction or regasification requirements, between transfer-system limits and transportation-interface conditions, between emergency-isolation requirements and operating procedures, or between monitoring specifications and Critical Infrastructure Conditions.

Technical coherence means that the specifications work together to support the behavior of the declared Infrastructure Quality Object as an integrated infrastructure asset or system.

Illustrative Context-Specific Quality Outcome Criteria

Technical specifications may be considered internally consistent and coherent when:

- technical requirements do not conflict across systems, disciplines, or interfaces;
- Assumptions are consistent across functional, process, mechanical, electrical, instrumentation, control, safety, environmental, and interface specifications;
- operating modes are consistently addressed across relevant specifications;

- lifecycle conditions are consistently addressed across relevant specifications;
- cryogenic, thermal, pressure, phase-transformation, storage, transfer, boil-off gas, regasification, and send-out conditions are coherently integrated where relevant;
- interface specifications are consistent with system specifications;
- safety, emergency, monitoring, and environmental specifications are aligned with the technical basis;
- technical specifications can be interpreted together as a coherent basis for infrastructure behavior and Infrastructure Quality Claim Statements.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- interdisciplinary design reviews;
- specification consistency reviews;
- design coordination records;
- interface coordination records;
- hazard-study action closeout records;
- technical query logs;
- deviation and concession logs;
- model review records;
- design-change records;
- process, mechanical, control, safety, and environmental cross-discipline reviews;
- commissioning readiness reviews;
- integrated system test records;
- unresolved interface issue logs.

4.3.4 Indicator 2.4 — Explicit Treatment of Technical Assumptions and Uncertainties

Context-Specific Interpretation

Technical specifications for LNG infrastructure often depend on Assumptions and Uncertainties that affect infrastructure behavior.

Such Assumptions may involve gas composition, feed-gas conditions, LNG composition, storage duration, ambient conditions, marine or transportation conditions, transfer rates, send-out requirements, pressure conditions, environmental exposure, utility availability, emergency-response capability, operating modes, lifecycle condition, equipment condition, or connected-system behavior.

Uncertainty may arise from incomplete information, changing operating conditions, brownfield constraints, aging infrastructure, modified infrastructure, multi-operator interfaces, emerging environmental conditions, evolving regulatory expectations, or limited monitoring visibility.

Technical Assumptions and Uncertainties should be explicit because they may affect integrity, process safety, environmental protection, operational reliability, monitoring interpretation, and Infrastructure Quality Claim Statement validity.

Unstated Assumptions may later be mistaken for verified conditions.

Illustrative Context-Specific Quality Outcome Criteria

Technical Assumptions and Uncertainties may be considered adequately treated when:

- technical Assumptions affecting infrastructure behavior are identified;

- technical Uncertainties affecting infrastructure behavior are identified;
- Assumptions about gas composition, cryogenic behavior, storage behavior, transfer conditions, regasification, send-out, environmental exposure, utilities, transportation interfaces, and connected infrastructure are stated where relevant;
- Uncertainties affecting Critical Infrastructure Conditions are identified;
- Assumptions and Uncertainties are traceable to functional requirements and technical specifications;
- unresolved Uncertainties are carried into conformity assessment, monitoring, documentation, and Infrastructure Quality Claim Statements where relevant;
- technical specifications distinguish verified conditions from Assumptions;
- Assumptions are reviewed when lifecycle conditions, boundaries, interfaces, operating modes, or Infrastructure Quality Claim Statements change.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- technical Assumptions registers;
- Uncertainty registers;
- design-basis Assumptions;
- gas-composition Assumptions;
- environmental design-basis records;
- operating-mode Assumptions;
- interface Assumptions;
- brownfield condition assessments;
- risk and hazard studies;
- technical queries;
- unresolved issue logs;
- Evidence-gap registers;
- management-of-change records;
- Assumption verification records;
- Infrastructure Quality Claim Statement limitation statements.

4.3.5 Indicator 2.5 — Alignment of Technical Specifications with Lifecycle Conditions

Context-Specific Interpretation

Technical specifications should be aligned with the lifecycle condition to which they apply.

In LNG infrastructure, the relevant technical conditions may differ during design, construction, acceptance, commissioning, cooldown, first LNG introduction, operation, maintenance, modification, expansion, temporary shutdown, conservation, recommissioning, repurposing, decommissioning, and post-operation residual conditions.

Technical requirements suitable for one lifecycle stage should not be assumed sufficient for another lifecycle stage without Evidence.

For example, design specifications may not by themselves demonstrate operational behavior.

Commissioning specifications may not by themselves demonstrate long-term reliability.

Operation specifications may not by themselves address temporary shutdown, recommissioning, repurposing, or decommissioning.

Lifecycle alignment is especially important where cryogenic behavior, thermal cycling, material condition, insulation condition, boil-off gas behavior, transfer compatibility, regasification and send-out behavior, monitoring capability, environmental exposure, or emergency readiness changes over time.

Illustrative Context-Specific Quality Outcome Criteria

Technical specifications may be considered aligned with lifecycle conditions when:

- the applicable lifecycle condition is stated;
- technical requirements are appropriate to the lifecycle condition being interpreted;
- commissioning, cooldown, first LNG introduction, operation, maintenance, modification, shutdown, recommissioning, repurposing, and decommissioning requirements are addressed where relevant;
- lifecycle transitions are recognized as quality-relevant interfaces;
- technical Assumptions are reviewed when lifecycle conditions change;
- Evidence requirements are aligned with the lifecycle condition;
- unresolved technical conditions are carried forward across lifecycle transitions where relevant;
- Infrastructure Quality Claim Statements identify the lifecycle condition supported by the technical Evidence.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- lifecycle-stage specifications;
- commissioning plans and records;
- cooldown procedures and records;
- first LNG introduction records;
- operating procedures;
- inspection and maintenance requirements;
- modification specifications;
- shutdown and conservation plans;
- recommissioning plans;
- repurposing assessments;
- decommissioning plans;
- lifecycle transition reviews;
- management-of-change records;
- technical closeout records;
- Infrastructure Quality Claim Statement lifecycle statements.

4.3.6 Indicator 2.6 — Traceability of Technical Specifications to Functional Requirements

Context-Specific Interpretation

Technical specifications should remain traceable to the functional requirements they are intended to realize.

In LNG infrastructure, traceability is necessary because technical requirements may be distributed across many documents, disciplines, contractors, vendors, lifecycle stages, and interface arrangements.

Without traceability, technical specifications may appear complete but fail to support the declared functional intent or the bounded Infrastructure Quality Claim Statement.

Traceability should connect the declared functional intent to technical requirements for relevant systems, interfaces, lifecycle conditions, Assumptions, Critical Infrastructure Conditions, Evidence, and Infrastructure Quality Claim Statements.

In the LNG context, traceability is important for cryogenic containment, phase transformation, thermal control, pressure control, storage, boil-off gas management, transfer, loading, unloading, regasification, send-out, monitoring, emergency functions, environmental protection, and connected-interface conditions.

Illustrative Context-Specific Quality Outcome Criteria

Technical specifications may be considered traceable to functional requirements when:

- technical requirements can be linked to corresponding functional requirements;
- technical requirements can be linked to the declared Infrastructure Quality Object and realization pathway;
- technical requirements can be linked to relevant boundaries and interfaces;
- technical requirements can be linked to Assumptions, Uncertainties, and Critical Infrastructure Conditions;
- technical requirements can be linked to lifecycle conditions;
- technical requirements can be linked to conformity assessment and Evidence where relevant;
- technical requirements can be linked to Infrastructure Quality Claim Statement scope and limitations where relevant;
- traceability is maintained when technical specifications change.

Traceability should be sufficient to show why a technical requirement exists, what functional requirement it supports, and whether it remains valid under the applicable lifecycle condition.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- requirements traceability matrices;
- functional-to-technical mapping;
- design-basis traceability;
- interface traceability records;
- equipment and system requirement allocations;
- safety requirement allocations;
- environmental requirement allocations;
- monitoring requirement allocations;
- commissioning requirement mapping;
- management-of-change records;
- vendor document registers;
- technical closeout records;
- Infrastructure Quality Claim Statement Evidence mapping.

4.3.7 Indicator 2.7 — Technical Specification Changes

Context-Specific Interpretation

Technical Specification Changes concern changes that affect the technical requirements of the declared LNG Infrastructure Quality Object.

In LNG infrastructure, technical changes may involve process configuration, equipment, materials, storage capacity, insulation, piping, transfer systems, loading or unloading systems, boil-off gas management, regasification systems, send-out systems, monitoring systems, control systems, safety systems, emergency systems, environmental controls, utilities, interfaces, or lifecycle Assumptions.

Technical changes may also arise from functional changes, regulatory changes, operating experience, aging, degradation, repairs, brownfield constraints, technology updates, environmental changes, or innovation.

Technical changes should be evaluated because they may affect integrity, process safety, environmental protection, operational reliability, competence, monitoring, documentation, Evidence sufficiency, and Infrastructure Quality Claim Statement validity.

A technical change should not be treated as minor merely because it is local, administrative, vendor-driven, or document-based.

Its significance depends on its effect on the declared Infrastructure Quality Object, boundaries, interfaces, lifecycle condition, Critical Infrastructure Conditions, and Infrastructure Quality Claim Statement.

Illustrative Context-Specific Quality Outcome Criteria

Technical specification changes may be considered adequately addressed when:

- technical changes are identified and documented;
- affected functional requirements are reviewed;
- affected boundaries and interfaces are reviewed;
- affected lifecycle conditions are reviewed;
- affected Assumptions and Uncertainties are updated;
- affected Critical Infrastructure Conditions are reviewed;
- conformity assessment implications are considered;
- integrity, process-safety, environmental, operational, monitoring, competence, and documentation implications are considered where relevant;
- technical traceability is preserved;
- Evidence is updated where necessary;
- Infrastructure Quality Claim Statements are revised, limited, withdrawn, or re-evidenced where the technical change affects claim validity.

Technical changes should be controlled in proportion to their potential effect on infrastructure behavior and Infrastructure Quality Claim Statement validity.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- management-of-change records;
- engineering change requests;
- technical specification revisions;
- design-change records;
- deviation and concession records;
- revised calculations;
- revised drawings;
- revised interface documents;
- vendor change notices;
- construction change records;
- commissioning change records;
- operating procedure revisions;

- risk and hazard reassessment records;
- environmental reassessment records;
- updated Assumptions registers;
- updated traceability matrices;
- revised Infrastructure Quality Claim Statements.

4.4 Factor 3 — Conformity Assessment

Purpose of the Factor

The authoritative IQC1 purpose is:

To ensure that the condition of the declared Infrastructure Quality Object and its alignment with Functional Intent and Technical Requirements are sufficiently examined and evidenced so that Conformity Findings and Conformity Statements reflect the identified Basis for Conformity Assessment rather than Assumption or unsupported assertion.

Core architecture role: Provides the demonstrability bridge between declared requirements and Evidence-Supported Findings about the realized Infrastructure Quality Object.

Definitions and Governing Terms

Governing WQI and IQI terms. Evidence, Evidence Sufficiency, Evidence-Supported Finding, Unresolved Condition, Quality State Determination, Quality Claim, and Infrastructure Quality Claim Statement apply with their authoritative WQI_VOC1 and IQI_VOC1 meanings.

IQC1 Factor-specific terms. Conformity, Conformity Assessment, Basis for Conformity Assessment, Conformity Finding, Conformity Statement, Non-Conformity, Assessment Limitation, Risk-Proportionate Assessment Depth, and Independence and Objectivity apply as defined in IQI_IQC1 and are not redefined in LNG1.

LNG1 context terms and anchors. material, fabrication, welding, insulation, tank, containment, piping, pressure-equipment, process-train, refrigeration, transfer, loading, unloading, regasification, MNT1 Interface, utility, instrumentation, control, shutdown, fire-and-gas, Commissioning, cooldown, first-fill, and operating conformity; treatment of Non-Conformity and Unresolved Conditions; and traceability of Conformity Statements. Their technical meaning, values, methods, and acceptance conditions depend on the declared Infrastructure Quality Object, applicable Context-Specific Quality Outcome Criteria, and the Reference Layer.

Context-specific boundary. Inspection, testing, verification, validation, sampling, assurance levels, certification, and audit methods are established by this Guide or the applicable Reference Layer. IQC1 does not prescribe universal methods.

Context-Specific Interpretation

Conformity Assessment concerns the quality of assessment activities used to determine whether the declared LNG Infrastructure Quality Object conforms to defined technical specifications and whether those specifications remain consistent with the declared functional intent.

In the LNG context, conformity assessment may involve design review, engineering verification, material verification, fabrication inspection, construction inspection, testing, commissioning, cooldown verification, operational readiness review, functional testing, interface verification, safety-system testing, environmental-control verification, monitoring-system verification, and review of lifecycle or change-related Evidence.

Conformity Assessment under this Guide should not be interpreted as a substitute for infrastructure quality itself.

A conformity assessment may provide Evidence that specified requirements have been met.

However, it does not by itself demonstrate that the declared LNG Infrastructure Quality Object realizes the invariant Core intended function across all relevant boundaries, interfaces, lifecycle conditions, Critical Infrastructure Conditions, Assumptions, limitations, and Evidence gaps.

In LNG infrastructure, conformity assessment should remain connected to the declared Infrastructure Quality Object, the declared LNG-context realization pathway, the technical specifications, the functional requirements, the applicable lifecycle condition, and the intended scope of any Infrastructure Quality Claim Statement.

Conformity findings at an MNT1 Interface, carrier Interface, or bulk road or rail transfer Interface support LNG1 interpretation only within the declared Boundary. They do not establish the Quality State of MNT1, the carrier, or LNGFS1.

Core Quality Indicators

The following Core Quality Indicator titles are invariant and governed by IQI_IQC1. The clauses under each Indicator provide LNG1 Context-Specific Interpretation, illustrative Context-Specific Quality Outcome Criteria, and Evidence considerations; they do not reproduce or replace the normative Core Indicator Statement.

4.4.1 Indicator 3.1 — Defined Basis for Conformity Assessment

Context-Specific Interpretation

In LNG infrastructure, conformity assessment should have a defined basis.

The basis for assessment should identify what is being assessed, against what requirements, within what boundary, at what lifecycle stage, using what Evidence, and for what purpose.

The assessment basis may include technical specifications, functional requirements, design-basis documents, engineering standards, regulatory requirements, project specifications, operator requirements, safety requirements, environmental requirements, interface requirements, commissioning requirements, operating requirements, or other defined criteria.

The basis should be appropriate to the declared LNG Infrastructure Quality Object and the declared LNG-context realization pathway.

A conformity assessment basis for a liquefaction facility may differ from one for an LNG storage facility, regasification terminal, FSRU, transfer system, loading or unloading system, satellite LNG facility, peak-shaving facility, or integrated LNG terminal.

A defined assessment basis is necessary to avoid general or misleading statements that infrastructure is “acceptable,” “approved,” “complete,” “compliant,” or “ready” without identifying the specific requirements, boundaries, lifecycle condition, and Evidence basis supporting that conclusion.

Illustrative Context-Specific Quality Outcome Criteria

The basis for conformity assessment may be considered adequately defined when:

- the declared Infrastructure Quality Object is identified;
- the LNG-context realization pathway is identified;
- the applicable lifecycle condition is identified;
- the technical specifications or other assessment criteria are identified;
- relevant functional requirements are linked to the assessment basis;
- relevant boundaries and interfaces are identified;
- included and excluded systems, interfaces, and lifecycle conditions are distinguishable;

- applicable Assumptions and limitations are stated;
- Critical Infrastructure Conditions requiring assessment are identified where relevant;
- the Evidence needed to support the assessment is defined;
- the intended use of the conformity assessment result is clear.

The assessment basis should be sufficiently specific to support traceable, repeatable, and bounded interpretation of conformity.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- conformity assessment plans;
- inspection and test plans;
- design verification plans;
- commissioning plans;
- cooldown verification plans;
- acceptance criteria;
- technical specification cross-references;
- regulatory and standards matrices;
- interface assessment plans;
- safety-system test plans;
- environmental-control verification plans;
- quality control plans;
- assessment scope statements;
- assessment boundary statements;
- lifecycle-stage assessment records;
- Infrastructure Quality Claim Statement Evidence plans.

4.4.2 Indicator 3.2 — Assessment of Conformity to Technical Specifications

Context-Specific Interpretation

In LNG infrastructure, assessment of conformity to technical specifications means determining whether the declared Infrastructure Quality Object, or relevant parts of it, conforms to defined technical requirements.

This assessment may concern materials, equipment, process systems, cryogenic containment, insulation, piping, storage systems, boil-off gas management systems, transfer systems, loading or unloading systems, regasification systems, send-out systems, monitoring systems, control systems, safety systems, emergency systems, environmental controls, utilities, and interface systems where relevant.

Assessment should be interpreted within the declared boundary and lifecycle condition.

Conformity of individual components does not automatically demonstrate conformity of the assembled Infrastructure Quality Object.

Similarly, conformity during construction does not automatically demonstrate conformity during commissioning, cooldown, operation, modification, recommissioning, or decommissioning.

In the LNG context, assessment should consider whether technical specifications have been met in a way that supports integrated infrastructure behavior, including cryogenic behavior, phase-transformation behavior, transfer compatibility, pressure control, thermal stability, environmental protection, and emergency readiness where relevant.

Illustrative Context-Specific Quality Outcome Criteria

Assessment of conformity to technical specifications may be considered adequate when:

- relevant technical specifications are identified;
- assessment methods are appropriate to the technical requirement being assessed;
- assessment covers relevant systems, interfaces, and lifecycle conditions within the declared boundary;
- component conformity is distinguished from integrated asset or system conformity;
- LNG-specific technical conditions are assessed where relevant, including cryogenic, thermal, pressure, storage, transfer, boil-off gas, regasification, send-out, monitoring, safety, emergency, and environmental conditions;
- assessment results are documented and traceable;
- deviations, exceptions, limitations, and Unresolved Conditions are identified;
- assessment Evidence is sufficient to support the intended Infrastructure Quality Claim Boundary;
- the assessment does not imply conformity beyond the Evidence basis.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- inspection records;
- test records;
- material certificates;
- equipment conformity records;
- fabrication inspection records;
- construction inspection records;
- non-destructive examination records;
- pressure test records;
- insulation inspection records;
- storage-system test records;
- boil-off gas system test records;
- transfer-system test records;
- loading and unloading test records;
- regasification and send-out test records;
- instrumentation and control test records;
- safety-system test records;
- emergency shutdown and isolation test records;
- environmental-control verification records;
- commissioning and cooldown records;
- punch-list and closeout records.

4.4.3 Indicator 3.3 — Assessment of Continued Consistency Between Technical and Functional Specifications

Context-Specific Interpretation

In LNG infrastructure, conformity assessment should not stop at checking technical specifications in isolation.

It should also consider whether technical specifications remain consistent with the declared functional requirements.

Technical requirements may conform to a specification while the specification itself may no longer fully support the declared functional intent because of changed Assumptions, changed operating modes, changed gas supply, changed gas composition, changed storage use, changed transfer conditions, changed regasification or send-out requirements, changed environmental exposure, changed interfaces, or changed lifecycle condition.

Continued consistency is especially important where LNG infrastructure is modified, expanded, debottlenecked, repurposed, operated under changed conditions, or connected to new upstream, downstream, marine, truck, rail, or pipeline interfaces.

Assessment should therefore consider whether technical requirements continue to support the declared LNG-context realization pathway and whether the functional intent remains traceable through technical specifications, Evidence, lifecycle transitions, and Infrastructure Quality Claim Statements.

Illustrative Context-Specific Quality Outcome Criteria

Assessment of continued consistency between technical and functional specifications may be considered adequate when:

- technical specifications are checked against the declared functional requirements;
- the declared Infrastructure Quality Object and realization pathway remain aligned with the technical basis;
- boundaries and interfaces remain consistent with functional intent;
- lifecycle conditions remain consistent with functional intent;
- Assumptions and Uncertainties are reviewed for continuing validity;
- changes in gas supply, gas composition, storage use, transfer mode, regasification, send-out, operating mode, environmental exposure, or connected infrastructure are considered where relevant;
- technical conformity findings do not obscure functional mismatch;
- unresolved inconsistencies are documented and carried into Evidence interpretation and Infrastructure Quality Claim Statements;
- Infrastructure Quality Claim Statements are revised, limited, withdrawn, or re-evidenced where consistency is not demonstrated.

Continued consistency should be assessed when material changes occur and when the Evidence basis for an Infrastructure Quality Claim Statement depends on alignment between functional and technical specifications.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- functional-to-technical consistency reviews;
- requirements traceability reviews;
- design-basis validation records;
- operating-basis validation records;
- management-of-change reviews;
- interface consistency reviews;
- gas-composition change assessments;
- storage-use change assessments;
- transfer-mode change assessments;
- regasification or send-out change assessments;
- lifecycle transition reviews;
- commissioning closeout reviews;

- operational readiness reviews;
- unresolved inconsistency logs;
- Infrastructure Quality Claim Statement review records.

4.4.4 Indicator 3.4 — Risk-Proportionate Depth of Conformity Assessment

Context-Specific Interpretation

In LNG infrastructure, the depth of conformity assessment should be proportionate to the quality significance of the item, system, interface, lifecycle condition, or Critical Infrastructure Condition being assessed.

Not all elements require the same depth of assessment.

However, where failure, degradation, Uncertainty, or loss of visibility may compromise the intended function, create unacceptable risk, affect environmental protection, disrupt operational reliability, or invalidate an Infrastructure Quality Claim Statement, the assessment should be deeper, more explicit, and more traceable.

Risk-proportionate assessment is especially important for LNG-context conditions involving cryogenic containment, pressure control, thermal management, storage integrity, boil-off gas management, transfer interfaces, loading and unloading, emergency shutdown and isolation, regasification and send-out, gas-quality compatibility, environmental exposure, monitoring limitations, and lifecycle transitions.

A superficial assessment may be insufficient where the relevant condition is critical to infrastructure behavior or Infrastructure Quality Claim Statement validity.

Illustrative Context-Specific Quality Outcome Criteria

The depth of conformity assessment may be considered risk-proportionate when:

- assessment depth reflects the quality significance of the requirement being assessed;
- Critical Infrastructure Conditions receive appropriate assessment depth;
- interfaces with high consequence or high Uncertainty receive appropriate assessment depth;
- lifecycle transitions receive assessment depth appropriate to their effect on infrastructure behavior;
- cryogenic, thermal, pressure, transfer, storage, boil-off gas, regasification, send-out, safety, emergency, environmental, and monitoring conditions receive depth appropriate to their significance;
- the assessment basis distinguishes routine checks from quality-critical assessments;
- Evidence sufficiency is evaluated in relation to consequence, Uncertainty, and claim scope;
- unresolved limitations are documented rather than hidden by general statements of conformity.

Risk-proportionate depth does not mean excessive assessment of every item.

It means assessment depth is aligned with the possible effect of the condition on realization of the intended function and the validity of the Infrastructure Quality Claim Statement.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- risk-based inspection and test plans;
- criticality assessments;
- hazard and operability studies;
- layers-of-protection studies;
- safety integrity assessments;
- quality-critical item lists;

- Critical Infrastructure Conditions registers;
- interface criticality reviews;
- commissioning criticality reviews;
- environmental consequence assessments;
- emergency-system verification records;
- monitoring-coverage assessments;
- lifecycle transition risk reviews;
- Evidence sufficiency reviews;
- Infrastructure Quality Claim Statement limitation records.

4.4.5 Indicator 3.5 — Independence and Objectivity of Conformity Assessment

Context-Specific Interpretation

In LNG infrastructure, conformity assessment should be sufficiently independent and objective for the intended purpose of the assessment and the Infrastructure Quality Claim Statement it may support.

Independence and objectivity do not require the same structure in all cases.

The needed degree of independence depends on the significance of the assessment, the consequence of failure, the level of Uncertainty, the role of the assessor, the lifecycle condition, the Critical Infrastructure Conditions involved, and the intended use of the assessment result.

For LNG infrastructure, objectivity may be especially important where conformity assessment concerns cryogenic containment, process safety, emergency shutdown and isolation, transfer interfaces, storage integrity, boil-off gas management, regasification and send-out compatibility, environmental protection, or Unresolved Conditions.

Assessment results may be weakened where the assessor lacks technical competence, lacks access to Evidence, has a conflict of interest, relies only on documentation without sufficient verification, or cannot distinguish component conformity from integrated infrastructure behavior.

Illustrative Context-Specific Quality Outcome Criteria

Independence and objectivity of conformity assessment may be considered adequate when:

- the assessor role and responsibility are defined;
- assessor competence is appropriate to the assessment scope;
- conflicts of interest are identified and controlled where relevant;
- assessment criteria are defined before or during the assessment rather than invented after the result;
- Evidence is evaluated against defined requirements;
- limitations in Evidence access are documented;
- judgments are traceable;
- findings, deviations, and unresolved conditions are not suppressed;
- the level of independence is proportionate to the quality significance of the assessment;
- the assessment result is not used to support claims beyond its scope or Evidence basis.

Objectivity should be sufficient to support confidence in the assessment result within the declared boundary, lifecycle condition, and Infrastructure Quality Claim Statement scope.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- assessor qualification records;

- inspection body or reviewer appointment records;
- independence declarations;
- conflict-of-interest records;
- third-party inspection records;
- owner inspection records;
- independent engineering review records;
- verification body reports;
- audit or assessment plans;
- defined assessment criteria;
- Evidence review records;
- technical review comments;
- deviation logs;
- unresolved finding logs;
- assessment limitation statements.

4.4.6 Indicator 3.6 — Treatment of Non-Conformity and Unresolved Conditions

Context-Specific Interpretation

In LNG infrastructure, non-conformities and Unresolved Conditions should be identified, evaluated, dispositioned, and carried forward where relevant.

A non-conformity may involve failure to meet a technical specification, functional requirement, interface requirement, regulatory requirement, construction requirement, commissioning requirement, testing requirement, monitoring requirement, documentation requirement, or lifecycle-transition requirement.

An unresolved finding may involve incomplete Evidence, unresolved technical questions, open punch-list items, temporary exceptions, deferred work, unverified Assumptions, incomplete interface verification, monitoring gaps, or unresolved Critical Infrastructure Conditions.

Treatment of non-conformity is quality-relevant because unresolved issues may affect infrastructure behavior even where construction is complete or operation begins.

In LNG infrastructure, Unresolved Conditions may be especially significant where they concern cryogenic containment, pressure control, thermal behavior, boil-off gas management, transfer compatibility, emergency isolation, regasification and send-out, environmental protection, monitoring visibility, or lifecycle transition readiness.

Illustrative Context-Specific Quality Outcome Criteria

Treatment of non-conformity and Unresolved Conditions may be considered adequate when:

- non-conformities are identified and documented;
- Unresolved Conditions are identified and documented;
- significance is evaluated in relation to the declared Infrastructure Quality Object and lifecycle condition;
- effects on functional requirements and technical specifications are considered;
- effects on boundaries and interfaces are considered;
- effects on Critical Infrastructure Conditions are considered;
- corrective actions, concessions, limitations, or compensating measures are documented where relevant;
- Unresolved Conditions are not closed without Evidence;

- deferred items remain visible across lifecycle transitions;
- Infrastructure Quality Claim Statements are limited, revised, withheld, or qualified where Unresolved Conditions affect claim validity.

Non-conformities and Unresolved Conditions should not be hidden by general statements of completion, compliance, operability, capacity, or absence of observed failure.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- non-conformance reports;
- corrective action records;
- concession and deviation records;
- punch-list records;
- commissioning exception lists;
- unresolved technical query logs;
- deferred work registers;
- temporary operating restriction records;
- interface issue logs;
- corrective action verification records;
- risk acceptance records;
- management-of-change records;
- operational readiness review records;
- lifecycle transition closeout records;
- Infrastructure Quality Claim Statement limitation statements.

4.4.7 Indicator 3.7 — Traceability of Conformity Statements

Context-Specific Interpretation

In LNG infrastructure, Conformity Statements should be traceable to the assessment basis, assessment scope, Evidence, results, limitations, and Unresolved Conditions.

A conformity claim may state that an item, system, interface, lifecycle condition, or Infrastructure Quality Object conforms to defined requirements.

Such a claim should not be confused with a broader Infrastructure Quality Claim Statement unless the claim is explicitly bounded and supported by sufficient Evidence across relevant Core Quality Factors and Core Quality Indicators.

Traceability is necessary because LNG conformity Evidence may be distributed across design, procurement, fabrication, construction, commissioning, cooldown, operation, modification, monitoring, inspection, maintenance, and interface records.

A conformity claim may be misleading if it does not identify whether it concerns component conformity, system conformity, interface conformity, commissioning readiness, operational readiness, regulatory compliance, technical specification conformity, or broader infrastructure-quality interpretation.

Illustrative Context-Specific Quality Outcome Criteria

Traceability of Conformity Statements may be considered adequate when:

- the claim identifies what conforms;
- the claim identifies the requirements to which conformity is claimed;
- the claim identifies the assessment basis;
- the claim identifies the Evidence supporting the claim;

- the claim identifies the applicable boundary and lifecycle condition;
- limitations, exclusions, deviations, non-conformities, and Unresolved Conditions are identified where relevant;
- component, system, interface, and integrated-infrastructure claims are distinguishable;
- Conformity Statements are not used to imply quality beyond their scope;
- Conformity Statements can be linked to Infrastructure Quality Claim Statement Evidence where used for that purpose.

Conformity claims should remain bounded, Evidence-based, and transparent.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- certificates of conformity;
- inspection release records;
- test completion certificates;
- commissioning completion certificates;
- operational readiness records;
- regulatory approval records;
- standards conformity records;
- technical compliance matrices;
- assessment reports;
- Evidence indexes;
- non-conformity closeout records;
- deviation and concession records;
- claim boundary statements;
- Infrastructure Quality Claim Statement Evidence files;
- traceability matrices connecting conformity Evidence to Infrastructure Quality Claim Statements.

4.5 Factor 4 — Structural and Functional Integrity

Purpose of the Factor

The authoritative IQC1 purpose is:

To ensure that the declared Infrastructure Quality Object preserves Structural Integrity and Functional Integrity required for realization of its Infrastructure Intended Functions and Infrastructure Intended Results, considering Degradation and Aging, damage, Interfaces, and foreseeable Abnormal Operating Conditions, Transient Conditions, and Degraded Conditions across the Lifecycle.

Core architecture role: Examines whether the integrated object preserves the structural and functional condition needed to realize intended functions over time.

Definitions and Governing Terms

Governing WQI and IQI terms. Infrastructure Quality Object, Infrastructure Asset, Infrastructure Configuration, Infrastructure System-of-Systems, Infrastructure Operating Condition, Degradation and Aging, Infrastructure Repair / Modification / Reconstruction, and Failure Mode apply with their authoritative WQI_VOC1 and IQI_VOC1 meanings.

IQC1 Factor-specific terms. Structural Integrity, Functional Integrity, Integrity-Critical Function, Integrity Margin, Damage, Abnormal Operating Condition, Transient Condition, and Degraded Condition apply as defined in IQI_IQC1 and are not redefined in LNG1.

LNG1 context terms and anchors. cryogenic tanks and containment systems; process trains, heat exchangers, compressors, pumps, piping, valves, vaporizers, transfer arms and hoses; foundations and structural systems; insulation and thermal barriers; brittle-fracture, thermal-cycling, pressure, fatigue, corrosion, erosion, settlement, vibration, aging, leakage, and loss-of-containment mechanisms; and integrity across MNT1 and bulk-carrier Interfaces. Their technical meaning, values, methods, and acceptance conditions depend on the declared Infrastructure Quality Object, applicable Context-Specific Quality Outcome Criteria, and the Reference Layer.

Context-specific boundary. Quantitative margins, damage criteria, inspection intervals, service-life models, and mechanism-specific acceptance criteria are established by this Guide or the Reference Layer.

Context-Specific Interpretation

Structural and Functional Integrity concerns the ability of the declared LNG Infrastructure Quality Object to preserve its essential structural and functional condition while realizing the invariant Core intended function within its declared boundary, interfaces, lifecycle condition, Assumptions, limitations, and Critical Infrastructure Conditions.

In the LNG context, integrity should not be interpreted only as mechanical soundness of individual components.

It includes the integrated behavior of structures, foundations, tanks, cryogenic containment, insulation systems, storage systems, process systems, transfer systems, loading arms, hoses, couplings, loading and unloading systems, boil-off gas management systems, regasification systems, send-out systems, pressure-control systems, monitoring systems, control systems, safety systems, emergency systems, utilities, marine or port interface structures where included, and supporting infrastructure where relevant.

Structural and Functional Integrity is quality-relevant because LNG infrastructure may be affected by cryogenic temperature, thermal stress, pressure conditions, phase transformation, material behavior, insulation degradation, storage behavior, transfer operations, environmental exposure, aging, modification, lifecycle transitions, and interface dependencies.

Integrity should be interpreted in relation to the declared Infrastructure Quality Object as an assembled asset or system.

Component conformity, inspection completion, or absence of observed failure should not by itself be interpreted as sufficient Evidence of structural and functional integrity for the declared LNG Infrastructure Quality Object.

Integrity interpretation shall include the LNG1 side of MNT1-connected receipt and send-out systems and the LNG1 side of bulk transfer Interfaces, while preserving the separate Boundaries of the connected pipeline, carrier, or downstream LNGFS1 object.

Core Quality Indicators

The following Core Quality Indicator titles are invariant and governed by IQI_IQC1. The clauses under each Indicator provide LNG1 Context-Specific Interpretation, illustrative Context-Specific Quality Outcome Criteria, and Evidence considerations; they do not reproduce or replace the normative Core Indicator Statement.

4.5.1 Indicator 4.1 — Definition of Integrity-Critical Functions and Failure Modes

Context-Specific Interpretation

In LNG infrastructure, integrity-critical functions are functions whose failure, degradation, Uncertainty, or loss of visibility may compromise structural condition, functional condition, safety, environmental protection, operational reliability, or Infrastructure Quality Claim Statement validity.

Integrity-critical functions may involve cryogenic containment, thermal control, pressure control, structural support, storage integrity, insulation performance, boil-off gas management, transfer integrity, loading and unloading integrity, emergency isolation, regasification integrity, send-out integrity, monitoring integrity, and protection against environmental exposure.

Failure modes may include physical failure, loss of containment, brittle fracture, thermal stress damage, insulation degradation, excessive heat ingress, uncontrolled pressure behavior, loss of boil-off gas control, transfer incompatibility, valve or isolation failure, monitoring failure, control-system failure, foundation or structural degradation, corrosion, fatigue, settlement, environmental damage, or failure of organizational or lifecycle controls affecting integrity.

Failure modes should be interpreted in relation to the declared LNG Infrastructure Quality Object and the applicable LNG-context realization pathway.

Illustrative Context-Specific Quality Outcome Criteria

Integrity-critical functions and failure modes may be considered adequately defined when:

- integrity-critical functions relevant to the declared LNG Infrastructure Quality Object are identified;
- failure modes relevant to LNG-context behavior are identified;
- cryogenic, thermal, pressure, containment, storage, transfer, boil-off gas, regasification, send-out, monitoring, safety, emergency, and environmental conditions are considered where relevant;
- internal and external interface-related failure modes are considered;
- lifecycle-stage and lifecycle-transition failure modes are considered;
- failure modes affecting Critical Infrastructure Conditions are identified;
- Assumptions and Uncertainties affecting integrity are documented;
- failure modes are traceable to functional requirements, technical specifications, conformity assessment, monitoring, Evidence, and Infrastructure Quality Claim Statements.

The definition of integrity-critical functions and failure modes should be sufficient to support later interpretation of integrity Evidence and claim validity.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- integrity basis documents;
- failure mode analyses;
- hazard and operability studies;
- design risk reviews;
- criticality assessments;
- structural analyses;
- thermal stress analyses;
- material selection records;
- containment integrity records;
- storage integrity assessments;

- boil-off gas system reviews;
- transfer-system integrity reviews;
- regasification and send-out reviews;
- emergency isolation reviews;
- inspection and maintenance strategies;
- Critical Infrastructure Conditions registers;
- integrity management records.

4.5.2 Indicator 4.2 — Integrity of the Declared Infrastructure Quality Object

Context-Specific Interpretation

In LNG infrastructure, integrity of the integrated asset means that the declared Infrastructure Quality Object should be interpreted as an assembled infrastructure asset or system rather than as a collection of conforming components.

The integrated asset may include process systems, storage systems, transfer systems, loading and unloading systems, regasification systems, send-out systems, boil-off gas management, utilities, safety systems, monitoring systems, control systems, emergency systems, structural systems, environmental protection systems, and interface systems where included in the declared boundary.

Integrity of the integrated asset depends on how these systems interact under expected operating conditions, abnormal conditions, transient conditions, lifecycle transitions, and interface conditions.

In the LNG context, integrated integrity may be affected by cryogenic operation, phase transformation, pressure control, thermal gradients, heat ingress, vibration, settlement, corrosion, fatigue, insulation condition, transfer conditions, emergency isolation, environmental exposure, and connected-system Assumptions.

A component may conform to its technical specification while the integrated asset may still have integrity concerns because of interface mismatch, system interaction, lifecycle change, unresolved Assumptions, or Evidence gaps.

Illustrative Context-Specific Quality Outcome Criteria

Integrity of the integrated asset may be considered adequately interpreted when:

- the declared Infrastructure Quality Object is evaluated as an integrated asset or system;
- relevant internal systems and interfaces are considered together;
- component conformity is distinguished from integrated asset integrity;
- cryogenic, thermal, pressure, phase-transformation, storage, transfer, boil-off gas, regasification, send-out, safety, emergency, monitoring, and environmental interactions are considered where relevant;
- lifecycle conditions and lifecycle transitions are considered;
- interface dependencies are considered;
- Unresolved Conditions, deviations, and Evidence limitations are carried into integrity interpretation;
- the Evidence basis supports the intended Infrastructure Quality Claim Boundary.

Integrated asset integrity should be sufficient to support confidence that the declared LNG Infrastructure Quality Object can preserve its essential structural and functional condition within the applicable lifecycle condition.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- integrated design reviews;
- system integration reviews;
- commissioning records;
- cooldown records;
- integrated system test records;
- operational readiness reviews;
- process safety reviews;
- inspection and maintenance records;
- monitoring records;
- integrity assessments;
- interface verification records;
- emergency-system test records;
- environmental protection verification records;
- management-of-change records;
- unresolved finding logs;
- Infrastructure Quality Claim Statement Evidence files.

4.5.3 Indicator 4.3 — Consideration of Degradation, Damage, and Aging Mechanisms

Context-Specific Interpretation

In LNG infrastructure, structural and functional integrity may change over time because of degradation, damage, and aging mechanisms.

These mechanisms may affect materials, foundations, structures, piping, tanks, insulation, transfer systems, loading and unloading systems, vaporizers, pressure-control systems, boil-off gas systems, instrumentation, control systems, safety systems, emergency systems, environmental protection systems, and supporting utilities.

LNG-specific degradation and damage considerations may include thermal cycling, cryogenic exposure, brittle fracture susceptibility, insulation degradation, corrosion, fatigue, vibration, settlement, erosion, mechanical damage, environmental exposure, marine exposure, weather exposure, seismic exposure, flooding exposure, and degradation resulting from abnormal or transient conditions.

Aging should not be interpreted only by calendar time.

It should be interpreted in relation to actual operating conditions, lifecycle history, maintenance history, modification history, environmental exposure, monitoring visibility, and Evidence continuity.

Illustrative Context-Specific Quality Outcome Criteria

Degradation, damage, and aging mechanisms may be considered adequately addressed when:

- relevant degradation and damage mechanisms are identified;
- relevant aging mechanisms are identified;
- LNG-specific mechanisms involving cryogenic, thermal, pressure, storage, transfer, boil-off gas, regasification, send-out, environmental, and lifecycle conditions are considered where relevant;
- degradation affecting Critical Infrastructure Conditions is identified;
- monitoring, inspection, maintenance, and Evidence strategies are aligned with relevant mechanisms;
- aging and degradation Assumptions are documented;
- degradation and damage findings are traceable across the lifecycle;

- changes in condition are carried into integrity interpretation and Infrastructure Quality Claim Statements.

Consideration of degradation, damage, and aging should be sufficient to support interpretation of whether the declared LNG Infrastructure Quality Object preserves integrity over the applicable lifecycle condition.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- degradation mechanism reviews;
- aging assessments;
- inspection records;
- maintenance records;
- corrosion monitoring records;
- insulation condition records;
- tank inspection records;
- piping inspection records;
- structural inspection records;
- foundation monitoring records;
- vibration records;
- thermal cycling records;
- cooldown and warm-up records;
- environmental exposure records;
- damage reports;
- repair records;
- fitness-for-service assessments;
- integrity reassessment records.

4.5.4 Indicator 4.4 — Integrity Under Foreseeable Abnormal and Transient Conditions

Context-Specific Interpretation

LNG infrastructure should be interpreted not only under normal operating conditions, but also under foreseeable abnormal and transient conditions that may affect structural or functional integrity.

Foreseeable abnormal and transient conditions may include startup, shutdown, cooldown, warm-up, first LNG introduction, pressure transients, thermal transients, transfer interruptions, emergency shutdown, emergency isolation, boil-off gas upsets, equipment trips, utility loss, control-system failure, monitoring failure, environmental extremes, marine or transportation interface disturbance, abnormal gas composition, abnormal send-out demand, and abnormal lifecycle-transition conditions.

In the LNG context, abnormal and transient conditions may create integrity stresses that are not visible during normal operation.

These conditions may affect cryogenic containment, pressure control, thermal stability, material behavior, insulation condition, transfer integrity, storage behavior, regasification behavior, send-out compatibility, emergency systems, monitoring reliability, and environmental protection.

Integrity interpretation should therefore include foreseeable abnormal and transient conditions where they are relevant to the declared Infrastructure Quality Object and Infrastructure Quality Claim Boundary.

Illustrative Context-Specific Quality Outcome Criteria

Integrity under foreseeable abnormal and transient conditions may be considered adequately addressed when:

- foreseeable abnormal and transient conditions are identified;
- their effects on structural and functional integrity are considered;
- cryogenic, thermal, pressure, storage, transfer, boil-off gas, regasification, send-out, safety, emergency, monitoring, and environmental effects are considered where relevant;
- abnormal and transient conditions affecting Critical Infrastructure Conditions are identified;
- Assumptions and limitations are documented;
- operating limits and response conditions are traceable to technical specifications and Evidence;
- emergency and protective functions are considered where relevant;
- unresolved abnormal or transient-condition issues are carried into Infrastructure Quality Claim Statements where relevant.

Integrity interpretation should be sufficient to support confidence that the declared Infrastructure Quality Object remains within acceptable structural and functional conditions during foreseeable abnormal and transient conditions or that limitations are clearly stated.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- abnormal operating condition analyses;
- transient analyses;
- startup and shutdown records;
- cooldown and warm-up records;
- emergency shutdown test records;
- pressure transient studies;
- thermal stress analyses;
- control-system response records;
- safety-system verification records;
- utility failure analyses;
- boil-off gas upset analyses;
- transfer interruption records;
- incident and near-miss records;
- emergency-response exercise records;
- operating limit records;
- Infrastructure Quality Claim Statement limitation statements.

4.5.5 Indicator 4.5 — Preservation of Integrity Through Change and Modification

Context-Specific Interpretation

Structural and functional integrity should be preserved when LNG infrastructure is changed, modified, expanded, repaired, repurposed, recommissioned, or operated under changed conditions.

Changes may affect the declared Infrastructure Quality Object, its boundaries, interfaces, lifecycle condition, technical specifications, Assumptions, Critical Infrastructure Conditions, monitoring visibility, Evidence basis, or Infrastructure Quality Claim Statement validity.

In LNG infrastructure, changes may include added liquefaction capacity, changed storage use, added or modified tanks, modified boil-off gas management, changed transfer systems, added loading or unloading modes, changed regasification or send-out conditions, changed gas composition, changed pipeline interface, changed marine or transportation interface, changed emergency systems, changed environmental Assumptions, changed operating philosophy, or changed organizational responsibility.

A change may appear local but still affect integrated asset integrity.

For example, a change in transfer configuration may affect cryogenic conditions, pressure control, emergency isolation, operational responsibility, monitoring, environmental exposure, and Evidence continuity.

Illustrative Context-Specific Quality Outcome Criteria

Integrity through change and modification may be considered adequately preserved when:

- changes affecting integrity are identified and documented;
- effects on the declared Infrastructure Quality Object are evaluated;
- effects on boundaries and interfaces are evaluated;
- effects on lifecycle condition are evaluated;
- effects on cryogenic, thermal, pressure, storage, transfer, boil-off gas, regasification, send-out, monitoring, safety, emergency, environmental, and support systems are considered where relevant;
- effects on Critical Infrastructure Conditions are reviewed;
- Assumptions and Uncertainties are updated;
- conformity assessment, inspection, testing, commissioning, and monitoring Evidence are updated where needed;
- Infrastructure Quality Claim Statements are revised, limited, withdrawn, or re-evidenced where integrity Assumptions change.

Change and modification should not be allowed to disconnect realized infrastructure behavior from the functional and technical basis supporting integrity interpretation.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- management-of-change records;
- modification assessments;
- engineering change records;
- revised design documents;
- revised technical specifications;
- integrity impact assessments;
- hazard reassessment records;
- interface reassessment records;
- commissioning records for modifications;
- inspection and test records;
- updated monitoring records;
- updated Assumptions registers;
- updated Critical Infrastructure Conditions registers;
- repair records;
- recommissioning records;
- revised Infrastructure Quality Claim Statements.

4.5.6 Indicator 4.6 — Integrity Margin and Tolerance to Uncertainty

Context-Specific Interpretation

Integrity margin and tolerance to Uncertainty concern the ability of the declared LNG Infrastructure Quality Object to preserve structural and functional integrity despite recognized Uncertainty, variability, degradation, abnormal conditions, and lifecycle change.

In LNG infrastructure, Uncertainty may arise from gas composition, operating conditions, cryogenic behavior, thermal behavior, pressure behavior, material behavior, insulation condition, degradation mechanisms, environmental exposure, transfer conditions, regasification and send-out Assumptions, connected-system behavior, monitoring limitations, or incomplete Evidence.

Integrity margin should be interpreted in relation to the declared Infrastructure Quality Object and the applicable Critical Infrastructure Conditions.

It should not be treated only as a numerical design margin or calculation reserve.

It also includes the ability of infrastructure interpretation to recognize Uncertainty, preserve visibility, avoid unsupported Assumptions, and prevent Infrastructure Quality Claim Statements from exceeding the Evidence basis.

Where Uncertainty is high or visibility is limited, Evidence interpretation and Infrastructure Quality Claim Statements should be appropriately bounded.

Illustrative Context-Specific Quality Outcome Criteria

Integrity margin and tolerance to Uncertainty may be considered adequately addressed when:

- relevant Uncertainties affecting integrity are identified;
- margins or tolerances relevant to structural and functional integrity are considered;
- Critical Infrastructure Conditions affected by Uncertainty are identified;
- Uncertainty in cryogenic, thermal, pressure, storage, transfer, boil-off gas, regasification, send-out, environmental, monitoring, and lifecycle conditions is considered where relevant;
- Assumptions are distinguished from verified conditions;
- Evidence limitations are documented;
- monitoring, inspection, testing, or reassessment is aligned with Uncertainty where relevant;
- Infrastructure Quality Claim Statements are bounded to reflect Uncertainty and Evidence limitations.

Integrity margin and tolerance to Uncertainty should be sufficient to support credible interpretation of structural and functional integrity within the declared boundary and lifecycle condition.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- design margin analyses;
- integrity margin assessments;
- Uncertainty registers;
- sensitivity analyses;
- fitness-for-service assessments;
- monitoring coverage assessments;
- inspection results;
- degradation assessments;
- operating envelope records;
- alarm and trip setpoint basis records;
- thermal and pressure analyses;

- structural analyses;
- environmental exposure assessments;
- risk assessments;
- Evidence-gap registers;
- Infrastructure Quality Claim Statement limitation statements.

4.5.7 Indicator 4.7 — Integrity-Relevant Information Retention

Context-Specific Interpretation

Integrity-relevant information retention concerns preservation of information needed to understand, assess, maintain, reassess, and claim structural and functional integrity across the lifecycle of the declared LNG Infrastructure Quality Object.

This Indicator is especially important in the LNG context because integrity Evidence may be distributed across design, procurement, fabrication, construction, acceptance, commissioning, cooldown, operation, inspection, maintenance, modification, repair, recommissioning, repurposing, and decommissioning records.

Integrity-relevant information may concern functional requirements, technical specifications, design Assumptions, material records, inspection records, test records, cooldown records, operating history, degradation Evidence, repair records, modification records, interface records, monitoring records, abnormal-condition records, non-conformities, Unresolved Conditions, Critical Infrastructure Conditions, and Infrastructure Quality Claim Statement Evidence.

Loss of integrity-relevant information may prevent credible interpretation of current condition, hide Assumption drift, weaken monitoring interpretation, obscure Unresolved Conditions, or invalidate Infrastructure Quality Claim Statements.

Retention should preserve not only documents, but also traceability between infrastructure condition, Assumptions, Evidence, limitations, and claim boundaries.

Illustrative Context-Specific Quality Outcome Criteria

Integrity-relevant information may be considered adequately retained when:

- information needed to understand integrity condition is identified;
- design, construction, commissioning, cooldown, operation, inspection, maintenance, modification, repair, and lifecycle transition records are retained where relevant;
- information concerning Critical Infrastructure Conditions is retained;
- information concerning Assumptions, Uncertainties, limitations, deviations, and Unresolved Conditions is retained;
- integrity information remains accessible and traceable across lifecycle stages;
- information remains connected to the declared Infrastructure Quality Object, boundaries, interfaces, and lifecycle condition;
- loss, fragmentation, or inaccessibility of information is identified as an Evidence limitation;
- Infrastructure Quality Claim Statements are not made beyond retained and traceable integrity Evidence.

Information retention should be sufficient to support future reassessment, change evaluation, lifecycle transition, and bounded Infrastructure Quality Claim Statements.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- integrity records;

- design records;
- material records;
- fabrication records;
- construction records;
- inspection and test records;
- commissioning records;
- cooldown records;
- operating history records;
- maintenance records;
- repair records;
- modification records;
- degradation records;
- monitoring records;
- abnormal event records;
- non-conformity and deviation records;
- Critical Infrastructure Conditions registers;
- Evidence indexes;
- document-control records;
- Infrastructure Quality Claim Statement Evidence files.

4.6 Factor 5 — Process Safety and Risk Mitigation

Purpose of the Factor

The authoritative IQC1 purpose is:

To ensure that Hazardous Energy, Hazardous Materials, Hazardous Processes, Loss-of-Control Scenarios, and relevant Risk are identified and interpreted so that Risk Controls and Risk Mitigation support Infrastructure Safety and prevent or limit high-consequence and Cascading Failure conditions. Applicable acceptable-Risk criteria remain context-specific Quality Outcome Criteria.

Core architecture role: Examines prevention and control of hazardous energy, materials, processes, and high-consequence loss-of-control conditions.

Definitions and Governing Terms

Governing WQI and IQI terms. Critical Condition, Non-Compensability, Critical Infrastructure Condition, Infrastructure Non-Substitutability, Infrastructure Operating Condition, and Infrastructure Safety apply with their authoritative WQI_VOC1 and IQI_VOC1 meanings. Abnormal Operating Condition, Transient Condition, and Degraded Condition apply as defined under Factor 4.

IQC1 Factor-specific terms. Hazard, Hazardous Energy, Hazardous Material, Hazardous Process, Risk, Loss-of-Control Scenario, High-Consequence Scenario, Risk Control Objective, Risk Control, Risk Mitigation, Operating Mode, Systemic Risk, Cumulative Risk, and Cascading Failure apply as defined in IQI_IQC1 and are not redefined in LNG1.

LNG1 context terms and anchors. LNG, natural gas, boil-off gas, refrigerants, fuel gas, cryogenic energy, pressure, fire, explosion, vapor dispersion, rapid phase transition, rollover, overfill, stratification, loss of utilities, transfer release, loading or unloading event, emergency shutdown, isolation, relief, flare, vent, fire-and-gas, spill control, public consequence, marine and port interaction, and cumulative or interacting risk. Their technical meaning, values, methods, and acceptance conditions depend on the declared Infrastructure Quality Object, applicable Context-Specific Quality Outcome Criteria, and the Reference Layer.

Context-specific boundary. Risk thresholds, tolerability criteria, hazard classifications, hazard-analysis methods, quantitative models, and required control performance are Context-Specific Quality Outcome Criteria supported by the applicable Reference Layer.

Context-Specific Interpretation

Process Safety and Risk Mitigation concerns the quality of identifying, understanding, controlling, and preserving protection against hazardous infrastructure conditions that may compromise realization of the invariant Core intended function.

In the LNG context, process safety and risk mitigation should be interpreted in relation to the declared LNG Infrastructure Quality Object, the declared LNG-context realization pathway, the applicable lifecycle condition, boundaries, interfaces, Assumptions, limitations, Critical Infrastructure Conditions, and Evidence basis.

LNG infrastructure may involve hazardous energy, hazardous materials, cryogenic conditions, pressure conditions, phase transformation, flammable gas behavior, dense vapor cloud behavior, vapor dispersion, rapid phase-transition effects where relevant, pool fire or vapor ignition scenarios where relevant, boil-off gas behavior, transfer operations, loading and unloading, regasification, send-out, emergency isolation, environmental exposure, and public-consequence conditions.

Process safety is not demonstrated merely by the existence of a safety program, compliance record, hazard study, operating procedure, emergency plan, or absence of observed incident.

Such Evidence may support interpretation.

However, process safety and risk mitigation under this Guide depend on whether risk-relevant infrastructure behavior is understood, controlled, evidenced, traceable, preserved under change, and bounded within a credible Infrastructure Quality Claim Statement.

Risk interpretation shall distinguish bulk LNG transfer involving carriers or transport containers from automotive fuel dispensing. The latter introduces a different downstream public-fueling context and is governed through LNGFS1 rather than LNG1.

Core Quality Indicators

The following Core Quality Indicator titles are invariant and governed by IQI_IQC1. The clauses under each Indicator provide LNG1 Context-Specific Interpretation, illustrative Context-Specific Quality Outcome Criteria, and Evidence considerations; they do not reproduce or replace the normative Core Indicator Statement.

4.6.1 Indicator 5.1 — Identification of Hazardous Energy, Materials, and Processes

Context-Specific Interpretation

In LNG infrastructure, hazardous energy, materials, and processes should be identified in relation to the declared Infrastructure Quality Object and its LNG-context realization pathway.

Hazardous materials may include LNG, natural gas, boil-off gas, refrigerants, fuel gas, chemicals, treatment media, or other materials where relevant to the declared boundary.

Hazardous energy may include cryogenic thermal conditions, pressure, stored energy, mechanical energy, electrical energy, hydraulic or pneumatic energy, thermal energy, fire and explosion potential, and energy associated with transfer, loading, unloading, regasification, and emergency conditions.

Hazardous processes may include liquefaction, cryogenic storage, boil-off gas management, transfer, loading, unloading, regasification, send-out, pressure control, cooldown, warm-up, emergency isolation, venting, flaring, and abnormal or transient operation where relevant.

Identification should not be limited to a general statement that LNG is hazardous.

It should make visible the specific hazardous materials, energy forms, process conditions, boundaries, interfaces, lifecycle stages, and Critical Infrastructure Conditions relevant to the declared LNG Infrastructure Quality Object.

Illustrative Context-Specific Quality Outcome Criteria

Hazardous energy, materials, and processes may be considered adequately identified when:

- LNG-relevant hazardous materials are identified within the declared boundary;
- hazardous energy forms are identified within the declared boundary;
- hazardous processes are identified within the declared LNG-context realization pathway;
- hazardous conditions at internal and external interfaces are considered;
- cryogenic, thermal, pressure, phase-transformation, storage, transfer, boil-off gas, regasification, send-out, emergency, and environmental conditions are considered where relevant;
- lifecycle-stage and lifecycle-transition hazards are identified;
- Assumptions and Uncertainties affecting hazard identification are documented;
- Critical Infrastructure Conditions associated with hazardous materials, energy, or processes are identified;
- hazard identification is traceable to functional requirements, technical specifications, conformity assessment, monitoring, documentation, and Infrastructure Quality Claim Statements.

Hazard identification should be sufficiently specific to support risk-control objectives and Evidence interpretation.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- hazard identification studies;
- process hazard analyses;
- hazard and operability studies;
- fire and explosion studies;
- vapor dispersion studies;
- cryogenic hazard reviews;
- pressure hazard reviews;
- boil-off gas hazard reviews;
- transfer and loading hazard reviews;
- regasification and send-out hazard reviews;
- emergency isolation reviews;
- process-flow diagrams;
- piping and instrumentation diagrams;
- hazardous materials inventories;
- safety data sheets;
- operating envelope documents;
- Critical Infrastructure Conditions registers.

4.6.2 Indicator 5.2 — Identification of High-Consequence and Loss-of-Control Scenarios

Context-Specific Interpretation

In LNG infrastructure, high-consequence and loss-of-control scenarios should be identified where failure, degradation, or loss of control may compromise essential function, create unacceptable risk, produce environmental harm, affect workers or communities, or invalidate an Infrastructure Quality Claim Statement.

Such scenarios may involve loss of containment, uncontrolled release of LNG or gas, vapor cloud formation, dense vapor cloud behavior, ignition, fire, explosion, pool fire or vapor ignition scenarios where relevant, rapid phase-transition effects where relevant, cryogenic exposure, overpressure, underpressure, uncontrolled boil-off gas behavior, tank stratification or rollover-related concerns where applicable, transfer failure, loading or unloading failure, emergency-release or emergency-isolation failure, regasification failure, send-out instability, utility loss, control-system failure, monitoring failure, abnormal gas composition, environmental exposure, or interface failure.

High-consequence scenarios should be interpreted in relation to the declared Infrastructure Quality Object and the affected boundaries and interfaces.

In the LNG context, loss-of-control scenarios may involve not only equipment failure, but also interaction among process systems, human decisions, organizational interfaces, transportation interfaces, emergency-response systems, environmental conditions, and lifecycle transitions.

Illustrative Context-Specific Quality Outcome Criteria

High-consequence and loss-of-control scenarios may be considered adequately identified when:

- relevant loss-of-control scenarios are identified for the declared Infrastructure Quality Object;
- scenarios involving cryogenic containment, pressure control, boil-off gas management, transfer, loading, unloading, regasification, send-out, and emergency isolation are considered where relevant;
- scenarios involving fire, explosion, vapor dispersion, cryogenic exposure, environmental harm, worker harm, public consequence, and infrastructure disruption are considered where relevant;
- internal and external interface-related scenarios are considered;
- lifecycle-transition scenarios are considered;
- scenarios involving monitoring limitations or delayed detection are considered;
- Assumptions and Uncertainties affecting scenario identification are documented;
- high-consequence scenarios affecting Critical Infrastructure Conditions are identified;
- scenario identification is traceable to risk-control objectives and Evidence interpretation.

Scenario identification should be sufficient to support proportionate risk mitigation and bounded Infrastructure Quality Claim Statements.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- process hazard analyses;
- hazard and operability studies;
- major accident scenario registers;
- loss-of-containment scenario analyses;
- quantitative or qualitative risk assessments;
- vapor dispersion modeling;
- fire and explosion studies;

- emergency shutdown scenario reviews;
- transfer failure analyses;
- marine, truck, rail, or pipeline interface risk assessments;
- utility failure analyses;
- control-system failure analyses;
- environmental consequence assessments;
- emergency-response planning records;
- incident and near-miss reviews;
- Critical Infrastructure Conditions registers.

4.6.3 Indicator 5.3 — Definition of Risk Control Objectives

Context-Specific Interpretation

In LNG infrastructure, risk control objectives should define what the risk controls are intended to achieve in relation to the identified hazardous energy, materials, processes, high-consequence scenarios, and loss-of-control scenarios.

Risk control objectives should be connected to the declared Infrastructure Quality Object, the LNG-context realization pathway, applicable lifecycle condition, boundaries, interfaces, Assumptions, limitations, and Critical Infrastructure Conditions.

Risk control objectives may address prevention, detection, limitation, isolation, mitigation, emergency response, environmental protection, worker protection, public-consequence limitation, operational recovery, and Evidence continuity.

In the LNG context, risk control objectives may concern cryogenic containment, pressure control, thermal management, boil-off gas management, transfer compatibility, emergency shutdown, emergency isolation, vapor dispersion limitation, fire and gas detection, spill control, regasification control, send-out compatibility, environmental protection, and protection of affected communities.

Risk control objectives should not be stated only as broad commitments to safety.

They should be sufficiently clear to support technical specification, conformity assessment, monitoring, operational interpretation, Evidence evaluation, and Infrastructure Quality Claim Statements.

Illustrative Context-Specific Quality Outcome Criteria

Risk control objectives may be considered adequately defined when:

- objectives are connected to identified hazards and scenarios;
- objectives are connected to the declared Infrastructure Quality Object and realization pathway;
- objectives identify the intended prevention, detection, control, mitigation, isolation, emergency, or recovery outcome;
- objectives address relevant boundaries and interfaces;
- objectives address lifecycle conditions and lifecycle transitions where relevant;
- objectives address Critical Infrastructure Conditions where relevant;
- objectives are traceable to technical specifications, risk controls, monitoring, Evidence, and Infrastructure Quality Claim Statements;
- objectives distinguish between prevention of loss of control and limitation of consequence after loss of control;
- limitations and Assumptions affecting risk control objectives are stated.

Risk control objectives should be sufficiently clear to make later assessment of risk-control effectiveness possible.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- risk-control objective statements;
- safety philosophy documents;
- design safety basis documents;
- protection layer descriptions;
- safety requirement specifications;
- emergency shutdown philosophy documents;
- fire and gas detection philosophy documents;
- spill control and containment philosophy documents;
- boil-off gas control philosophy documents;
- transfer safety philosophy documents;
- regasification and send-out control documents;
- environmental protection objectives;
- emergency-response objectives;
- interface-control objectives;
- Critical Infrastructure Conditions registers;
- Infrastructure Quality Claim Statement Evidence mapping.

4.6.4 Indicator 5.4 — Effectiveness of Risk Controls Across Operating Modes

Context-Specific Interpretation

Risk controls should remain effective across the operating modes relevant to the declared LNG Infrastructure Quality Object and Infrastructure Quality Claim Statement.

In LNG infrastructure, operating modes may include startup, cooldown, first LNG introduction, normal operation, storage, transfer, loading, unloading, regasification, send-out, boil-off gas management, marine interface operation, truck or rail loading, standby, reduced operation, maintenance, abnormal operation, emergency operation, shutdown, warm-up, temporary shutdown, conservation, recommissioning, repurposing, and decommissioning where relevant.

Risk controls may be effective in one operating mode but incomplete, unavailable, degraded, bypassed, unsuitable, or insufficient in another.

For example, a control effective during normal storage may not be sufficient during transfer, cooldown, abnormal pressure behavior, emergency shutdown, or recommissioning.

In the LNG context, risk-control effectiveness should be interpreted in relation to actual infrastructure behavior, not merely the existence of controls on drawings, procedures, or safety studies.

Illustrative Context-Specific Quality Outcome Criteria

Risk controls may be considered effective across operating modes when:

- relevant operating modes are identified;
- risk controls are identified for each relevant operating mode;
- controls remain aligned with hazards and scenarios in each mode;
- controls address cryogenic, thermal, pressure, storage, transfer, boil-off gas, regasification, send-out, emergency, environmental, monitoring, and interface conditions where relevant;
- controls are available and functional when needed;
- degraded, bypassed, temporary, or compensating controls are identified;

- control effectiveness is supported by Evidence appropriate to the lifecycle condition;
- limitations in control effectiveness are documented;
- Infrastructure Quality Claim Statements reflect any operating-mode limitations.

Effectiveness across operating modes should be sufficient to support confidence that risk mitigation remains aligned with the declared Infrastructure Quality Object and claim boundary.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- operating-mode analyses;
- protection layer verification records;
- safety-system test records;
- emergency shutdown test records;
- fire and gas detection test records;
- alarm and trip verification records;
- operating procedures;
- startup and cooldown records;
- transfer operation records;
- loading and unloading records;
- boil-off gas management records;
- regasification and send-out records;
- maintenance and bypass records;
- abnormal operation records;
- emergency drill records;
- commissioning and recommissioning records;
- control effectiveness reviews.

4.6.5 Indicator 5.5 — Systemic and Cumulative Risk Consideration

Context-Specific Interpretation

Systemic and cumulative risk consideration means that risk should not be interpreted only as isolated equipment risk or isolated scenario risk.

In LNG infrastructure, risk may arise from interactions among systems, interfaces, lifecycle stages, operating modes, organizational responsibilities, environmental conditions, transportation interfaces, emergency-response capability, monitoring limitations, and Unresolved Conditions.

Cumulative risk may arise when multiple individually acceptable conditions combine to create a quality-relevant risk.

Examples may include simultaneous maintenance and transfer activity, degraded monitoring and abnormal operation, changed gas composition and unchanged technical Assumptions, increased throughput and aging infrastructure, multiple deferred findings, extreme weather and limited emergency access, or overlapping organizational responsibilities during interface operations.

Systemic risk is especially relevant in LNG infrastructure because process safety may depend on the integrated behavior of cryogenic storage, pressure control, boil-off gas management, transfer systems, emergency isolation, monitoring systems, utilities, environmental controls, transportation systems, and human decision-making.

Illustrative Context-Specific Quality Outcome Criteria

Systemic and cumulative risk may be considered adequately addressed when:

- risk interactions among systems and interfaces are considered;
- cumulative effects of multiple deviations, limitations, or degraded conditions are considered;
- lifecycle-stage and lifecycle-transition risk accumulation is considered;
- organizational and responsibility-interface risks are considered;
- environmental and public-consequence interactions are considered;
- monitoring limitations and Evidence gaps are considered as possible contributors to cumulative risk;
- Critical Infrastructure Conditions are considered in relation to systemic and cumulative risk;
- risk interpretation is updated when operating context changes;
- Infrastructure Quality Claim Statements do not treat isolated conformity as sufficient where systemic or cumulative risk remains unresolved.

Systemic and cumulative risk consideration should be sufficient to prevent fragmented Evidence from producing an unsupported conclusion about infrastructure quality.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- system risk assessments;
- cumulative risk reviews;
- simultaneous operations reviews;
- interface risk assessments;
- operational risk reviews;
- management-of-change reviews;
- environmental risk assessments;
- emergency-response capability reviews;
- monitoring limitation reviews;
- deferred action registers;
- non-conformity trend reviews;
- abnormal event reviews;
- incident and near-miss trend analyses;
- organizational interface reviews;
- Critical Infrastructure Conditions reviews;
- Infrastructure Quality Claim Statement limitation records.

4.6.6 Indicator 5.6 — Preservation of Risk Mitigation Alignment Under Change

Context-Specific Interpretation

Risk mitigation should remain aligned with hazards, scenarios, operating modes, lifecycle conditions, boundaries, interfaces, and Critical Infrastructure Conditions when LNG infrastructure changes.

Changes may include functional changes, technical changes, operational changes, organizational changes, ownership changes, interface changes, environmental changes, regulatory changes, technology changes, aging, degradation, modification, expansion, repurposing, recommissioning, or decommissioning.

In LNG infrastructure, risk mitigation alignment may be affected by changed gas supply, changed gas composition, changed storage use, changed transfer configuration, added loading or unloading modes, changed boil-off gas management, changed regasification or send-out conditions, modified emergency systems, changed monitoring coverage, changed environmental exposure, changed transportation interfaces, or changed emergency-response arrangements.

A risk control may remain physically present but no longer remain aligned with the changed infrastructure context.

Therefore, preservation of risk mitigation alignment requires review of whether existing controls, Evidence, Assumptions, and Infrastructure Quality Claim Statements remain valid after change.

Illustrative Context-Specific Quality Outcome Criteria

Risk mitigation alignment under change may be considered preserved when:

- changes affecting hazards, scenarios, controls, interfaces, or lifecycle conditions are identified;
- effects on risk control objectives are evaluated;
- effects on Critical Infrastructure Conditions are evaluated;
- effects on cryogenic, thermal, pressure, storage, transfer, boil-off gas, regasification, send-out, emergency, environmental, monitoring, and interface conditions are considered where relevant;
- Assumptions and Uncertainties are updated;
- control effectiveness is reassessed where needed;
- Evidence is updated where needed;
- unresolved change-related risk is documented;
- Infrastructure Quality Claim Statements are revised, limited, withdrawn, or re-evidenced where risk mitigation alignment changes.

Risk mitigation should not be presumed preserved merely because existing controls remain installed or procedures remain in place.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- management-of-change records;
- risk reassessment records;
- hazard study revalidation records;
- safety-system change records;
- emergency-system change records;
- operating procedure revisions;
- interface change records;
- gas-composition change assessments;
- transfer configuration change assessments;
- regasification or send-out change assessments;
- environmental change assessments;
- organizational change reviews;
- monitoring coverage reassessments;
- updated Critical Infrastructure Conditions registers;
- revised Infrastructure Quality Claim Statements.

4.6.7 Indicator 5.7 — Risk Information Retention and Transparency

Context-Specific Interpretation

Risk information retention and transparency concerns preservation and communication of information needed to understand, assess, maintain, and claim process safety and risk mitigation across the lifecycle of the declared LNG Infrastructure Quality Object.

In LNG infrastructure, risk information may be distributed across hazard studies, risk assessments, design reviews, operating procedures, safety-system records, emergency-response records, environmental records, monitoring records, incident records, near-miss records, non-conformity records, management-of-change records, interface records, and Infrastructure Quality Claim Statement Evidence.

Risk information should be retained in a way that preserves traceability between hazards, scenarios, controls, Assumptions, Uncertainties, Critical Infrastructure Conditions, Evidence, Unresolved Conditions, limitations, and Infrastructure Quality Claim Statements.

Loss of risk information may cause Assumption drift, repeated unresolved issues, inadequate change evaluation, weak operational understanding, hidden cumulative risk, or misleading Infrastructure Quality Claim Statements.

Transparency is especially important where risk information affects workers, operators, emergency responders, regulators, affected communities, connected infrastructure operators, or Infrastructure Quality Claim Statement users.

Illustrative Context-Specific Quality Outcome Criteria

Risk information may be considered adequately retained and transparent when:

- risk-relevant information is identified and retained;
- hazard, scenario, control, and Evidence records remain traceable;
- information concerning Critical Infrastructure Conditions is retained;
- Assumptions, Uncertainties, limitations, deviations, and Unresolved Conditions are retained;
- risk information remains accessible to appropriate users across lifecycle stages;
- changes to risk information are documented;
- risk information supports reassessment after change, incident, abnormal condition, or lifecycle transition;
- Infrastructure Quality Claim Statements identify the risk information basis and limitations where relevant;
- loss, fragmentation, or inaccessibility of risk information is identified as an Evidence limitation.

Risk information retention should support continued interpretation of process safety and risk mitigation within the declared boundary and lifecycle condition.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- hazard study records;
- risk assessment records;
- major accident scenario registers;
- safety requirement specifications;
- protection layer records;
- emergency shutdown records;
- fire and gas detection records;
- emergency-response records;
- incident and near-miss records;
- operating envelopes;
- alarm and trip setpoint basis records;
- management-of-change records;
- interface risk records;
- environmental risk records;
- non-conformity and unresolved finding records;
- Critical Infrastructure Conditions registers;

- document-control records;
- Infrastructure Quality Claim Statement Evidence files.

4.7 Factor 6 — Environmental Protection

Purpose of the Factor

The authoritative IQC1 purpose is:

To ensure that Environmental Protection is interpreted as an integral dimension of Infrastructure Quality, including Environmental Interactions, Exposure Pathways, emissions, discharges, Unintended Releases, Environmental Harm, and cumulative or long-term effects across the Lifecycle.

Core architecture role: Examines whether environmental interactions and consequences remain consistent with intended function, applicable criteria, and bounded claims.

Definitions and Governing Terms

Governing terms. Infrastructure Quality Object, Infrastructure Operating Condition, Evidence, Critical Condition, and the Factor 4 definitions of Abnormal Operating Condition, Transient Condition, and Degraded Condition govern their use in this Factor.

IQC1 Factor-specific terms. Environmental Interaction, Exposure Pathway, Environmental Harm, Unintended Release, Emission, Discharge, Cumulative Environmental Effect, Long-Term Environmental Effect, and Residual Environmental Impact apply as defined in IQI_IQC1 and are not redefined in LNG1.

LNG1 context terms and anchors. methane, natural gas, boil-off gas, refrigerant, combustion, flare, vent, vapor, spill, wastewater, stormwater, cooling-water, thermal-discharge, chemical, firewater, waste, noise, light, marine, coastal, land, air, water, soil, groundwater, ecosystem, traffic, and cumulative environmental interactions across liquefaction, storage, transfer, regasification, and lifecycle transitions. Their technical meaning, values, methods, and acceptance conditions depend on the declared Infrastructure Quality Object, applicable Context-Specific Quality Outcome Criteria, and the Reference Layer.

Context-specific boundary. Emission and discharge limits, permit conditions, receptor classifications, impact-assessment methods, remediation criteria, and environmental acceptance thresholds remain in this Guide or the Reference Layer.

Context-Specific Interpretation

Environmental Protection concerns the quality of identifying, understanding, preventing, limiting, monitoring, and transparently addressing environmental interactions associated with the declared LNG Infrastructure Quality Object.

In the LNG context, environmental protection should be interpreted in relation to the declared Infrastructure Quality Object, the declared LNG-context realization pathway, applicable lifecycle condition, boundaries, interfaces, Assumptions, limitations, Critical Infrastructure Conditions, and Evidence basis.

LNG infrastructure may interact with air, water, soil, marine environments, coastal zones, rivers, ports, industrial sites, urban areas, ecological receptors, climate-related conditions, extreme weather, surrounding communities, emergency-response systems, and connected infrastructure systems. Where relevant, environmental interpretation should also keep visible fugitive methane, combustion emissions, refrigerants, flaring or venting, stormwater, wastewater, firewater, spill pathways, water-intake and outfall conditions, thermal discharge, and marine ecological exposure.

Environmental protection should not be interpreted only as permitting status, regulatory compliance, environmental documentation, or absence of observed environmental incident.

Such Evidence may support interpretation.

However, environmental protection under this Guide depends on whether environmental interactions, exposure pathways, emissions, discharges, abnormal conditions, degraded conditions, cumulative effects, lifecycle changes, monitoring limitations, and Evidence limitations are understood, controlled, retained, and transparently reflected in Infrastructure Quality Claim Statements.

Core Quality Indicators

The following Core Quality Indicator titles are invariant and governed by IQI_IQC1. The clauses under each Indicator provide LNG1 Context-Specific Interpretation, illustrative Context-Specific Quality Outcome Criteria, and Evidence considerations; they do not reproduce or replace the normative Core Indicator Statement.

4.7.1 Indicator 6.1 — Identification of Environmental Interactions and Exposure Pathways

Context-Specific Interpretation

In LNG infrastructure, environmental interactions and exposure pathways should be identified in relation to the declared Infrastructure Quality Object and its LNG-context realization pathway.

Environmental interactions may arise from liquefaction, cryogenic storage, boil-off gas management, LNG transfer, loading, unloading, regasification, send-out, utilities, emergency systems, marine interfaces, truck or rail interfaces, pipeline interfaces, maintenance, modification, temporary shutdown, recommissioning, repurposing, or decommissioning.

Exposure pathways may include air emissions, water discharges, soil exposure, stormwater pathways, groundwater pathways, marine or river pathways, coastal interaction, thermal effects, noise, light, traffic-related exposure, spill pathways, vapor dispersion, fire or emergency response pathways, waste pathways, and community exposure pathways.

Identification should not be limited to normal operating conditions.

It should also consider abnormal conditions, degraded conditions, emergency conditions, lifecycle transitions, environmental change, interface conditions, and unresolved Evidence gaps.

Illustrative Context-Specific Quality Outcome Criteria

Environmental interactions and exposure pathways may be considered adequately identified when:

- relevant environmental receptors are identified;
- relevant air, water, soil, marine, ecological, climate-related, and community pathways are identified where applicable;
- normal, abnormal, degraded, emergency, and lifecycle-transition conditions are considered;
- LNG-specific interactions involving cryogenic storage, transfer, boil-off gas, regasification, send-out, emissions, discharges, spills, vapor dispersion, fire, or emergency response are considered where relevant;
- internal and external interfaces affecting environmental exposure are identified;
- environmental Assumptions and Uncertainties are documented;
- environmental Critical Infrastructure Conditions are identified where relevant;
- exposure pathways are traceable to functional requirements, technical specifications, conformity assessment, monitoring, documentation, Evidence, and Infrastructure Quality Claim Statements.

Environmental interaction identification should be sufficiently complete to support prevention, limitation, monitoring, and transparent claim interpretation.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- environmental impact assessments;
- environmental baseline studies;
- environmental receptor studies;
- air pathway assessments;
- water pathway assessments;
- soil and groundwater assessments;
- marine or coastal assessments;
- stormwater management records;
- spill pathway analyses;
- vapor dispersion studies;
- fire and emergency-response consequence studies;
- environmental permit basis documents;
- ecological studies;
- community impact studies;
- environmental monitoring plans;
- Critical Infrastructure Conditions registers.

4.7.2 Indicator 6.2 — Prevention and Limitation of Unintended Releases and Environmental Harm

Context-Specific Interpretation

In LNG infrastructure, prevention and limitation of unintended releases and environmental harm concerns the ability of the declared Infrastructure Quality Object to avoid, control, limit, detect, respond to, and learn from environmental harm pathways.

Unintended releases may include LNG releases, natural gas releases, boil-off gas releases, refrigerant releases, chemical releases, fuel releases, wastewater releases, stormwater contamination, waste releases, air emissions outside intended control conditions, and other releases relevant to the declared boundary.

Environmental harm may arise from releases to air, water, soil, marine environments, ecological receptors, or surrounding communities.

In the LNG context, prevention and limitation may involve containment, pressure control, boil-off gas control, transfer control, loading and unloading control, emergency isolation, fire and gas detection, spill containment, drainage control, vapor dispersion limitation, environmental monitoring, emergency response, and interface coordination.

Prevention and limitation should be interpreted as infrastructure behavior, not only as written procedures or regulatory compliance.

Illustrative Context-Specific Quality Outcome Criteria

Prevention and limitation of unintended releases and environmental harm may be considered adequate when:

- relevant unintended release scenarios are identified;

- release prevention and limitation measures are defined;
- controls are aligned with the declared Infrastructure Quality Object and lifecycle condition;
- controls address LNG-specific conditions such as cryogenic containment, pressure control, boil-off gas behavior, transfer operations, loading, unloading, regasification, send-out, and emergency isolation where relevant;
- environmental protection measures address relevant air, water, soil, marine, ecological, and community pathways;
- abnormal and emergency conditions are considered;
- interface responsibilities are defined where environmental protection depends on connected systems or organizations;
- monitoring and response Evidence is available where relevant;
- unresolved limitations are documented and carried into Infrastructure Quality Claim Statements where relevant.

Prevention and limitation should be sufficient to support confidence that environmental harm is controlled within the declared boundary, lifecycle condition, and Evidence basis.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- release prevention studies;
- containment design records;
- spill prevention and control plans;
- drainage system records;
- boil-off gas control records;
- pressure-control records;
- transfer and loading control records;
- emergency shutdown and isolation test records;
- fire and gas detection records;
- vapor dispersion studies;
- environmental protection system test records;
- emergency-response plans;
- incident and near-miss records;
- environmental inspection records;
- corrective action records;
- environmental monitoring records;
- Infrastructure Quality Claim Statement limitation statements.

4.7.3 Indicator 6.3 — Environmental Protection Under Abnormal and Degraded Conditions

Context-Specific Interpretation

Environmental protection should remain interpretable under abnormal and degraded conditions, not only during normal operation.

In LNG infrastructure, abnormal and degraded conditions may include equipment failure, loss of containment, insulation degradation, increased boil-off gas, pressure-control upset, transfer interruption, loading or unloading failure, regasification upset, utility loss, monitoring failure, emergency shutdown, fire or gas detection event, extreme weather, flooding, seismic event, marine interface disturbance, transportation interface disruption, or emergency-response constraint.

Environmental protection may also be affected by degraded infrastructure condition, aging, corrosion, damaged containment, degraded drainage systems, incomplete monitoring, deferred maintenance, unresolved non-conformities, or temporary operating conditions.

Environmental protection under abnormal and degraded conditions should be evaluated because many environmental consequences become visible only when infrastructure behavior departs from normal operation.

Illustrative Context-Specific Quality Outcome Criteria

Environmental protection under abnormal and degraded conditions may be considered adequately addressed when:

- foreseeable abnormal and degraded conditions are identified;
- environmental consequences of those conditions are considered;
- controls for preventing or limiting harm under abnormal and degraded conditions are defined;
- cryogenic, pressure, storage, transfer, boil-off gas, regasification, send-out, emergency, and environmental interface conditions are considered where relevant;
- degraded monitoring or delayed detection is considered;
- emergency-response and environmental-response conditions are considered;
- Assumptions and limitations are documented;
- unresolved abnormal or degraded-condition issues are carried into Evidence interpretation and Infrastructure Quality Claim Statements where relevant.

Environmental protection should be sufficient to support credible interpretation of environmental behavior under the lifecycle condition and claim boundary being addressed.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- abnormal condition analyses;
- degraded condition assessments;
- environmental risk assessments;
- emergency scenario analyses;
- utility failure analyses;
- monitoring failure analyses;
- spill response records;
- stormwater and drainage assessments;
- fire and vapor dispersion consequence studies;
- extreme weather assessments;
- flooding assessments;
- seismic assessments;
- incident and near-miss records;
- inspection and maintenance records;
- environmental monitoring records;
- emergency drill records;
- corrective action records.

4.7.4 Indicator 6.4 — Consideration of Cumulative and Long-Term Environmental Effects

Context-Specific Interpretation

Environmental protection in LNG infrastructure should consider cumulative and long-term effects where they are relevant to the declared Infrastructure Quality Object, lifecycle condition, boundaries, interfaces, and Infrastructure Quality Claim Statement.

Cumulative effects may arise from repeated small releases, recurring emissions, repeated discharges, routine flaring or venting where applicable, stormwater impacts, vessel or vehicle traffic, noise, light, waste generation, maintenance activities, overlapping industrial activities, or combined effects with connected infrastructure.

Long-term effects may arise from aging infrastructure, changing environmental exposure, climate-related conditions, coastal change, flooding risk, corrosion, ecological change, land-use change, community exposure, or accumulated operating history.

Cumulative and long-term effects should not be ignored merely because individual events or emissions are within allowed limits or because no immediate failure has been observed.

In the LNG context, cumulative and long-term interpretation is important where environmental protection depends on monitoring visibility, operating trends, condition changes, interface Assumptions, emergency access, or community exposure over time.

Illustrative Context-Specific Quality Outcome Criteria

Cumulative and long-term environmental effects may be considered adequately addressed when:

- relevant cumulative environmental interactions are identified;
- relevant long-term environmental effects are identified;
- repeated, recurring, or chronic exposure pathways are considered where applicable;
- emissions, discharges, waste, traffic, noise, light, stormwater, marine, coastal, ecological, and community effects are considered where relevant;
- aging, degradation, operating history, and environmental change are considered;
- monitoring and trend information is evaluated where relevant;
- Assumptions and Uncertainties are documented;
- cumulative or long-term Critical Infrastructure Conditions are identified where relevant;
- Infrastructure Quality Claim Statements do not treat short-term absence of observed harm as proof that cumulative or long-term effects are controlled.

Consideration of cumulative and long-term effects should be sufficient to support lifecycle-aware environmental protection interpretation.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- cumulative impact assessments;
- long-term environmental monitoring records;
- emissions trend records;
- discharge trend records;
- stormwater monitoring records;
- waste management records;
- noise and light monitoring records;
- traffic and transportation impact records;

- marine and coastal monitoring records;
- ecological monitoring records;
- corrosion and environmental exposure records;
- climate-related exposure assessments;
- community complaint and response records;
- operating history records;
- environmental performance reviews;
- Infrastructure Quality Claim Statement limitation statements.

4.7.5 Indicator 6.5 — Environmental Protection Alignment Under Change

Context-Specific Interpretation

Environmental protection should remain aligned when LNG infrastructure changes.

Changes may include functional changes, technical changes, operational changes, lifecycle changes, interface changes, environmental changes, regulatory changes, ownership or organizational changes, expansion, modification, repair, temporary shutdown, recommissioning, repurposing, or decommissioning.

In LNG infrastructure, environmental protection alignment may be affected by changed throughput, changed gas composition, changed storage use, changed boil-off gas management, changed transfer mode, added loading or unloading functions, changed regasification or send-out conditions, changed marine or transportation interface, changed emergency-response arrangements, changed environmental exposure, or changed monitoring coverage.

A control that was adequate under one configuration or lifecycle condition may not remain adequate after change.

Therefore, environmental protection should be reassessed where change affects environmental interactions, exposure pathways, emissions, discharges, abnormal conditions, degraded conditions, cumulative effects, Critical Infrastructure Conditions, or Infrastructure Quality Claim Statement validity.

Illustrative Context-Specific Quality Outcome Criteria

Environmental protection alignment under change may be considered preserved when:

- changes affecting environmental interactions are identified;
- changes affecting exposure pathways are evaluated;
- changes affecting emissions, discharges, waste, stormwater, noise, traffic, marine, ecological, or community effects are considered where relevant;
- effects on environmental Critical Infrastructure Conditions are reviewed;
- effects on monitoring, Evidence, emergency response, and interface responsibilities are considered;
- Assumptions and Uncertainties are updated;
- environmental protection measures are revised where necessary;
- unresolved change-related environmental limitations are documented;
- Infrastructure Quality Claim Statements are revised, limited, withdrawn, or re-evidenced where environmental protection alignment changes.

Environmental protection should not be presumed preserved merely because existing permits, procedures, or controls remain in place.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- management-of-change records;

- environmental change assessments;
- permit applicability reviews;
- emissions reassessments;
- discharge reassessments;
- stormwater reassessments;
- waste management reassessments;
- marine or transportation interface reassessments;
- emergency-response reassessments;
- monitoring coverage reassessments;
- environmental risk reassessments;
- community impact reassessments;
- updated Assumptions registers;
- updated Critical Infrastructure Conditions registers;
- revised Infrastructure Quality Claim Statements.

4.7.6 Indicator 6.6 — Understanding and Limitation of Emissions and Discharges

Context-Specific Interpretation

Understanding and limitation of emissions and discharges concerns whether emissions and discharges associated with the declared LNG Infrastructure Quality Object are identified, characterized, controlled, monitored, and interpreted within the applicable boundary and lifecycle condition.

In the LNG context, emissions and discharges may include combustion emissions, vented or flared gas where applicable, fugitive methane emissions, boil-off gas-related emissions, refrigerant emissions, emergency releases, wastewater discharges, stormwater discharges, process-related discharges, drainage system discharges, firewater or foam runoff, water-intake and outfall effects, thermal discharge where applicable, waste streams, and other release pathways relevant to the declared boundary.

Understanding emissions and discharges means more than identifying that regulatory limits exist.

It requires visibility of what emissions and discharges may occur, under what conditions, through which pathways, with what controls, with what monitoring, and with what limitations in Evidence.

Limitation of emissions and discharges should be interpreted in relation to normal operation, abnormal operation, degraded conditions, lifecycle transitions, and changes in infrastructure behavior.

Illustrative Context-Specific Quality Outcome Criteria

Emissions and discharges may be considered adequately understood and limited when:

- relevant emissions and discharge sources are identified;
- pathways to air, water, soil, marine environments, and communities are identified where applicable;
- normal, abnormal, degraded, emergency, and lifecycle-transition conditions are considered;
- emissions and discharges associated with boil-off gas, flaring, venting, combustion, refrigerants, transfer operations, regasification, utilities, drainage, stormwater, and waste are considered where relevant;
- controls for limiting emissions and discharges are defined;
- monitoring or estimation methods are identified where relevant;
- Assumptions, Uncertainties, and Evidence limitations are documented;
- emissions or discharge-related Critical Infrastructure Conditions are identified where relevant;

- Infrastructure Quality Claim Statements do not imply environmental protection beyond the emissions and discharge Evidence basis.

Understanding and limitation should be sufficient to support transparent interpretation of environmental protection within the declared Infrastructure Quality Object and claim boundary.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- emissions inventories;
- greenhouse gas inventories;
- fugitive emissions monitoring records;
- methane monitoring records;
- flaring and venting records;
- boil-off gas management records;
- combustion emissions records;
- refrigerant management records;
- wastewater discharge records;
- stormwater discharge records;
- drainage system records;
- waste management records;
- environmental monitoring records;
- permit reporting records;
- emissions calculations;
- discharge sampling records;
- abnormal release records;
- corrective action records;
- Infrastructure Quality Claim Statement Evidence files.

4.7.7 Indicator 6.7 — Environmental Information Retention and Transparency

Context-Specific Interpretation

Environmental information retention and transparency concerns preservation and communication of information needed to understand, assess, maintain, and claim environmental protection across the lifecycle of the declared LNG Infrastructure Quality Object.

In LNG infrastructure, environmental information may include environmental baseline records, environmental impact assessments, permit basis records, emissions records, discharge records, monitoring records, incident records, abnormal release records, emergency-response records, inspection records, maintenance records, management-of-change records, community impact records, complaints, corrective actions, and Infrastructure Quality Claim Statement Evidence.

Environmental information should be retained in a way that preserves traceability between environmental interactions, exposure pathways, controls, Assumptions, Uncertainties, Critical Infrastructure Conditions, monitoring results, Unresolved Conditions, limitations, and Infrastructure Quality Claim Statements.

Loss or fragmentation of environmental information may weaken understanding of cumulative effects, long-term effects, emissions, discharges, environmental protection alignment under change, and claim validity.

Transparency is especially important where environmental information affects regulators, operators, emergency responders, affected stakeholders, communities, connected infrastructure operators, or users of an Infrastructure Quality Claim Statement.

Illustrative Context-Specific Quality Outcome Criteria

Environmental information may be considered adequately retained and transparent when:

- environmental information relevant to the declared Infrastructure Quality Object is identified and retained;
- environmental interactions, exposure pathways, emissions, discharges, monitoring results, Assumptions, limitations, and Unresolved Conditions remain traceable;
- environmental information concerning Critical Infrastructure Conditions is retained;
- environmental records remain accessible to appropriate users across lifecycle stages;
- environmental information supports reassessment after change, abnormal condition, incident, lifecycle transition, or environmental change;
- cumulative and long-term information is retained where relevant;
- loss, fragmentation, or inaccessibility of environmental information is identified as an Evidence limitation;
- Infrastructure Quality Claim Statements identify the environmental Evidence basis and limitations where relevant.

Environmental information retention should support continued interpretation of environmental protection within the declared boundary and lifecycle condition.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- environmental baseline records;
- environmental impact assessment records;
- environmental permit basis records;
- emissions records;
- discharge records;
- monitoring records;
- sampling records;
- inspection records;
- environmental incident records;
- abnormal release records;
- emergency-response records;
- corrective action records;
- community complaint and response records;
- environmental management-of-change records;
- cumulative impact records;
- long-term trend records;
- Critical Infrastructure Conditions registers;
- document-control records;
- Infrastructure Quality Claim Statement Evidence files.

4.8 Factor 7 — Operational Reliability

Purpose of the Factor

The authoritative IQC1 purpose is:

To ensure that the declared Infrastructure Quality Object realizes its Infrastructure Intended Functions and Infrastructure Intended Results consistently, stably, and recoverably under applicable Infrastructure Operating Conditions, including Operational Variability, Operational Disturbance, Disruption, Degradation and Aging, and change across the Lifecycle.

Core architecture role: Examines continuity, stability, disturbance tolerance, and recovery of intended functional performance under relevant operating conditions.

Definitions and Governing Terms

Governing IQI terms. Infrastructure Operating Condition and Degradation and Aging apply with their authoritative IQI_VOC1 meanings. Operating Envelope applies as defined under Factor 1, and the Factor 4 condition terms apply where relevant.

IQC1 Factor-specific terms. Operational Reliability, Reliability-Critical Function, Operational Variability, Operational Disturbance, Disruption, Recovery Capability, and Continuity, Stability, and Recoverability apply as defined in IQI_IQC1 and are not redefined in LNG1.

LNG1 context terms and anchors. feed-gas receipt, liquefaction, refrigeration, cryogenic storage, inventory control, boil-off gas management, transfer, loading, unloading, regasification, send-out, MNT1 Interface continuity, utility and control-system availability, berth and carrier coordination, operating-mode transition, startup, shutdown, cooldown, first fill, recovery, maintenance, and restoration under variable demand and environmental conditions. Their technical meaning, values, methods, and acceptance conditions depend on the declared Infrastructure Quality Object, applicable Context-Specific Quality Outcome Criteria, and the Reference Layer.

Context-specific boundary. Availability targets, reliability targets, redundancy levels, recovery times, service-continuity requirements, and performance thresholds are established through Context-Specific Quality Outcome Criteria and the applicable Reference Layer. The broad term resilience shall not substitute for the more precise Core term applicable to the condition being examined.

Context-Specific Interpretation

Operational Reliability concerns the ability of the declared LNG Infrastructure Quality Object to perform its intended infrastructure function consistently under expected operating conditions, tolerate operational variability, recover from disruption, and preserve reliable behavior as infrastructure conditions change over time.

In the LNG context, operational reliability should be interpreted in relation to the declared Infrastructure Quality Object, the declared LNG-context realization pathway, applicable lifecycle condition, boundaries, interfaces, Assumptions, limitations, Critical Infrastructure Conditions, and Evidence basis.

Operational reliability may involve liquefaction continuity, cryogenic storage availability, boil-off gas management, transfer reliability, loading and unloading reliability, regasification reliability, send-out reliability, berth or mooring availability where applicable, metocean operating limits where applicable, utility and power reliability, monitoring reliability, control-system reliability, safety-system availability, emergency-system readiness, environmental-control reliability, and interface reliability where relevant.

Operational Reliability is not demonstrated merely by nameplate capacity, production volume, storage capacity, send-out capacity, successful operation on a particular day, or absence of observed interruption.

It is demonstrated by the extent to which the declared LNG Infrastructure Quality Object preserves functional performance within its intended operating envelope, lifecycle condition, boundaries, interfaces, Uncertainties, Evidence limitations, and Infrastructure Quality Claim Statement scope.

Operational Reliability includes continuity and compatibility at MNT1-connected feed-gas and send-out Interfaces. It does not imply the reliability of MNT1 or of a downstream LNGFS1 object outside the declared claim Boundary.

Core Quality Indicators

The following Core Quality Indicator titles are invariant and governed by IQI_IQC1. The clauses under each Indicator provide LNG1 Context-Specific Interpretation, illustrative Context-Specific Quality Outcome Criteria, and Evidence considerations; they do not reproduce or replace the normative Core Indicator Statement.

4.8.1 Indicator 7.1 — Definition of Reliability-Critical Functions

Context-Specific Interpretation

In LNG infrastructure, reliability-critical functions are functions whose failure, degradation, unavailability, or loss of visibility may prevent the declared Infrastructure Quality Object from realizing its intended function within the declared boundary and lifecycle condition.

Reliability-critical functions may include gas receipt, liquefaction, cryogenic storage, boil-off gas management, pressure control, thermal control, LNG transfer, loading, unloading, regasification, send-out, utility supply, power supply, control-system operation, monitoring, communication, safety-system availability, emergency isolation, environmental-control functions, and interface coordination where relevant.

The identification of reliability-critical functions should depend on the declared LNG-context realization pathway.

For example, the reliability-critical functions of an LNG storage facility may differ from those of a liquefaction facility, regasification terminal, FSRU, transfer system, satellite LNG facility, peak-shaving facility, or integrated LNG terminal.

Reliability-critical functions should also be understood in relation to Critical Infrastructure Conditions, lifecycle transitions, and external interface dependencies.

Illustrative Context-Specific Quality Outcome Criteria

Reliability-critical functions may be considered adequately defined when:

- the principal functions necessary for reliable realization of the declared LNG-context pathway are identified;
- reliability-critical functions are linked to the declared Infrastructure Quality Object;
- relevant operating modes are identified;
- relevant boundaries and interfaces are identified;
- functions involving cryogenic storage, liquefaction, transfer, loading, unloading, boil-off gas management, regasification, send-out, utilities, monitoring, control, safety, emergency, and environmental systems are considered where applicable;
- dependencies on connected infrastructure are identified where relevant;
- lifecycle-stage and lifecycle-transition reliability needs are considered;
- reliability-critical functions affecting Critical Infrastructure Conditions are identified;
- reliability-critical functions are traceable to functional requirements, technical specifications, monitoring, Evidence, and Infrastructure Quality Claim Statements.

Reliability-critical functions should be sufficiently defined to support later interpretation of operational performance, degradation, disruption, recovery, change, and claim validity.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- reliability basis documents;
- operating philosophy documents;
- functional requirement documents;
- reliability-critical function lists;
- system availability studies;
- process availability studies;
- utility dependency assessments;
- interface dependency assessments;
- operational readiness reviews;
- critical equipment or system lists;
- operating-mode analyses;
- maintenance strategies;
- monitoring strategies;
- Critical Infrastructure Conditions registers;
- Infrastructure Quality Claim Statement Evidence mapping.

4.8.2 Indicator 7.2 — Consistency of Functional Performance Under Expected Operating Conditions

Context-Specific Interpretation

In LNG infrastructure, consistency of functional performance under expected operating conditions means that the declared Infrastructure Quality Object can perform its intended function in a stable, controlled, and repeatable manner within its stated operating envelope.

Expected operating conditions may include normal operation, startup, cooldown, first LNG introduction, storage, transfer, loading, unloading, regasification, send-out, boil-off gas management, standby operation, planned maintenance conditions, and expected interface conditions where relevant.

Consistency should be interpreted in relation to the declared LNG-context realization pathway.

For example, consistent performance for a liquefaction facility may involve stable liquefaction and associated process conditions, while consistent performance for a regasification terminal may involve stable regasification and send-out behavior.

In the LNG context, performance consistency may be affected by gas composition, ambient conditions, cryogenic conditions, pressure control, thermal stability, boil-off gas behavior, storage duration, transfer rates, utility availability, monitoring reliability, and connected-system Assumptions.

Illustrative Context-Specific Quality Outcome Criteria

Functional performance under expected operating conditions may be considered consistent when:

- expected operating conditions are identified;
- operating envelope Assumptions are stated;
- the declared Infrastructure Quality Object performs the intended function within the applicable operating envelope;
- cryogenic, thermal, pressure, storage, transfer, boil-off gas, regasification, send-out, utility, monitoring, control, and interface conditions remain stable where relevant;
- performance is supported by Evidence appropriate to the lifecycle condition;
- deviations, interruptions, degraded conditions, and operating limitations are documented;

- performance Evidence is connected to functional requirements and technical specifications;
- Infrastructure Quality Claim Statements identify the operating conditions to which the reliability interpretation applies.

Consistency should be sufficient to support confidence that the declared LNG Infrastructure Quality Object can realize its intended function under the expected conditions claimed.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- operating records;
- production records;
- storage records;
- transfer records;
- loading and unloading records;
- regasification records;
- send-out records;
- boil-off gas management records;
- process trend data;
- alarm and trip records;
- utility availability records;
- control-system performance records;
- monitoring records;
- operational readiness records;
- maintenance records;
- operating envelope records;
- Infrastructure Quality Claim Statement limitation statements.

4.8.3 Indicator 7.3 — Tolerance to Operational Variability and Disturbance

Context-Specific Interpretation

LNG infrastructure should be interpreted in relation not only to stable expected conditions, but also to operational variability and disturbance.

Operational variability may arise from changes in gas composition, feed-gas conditions, ambient conditions, storage levels, transfer rates, shipping schedules, truck or rail loading conditions, downstream demand, send-out requirements, utility availability, operating modes, maintenance conditions, environmental exposure, or connected-system behavior.

Disturbance may arise from equipment trips, utility loss, control-system issues, abnormal pressure behavior, increased boil-off gas generation, transfer interruption, delayed vessel or truck arrival, downstream constraint, weather event, emergency isolation, or monitoring limitation.

Tolerance to operational variability and disturbance does not mean unlimited ability to operate under any condition.

It means that relevant variability and disturbance are understood, bounded, controlled, monitored, and reflected in Evidence and Infrastructure Quality Claim Statements.

Illustrative Context-Specific Quality Outcome Criteria

Tolerance to operational variability and disturbance may be considered adequate when:

- relevant sources of operational variability are identified;
- relevant disturbance scenarios are identified;

- operating limits and response conditions are defined;
- cryogenic, thermal, pressure, storage, transfer, boil-off gas, regasification, send-out, utility, monitoring, safety, emergency, and interface effects are considered where relevant;
- variability or disturbance affecting Critical Infrastructure Conditions is identified;
- controls, procedures, monitoring, or recovery measures are aligned with the variability or disturbance;
- Evidence supports the claimed tolerance;
- limitations are documented;
- Infrastructure Quality Claim Statements do not imply reliability under conditions outside the demonstrated or bounded operating envelope.

Tolerance should be sufficient to support credible interpretation of operational reliability within the declared boundary and lifecycle condition.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- operating envelope analyses;
- variability studies;
- disturbance response analyses;
- process trend records;
- alarm and trip history;
- utility interruption records;
- transfer interruption records;
- boil-off gas upset records;
- regasification and send-out variability records;
- downstream constraint records;
- weather and environmental event records;
- abnormal operation records;
- incident and near-miss records;
- control-system response records;
- operational risk reviews;
- Infrastructure Quality Claim Statement limitation statements.

4.8.4 Indicator 7.4 — Recovery Capability Following Disruption

Context-Specific Interpretation

Recovery capability concerns the ability of the declared LNG Infrastructure Quality Object to restore intended infrastructure behavior after disruption within a defined boundary, lifecycle condition, and operating context.

In LNG infrastructure, disruptions may include process trips, utility failure, transfer interruption, loading or unloading interruption, boil-off gas upset, pressure-control upset, regasification interruption, send-out interruption, monitoring failure, control-system failure, environmental event, emergency shutdown, equipment failure, transportation delay, or connected-system constraint.

Recovery should be interpreted as infrastructure behavior, not merely as the existence of a restart procedure or emergency plan.

Recovery may depend on equipment condition, control-system capability, safety-system status, emergency isolation, utility availability, personnel competence, interface coordination, environmental conditions, monitoring visibility, and retained Evidence.

In the LNG context, recovery may be especially sensitive to cryogenic condition, thermal transition, pressure stabilization, storage condition, boil-off gas management, and interface readiness.

Illustrative Context-Specific Quality Outcome Criteria

Recovery capability following disruption may be considered adequate when:

- relevant disruption scenarios are identified;
- recovery objectives and limits are defined;
- recovery actions are aligned with the declared Infrastructure Quality Object and lifecycle condition;
- cryogenic, thermal, pressure, storage, transfer, boil-off gas, regasification, send-out, utility, monitoring, control, safety, emergency, environmental, and interface conditions are considered where relevant;
- recovery does not create unacceptable additional risk or environmental harm;
- Evidence supports recovery capability where claimed;
- limitations, dependencies, and unresolved conditions are documented;
- Infrastructure Quality Claim Statements reflect recovery limitations where relevant.

Recovery capability should be sufficient to support credible interpretation of reliability following disruption within the claim boundary and Evidence basis.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- restart procedures;
- recovery plans;
- emergency-response plans;
- disruption scenario analyses;
- emergency shutdown and restart records;
- process trip records;
- utility failure response records;
- transfer interruption response records;
- boil-off gas upset response records;
- regasification restart records;
- send-out restoration records;
- control-system recovery records;
- operational drills;
- incident and near-miss reviews;
- corrective action records;
- operational readiness reviews;
- Infrastructure Quality Claim Statement limitation statements.

4.8.5 Indicator 7.5 — Reliability Implications of Degradation and Aging

Context-Specific Interpretation

Operational reliability may decrease as LNG infrastructure degrades or ages.

Reliability interpretation should therefore consider degradation and aging mechanisms that may affect the ability of the declared Infrastructure Quality Object to perform its intended function over time.

In LNG infrastructure, degradation and aging may affect tanks, containment systems, insulation, piping, valves, pumps, compressors, vaporizers, heat exchangers, transfer systems, loading arms, hoses, electrical systems, instrumentation, control systems, safety systems, emergency systems, utilities, foundations, structures, environmental controls, and monitoring systems.

Reliability may also be affected by condition history, maintenance history, operating history, thermal cycling, cooldown and warm-up cycles, corrosion, fatigue, vibration, settlement, obsolescence, spare parts availability, software or control-system aging, and changes in organizational knowledge.

Aging should not be interpreted only as calendar age.

It should be interpreted in relation to actual operating conditions, condition Evidence, maintenance effectiveness, monitoring visibility, modification history, and Unresolved Conditions.

Illustrative Context-Specific Quality Outcome Criteria

Reliability implications of degradation and aging may be considered adequately addressed when:

- degradation and aging mechanisms affecting reliability are identified;
- reliability-critical systems and functions affected by degradation are identified;
- cryogenic, thermal, pressure, storage, transfer, boil-off gas, regasification, send-out, utility, monitoring, safety, emergency, and environmental systems are considered where relevant;
- maintenance, inspection, testing, monitoring, and reassessment are aligned with reliability-relevant degradation;
- aging-related Assumptions and Uncertainties are documented;
- obsolete, degraded, temporary, or unsupported systems are identified where relevant;
- degradation affecting Critical Infrastructure Conditions is tracked;
- Infrastructure Quality Claim Statements reflect degradation, aging, Evidence limitations, and lifecycle condition where relevant.

Reliability interpretation should be sufficient to support understanding of whether the declared Infrastructure Quality Object can continue to perform its intended function over time.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- reliability assessments;
- aging assessments;
- degradation mechanism reviews;
- inspection records;
- maintenance records;
- failure history records;
- equipment condition records;
- spare parts and obsolescence records;
- tank and piping inspection records;
- insulation condition records;
- pump, compressor, vaporizer, and heat-exchanger records;
- control-system and instrumentation records;
- safety-system proof test records;
- utility availability records;
- monitoring records;
- corrective action records;
- lifecycle reassessment records.

4.8.6 Indicator 7.6 — Reliability Under Change and Modification

Context-Specific Interpretation

Operational reliability should remain interpretable when LNG infrastructure is changed, modified, expanded, repaired, repurposed, recommissioned, or operated under changed conditions.

Changes may affect the declared Infrastructure Quality Object, operating envelope, lifecycle condition, boundaries, interfaces, Assumptions, reliability-critical functions, Critical Infrastructure Conditions, monitoring coverage, Evidence basis, or Infrastructure Quality Claim Statement validity.

In LNG infrastructure, reliability may be affected by changes to gas supply, gas composition, liquefaction capacity, storage use, storage duration, boil-off gas management, transfer configuration, loading or unloading mode, regasification capacity, send-out requirements, utility systems, control systems, safety systems, monitoring systems, emergency response, environmental conditions, transportation interfaces, or organizational responsibilities.

A change may improve one aspect of performance while reducing reliability elsewhere.

For example, increased throughput may affect equipment loading, maintenance windows, boil-off gas behavior, transfer scheduling, utility demand, monitoring needs, or downstream interface stability.

Illustrative Context-Specific Quality Outcome Criteria

Reliability under change and modification may be considered adequately addressed when:

- changes affecting reliability are identified and documented;
- effects on reliability-critical functions are evaluated;
- effects on operating modes and operating envelope are evaluated;
- effects on boundaries and interfaces are evaluated;
- effects on lifecycle condition are evaluated;
- effects on cryogenic, thermal, pressure, storage, transfer, boil-off gas, regasification, send-out, utility, monitoring, control, safety, emergency, environmental, and interface systems are considered where relevant;
- Assumptions, Uncertainties, and Critical Infrastructure Conditions are updated;
- operating Evidence, monitoring Evidence, maintenance strategy, and recovery capability are updated where needed;
- Infrastructure Quality Claim Statements are revised, limited, withdrawn, or re-evidenced where reliability Assumptions change.

Reliability should not be presumed preserved merely because modified infrastructure remains operational.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- management-of-change records;
- reliability impact assessments;
- operating envelope revisions;
- throughput change assessments;
- transfer configuration change assessments;
- boil-off gas management change records;
- regasification or send-out change assessments;
- utility system change assessments;
- control-system modification records;

- monitoring coverage reassessments;
- maintenance strategy revisions;
- commissioning and recommissioning records;
- operational readiness reviews;
- updated Critical Infrastructure Conditions registers;
- revised Infrastructure Quality Claim Statements.

4.8.7 Indicator 7.7 — Reliability-Relevant Information Retention

Context-Specific Interpretation

Reliability-relevant information retention concerns preservation of information needed to understand, assess, maintain, restore, and claim operational reliability across the lifecycle of the declared LNG Infrastructure Quality Object.

In LNG infrastructure, reliability information may be distributed across design records, operating records, maintenance records, inspection records, monitoring records, failure records, alarm and trip records, repair records, spare parts records, modification records, commissioning records, recommissioning records, interface records, emergency records, and Infrastructure Quality Claim Statement Evidence.

Reliability information should preserve traceability between intended function, operating envelope, reliability-critical functions, degradation, disruptions, recovery actions, Assumptions, limitations, Critical Infrastructure Conditions, Evidence, and Infrastructure Quality Claim Statements.

Loss or fragmentation of reliability information may obscure degradation trends, repeated failures, Assumption drift, unresolved operational limitations, interface weakness, or Evidence limitations.

Retention of reliability-relevant information is especially important for aging, modified, brownfield, multi-operator, floating, transportation-connected, or interface-dependent LNG infrastructure.

Illustrative Context-Specific Quality Outcome Criteria

Reliability-relevant information may be considered adequately retained when:

- information needed to understand reliability condition is identified and retained;
- operating, maintenance, inspection, monitoring, failure, repair, modification, and lifecycle transition records are retained where relevant;
- information concerning reliability-critical functions is retained;
- information concerning Critical Infrastructure Conditions is retained;
- Assumptions, Uncertainties, limitations, disruptions, and Unresolved Conditions are retained;
- reliability information remains accessible and traceable across lifecycle stages;
- information remains connected to the declared Infrastructure Quality Object, boundaries, interfaces, and lifecycle condition;
- loss, fragmentation, or inaccessibility of reliability information is identified as an Evidence limitation;
- Infrastructure Quality Claim Statements are not made beyond retained and traceable reliability Evidence.

Information retention should be sufficient to support future reassessment, recovery evaluation, change evaluation, lifecycle transition, and bounded Infrastructure Quality Claim Statements.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- operating history records;
- reliability records;
- maintenance records;

- inspection records;
- monitoring records;
- failure history records;
- alarm and trip records;
- process trend records;
- repair records;
- spare parts records;
- obsolescence records;
- modification records;
- commissioning and recommissioning records;
- recovery records;
- interface reliability records;
- Critical Infrastructure Conditions registers;
- Evidence indexes;
- document-control records;
- Infrastructure Quality Claim Statement Evidence files.

4.9 Factor 8 — Workplace Human Interaction and Safety

Purpose of the Factor

The authoritative IQC1 purpose is:

To ensure that Infrastructure Quality accounts for Workplace Human-Infrastructure Interaction and the ways in which Infrastructure Configuration, condition, Interfaces, operating context, Human Capabilities and Limitations, and Error-Provoking Conditions affect Infrastructure Safety and Function Realization across the Lifecycle.

Core architecture role: Examines workplace human–infrastructure interfaces where design, condition, information, or operating context can affect safe Function Realization.

Definitions and Governing Terms

Governing WQI and IQI terms. Assumption, Infrastructure Safety, Infrastructure Operating Condition, and the Factor 4 definitions of Abnormal Operating Condition, Transient Condition, and Degraded Condition govern their use in this Factor.

IQC1 Factor-specific terms. Workplace Human-Infrastructure Interaction, Workplace Human-Infrastructure Interaction Point, Human Capability, Human Limitation, Human Performance Assumption, Error-Provoking Workplace Condition, Human Error, Workplace Contextual Pressure, and Workplace Safety apply as defined in IQI_IQC1 and are not redefined in LNG1.

LNG1 context terms and anchors. cryogenic and pressure exposure; control-room and field interaction; process trains, tanks, pumps, compressors, valves, vaporizers, loading arms, hoses, berths, road-tanker, rail, and ISO-container bulk-transfer areas; marine and port coordination; confined or restricted areas; startup, cooldown, transfer, maintenance, simultaneous operations, emergency response, alarms, shutdowns, fatigue, workload, communication, and error-provoking workplace conditions. Automotive LNG fueling operations remain outside LNG1 and within LNGFS1. Their technical meaning, values, methods, and acceptance conditions depend on the declared Infrastructure Quality Object, applicable Context-Specific Quality Outcome Criteria, and the Reference Layer.

Context-specific boundary. Training content, staffing requirements, qualification rules, ergonomic limits, personal protective provisions, and occupational-safety thresholds remain governed by the Context Guide or applicable Reference Layer. Personnel Competence is addressed under Factor 9.

Context-Specific Interpretation

Workplace Human Interaction and Safety concerns the quality of interaction between people and the declared LNG Infrastructure Quality Object where human work, observation, decision-making, operation, maintenance, inspection, emergency response, or other workplace activity affects infrastructure quality.

In the LNG context, workplace human interaction should be interpreted in relation to the declared Infrastructure Quality Object, the declared LNG-context realization pathway, applicable lifecycle condition, boundaries, interfaces, Assumptions, limitations, Critical Infrastructure Conditions, and Evidence basis.

LNG infrastructure may involve workplace interactions with cryogenic systems, storage systems, transfer systems, loading and unloading systems, boil-off gas management systems, regasification systems, send-out systems, control rooms, monitoring systems, safety systems, emergency systems, utilities, marine interfaces, truck or rail interfaces, maintenance areas, and environmental protection systems.

Workplace safety should not be interpreted only as occupational injury prevention or compliance with workplace safety rules.

Under this Guide, workplace human interaction is quality-relevant because human understanding, visibility, access, communication, physical layout, control interfaces, alarm interpretation, maintenance conditions, emergency response, and contextual pressures may affect the behavior of the declared LNG Infrastructure Quality Object and the validity of Infrastructure Quality Claim Statements.

Core Quality Indicators

The following Core Quality Indicator titles are invariant and governed by IQI_IQC1. The clauses under each Indicator provide LNG1 Context-Specific Interpretation, illustrative Context-Specific Quality Outcome Criteria, and Evidence considerations; they do not reproduce or replace the normative Core Indicator Statement.

4.9.1 Indicator 8.1 — Identification of Workplace Human–Infrastructure Interaction Points

Context-Specific Interpretation

In LNG infrastructure, workplace human–infrastructure interaction points should be identified where people interact with the declared Infrastructure Quality Object during planning, construction, commissioning, cooldown, operation, maintenance, inspection, testing, monitoring, transfer, loading, unloading, regasification, send-out, emergency response, modification, recommissioning, repurposing, or decommissioning.

Interaction points may include control rooms, field equipment, valves, loading arms, hoses, transfer connections, tanks, pumps, compressors, vaporizers, instrumentation, control panels, alarms, emergency shutdown devices, fire and gas systems, access routes, inspection points, maintenance areas, marine interfaces, truck or rail loading areas, utility systems, environmental monitoring points, and emergency-response locations.

Identification should include both routine and non-routine interaction points.

In the LNG context, human interaction points may be especially significant where cryogenic conditions, pressure, flammable gas, restricted access, limited visibility, emergency isolation, simultaneous operations, or multi-organization interfaces are present.

Illustrative Context-Specific Quality Outcome Criteria

Workplace human–infrastructure interaction points may be considered adequately identified when:

- relevant routine interaction points are identified;
- relevant non-routine interaction points are identified;
- interaction points during commissioning, cooldown, first LNG introduction, operation, maintenance, inspection, transfer, loading, unloading, regasification, send-out, emergency response, modification, recommissioning, and decommissioning are considered where applicable;
- interaction points involving cryogenic, pressure, transfer, boil-off gas, safety, emergency, monitoring, control, environmental, and utility systems are identified where relevant;
- interaction points at internal and external interfaces are considered;
- interaction points affecting Critical Infrastructure Conditions are identified;
- Assumptions and limitations regarding human access, visibility, communication, and control are documented;
- interaction points are traceable to functional requirements, technical specifications, monitoring, Evidence, and Infrastructure Quality Claim Statements.

Identification should be sufficient to support evaluation of whether workplace interaction supports or weakens infrastructure quality.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- workplace interaction maps;
- control-room interface descriptions;
- human-machine interface descriptions;
- operating procedure maps;
- task analyses;
- job safety analyses;
- maintenance access reviews;
- inspection access reviews;
- emergency-response access reviews;
- transfer and loading interface reviews;
- marine, truck, or rail interface records;
- alarm and control-system reviews;
- field walkdown records;
- commissioning and operational readiness reviews;
- Critical Infrastructure Conditions registers.

4.9.2 Indicator 8.2 — Consideration of Human Capabilities and Limitations in Workplace Interaction

Context-Specific Interpretation

In LNG infrastructure, workplace interaction should consider human capabilities and limitations relevant to safe and reliable interaction with the declared Infrastructure Quality Object.

Human capabilities and limitations may involve perception, attention, memory, physical access, communication, fatigue, workload, decision-making, response time, situational awareness, interpretation of alarms, understanding of abnormal conditions, and ability to act under emergency or degraded conditions.

In the LNG context, these considerations may be especially important where people must interpret cryogenic conditions, pressure conditions, boil-off gas behavior, transfer conditions, abnormal process behavior, alarm sequences, emergency shutdown conditions, environmental warnings, or interface conditions with marine, truck, rail, pipeline, or emergency-response systems.

The purpose is not to create a separate human-factors standard.

The purpose is to ensure that workplace human interaction does not become an invisible weakness in the infrastructure-quality interpretation.

Illustrative Context-Specific Quality Outcome Criteria

Human capabilities and limitations may be considered adequately addressed when:

- relevant human tasks and decisions are identified;
- physical access and visibility limitations are considered;
- control-room and field interaction conditions are considered;
- alarm, monitoring, and communication conditions are considered;
- fatigue, workload, time pressure, simultaneous operations, and emergency conditions are considered where relevant;
- interaction with cryogenic, pressure, transfer, boil-off gas, regasification, send-out, safety, emergency, and environmental systems is considered where relevant;
- human limitations affecting Critical Infrastructure Conditions are identified;
- Assumptions about human response or decision-making are documented;
- workplace interaction Evidence supports the intended Infrastructure Quality Claim Boundary.

Consideration should be sufficient to support confidence that the infrastructure can be understood, operated, maintained, monitored, and responded to within realistic workplace conditions.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- human factors reviews;
- task analyses;
- control-room reviews;
- human-machine interface reviews;
- alarm management reviews;
- workload assessments;
- staffing and shift assessments;
- fatigue risk assessments;
- field access reviews;
- maintenance access reviews;
- emergency response drills;
- operating procedure validation records;
- simulation or training records;
- incident and near-miss reviews;
- operational readiness reviews.

4.9.3 Indicator 8.3 — Error-Provoking Workplace Conditions

Context-Specific Interpretation

Error-provoking workplace conditions are conditions that make human error more likely or make error consequences more severe.

In LNG infrastructure, such conditions may include unclear controls, confusing displays, alarm overload, poor visibility, restricted access, inadequate labeling, difficult valve identification, complex transfer steps, simultaneous operations, time pressure, fatigue, poor communication, unclear responsibility, inconsistent procedures, degraded equipment, temporary bypasses, abnormal operating states, environmental stress, or multi-operator interface complexity.

Error-provoking conditions may arise during routine operations, but they may be especially important during commissioning, cooldown, first LNG introduction, transfer, loading, unloading, abnormal operation, emergency response, maintenance, modification, temporary shutdown, recommissioning, and decommissioning.

In the LNG context, human error may affect cryogenic containment, pressure control, boil-off gas management, transfer integrity, emergency isolation, regasification and send-out, environmental protection, monitoring interpretation, and Infrastructure Quality Claim Statement validity.

Illustrative Context-Specific Quality Outcome Criteria

Error-provoking workplace conditions may be considered adequately addressed when:

- workplace conditions that may increase error likelihood are identified;
- workplace conditions that may increase error consequence are identified;
- error-provoking conditions affecting Critical Infrastructure Conditions are identified;
- confusing, inconsistent, inaccessible, overloaded, temporary, or degraded workplace conditions are reviewed;
- interaction conditions during abnormal, degraded, emergency, and lifecycle-transition states are considered;
- controls, procedures, communication methods, labeling, training, access, monitoring, or verification measures are aligned with the error risk;
- unresolved error-provoking conditions are documented;
- Infrastructure Quality Claim Statements do not assume reliable human performance where workplace conditions make such performance unsupported.

The interpretation should be sufficient to make visible where workplace conditions may undermine infrastructure behavior or Evidence credibility.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- human error analyses;
- task analyses;
- procedure validation records;
- control-room and field interface reviews;
- alarm rationalization records;
- labeling and identification reviews;
- simultaneous operations reviews;
- communication protocol records;
- maintenance and access reviews;
- incident and near-miss records;

- corrective action records;
- emergency exercise records;
- operational readiness reviews;
- management-of-change records;
- unresolved workplace condition logs.

4.9.4 Indicator 8.4 — Workplace Safety Under Abnormal and Degraded Conditions

Context-Specific Interpretation

Workplace safety should remain interpretable under abnormal and degraded infrastructure conditions, not only during normal operation.

In LNG infrastructure, abnormal and degraded conditions may include emergency shutdown, loss of containment, fire or gas detection, vapor dispersion, cryogenic spill, transfer interruption, pressure-control upset, boil-off gas upset, utility loss, control-system failure, monitoring failure, extreme weather, marine or transportation interface disturbance, equipment degradation, temporary bypass, deferred maintenance, or unresolved non-conformity.

Workplace safety under such conditions is quality-relevant because workers, operators, contractors, inspectors, emergency responders, and other personnel may need to observe, decide, access, isolate, repair, evacuate, communicate, or respond under difficult conditions.

In the LNG context, degraded workplace safety can also affect infrastructure behavior by weakening emergency response, delaying detection, increasing error, limiting maintenance, reducing monitoring quality, or preventing recovery.

Illustrative Context-Specific Quality Outcome Criteria

Workplace safety under abnormal and degraded conditions may be considered adequately addressed when:

- foreseeable abnormal and degraded workplace conditions are identified;
- workplace interaction under emergency, degraded, and transient conditions is considered;
- access, egress, visibility, communication, protective systems, emergency isolation, and response actions are considered where relevant;
- cryogenic, pressure, transfer, boil-off gas, fire, gas detection, environmental, utility, and interface conditions are considered where relevant;
- human actions affecting Critical Infrastructure Conditions are identified;
- limitations affecting worker, operator, contractor, or emergency-responder safety are documented;
- response Evidence is available where relevant;
- Infrastructure Quality Claim Statements reflect workplace safety limitations that affect infrastructure quality or claim validity.

Workplace safety interpretation should support confidence that abnormal and degraded conditions do not make required human interaction unrealistic, unsafe, or unsupported.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- emergency response plans;
- evacuation plans;
- abnormal operating procedures;
- degraded mode procedures;

- emergency shutdown test records;
- fire and gas detection test records;
- access and egress reviews;
- emergency drill records;
- personal protective equipment assessments;
- rescue and response records;
- maintenance under degraded conditions reviews;
- incident and near-miss records;
- corrective action records;
- operational readiness reviews;
- interface coordination records.

4.9.5 Indicator 8.5 — Alignment Between Infrastructure Design and Human Understanding

Context-Specific Interpretation

LNG infrastructure should be designed, presented, documented, and operated in a way that supports human understanding of relevant infrastructure behavior.

Alignment between infrastructure design and human understanding means that people who must operate, monitor, maintain, inspect, assess, or respond to the infrastructure can understand the relevant systems, boundaries, interfaces, controls, alarms, operating modes, limitations, and Critical Infrastructure Conditions.

In the LNG context, understanding may be challenged by complex process behavior, cryogenic conditions, phase transformation, boil-off gas behavior, automated systems, alarm sequences, distributed controls, marine or transportation interfaces, multi-operator responsibilities, emergency conditions, and hidden or delayed visibility of degradation.

A technically sophisticated design may still present quality risk if its behavior is not understandable to the people responsible for safe and reliable interaction.

Alignment does not mean simplifying the infrastructure beyond its technical needs.

It means that infrastructure information, controls, procedures, displays, training, and Evidence support appropriate human understanding.

Illustrative Context-Specific Quality Outcome Criteria

Alignment between infrastructure design and human understanding may be considered adequate when:

- users who must understand the infrastructure are identified;
- relevant systems, controls, operating modes, boundaries, interfaces, and limitations are explainable to those users;
- displays, alarms, labels, procedures, and documentation support correct interpretation;
- cryogenic, pressure, transfer, boil-off gas, regasification, send-out, emergency, environmental, and monitoring conditions are understandable where relevant;
- Critical Infrastructure Conditions and response expectations are communicated where relevant;
- changes to infrastructure are reflected in updated procedures, displays, training, and records;
- misunderstandings, ambiguous instructions, or unclear interfaces are identified and corrected;
- Infrastructure Quality Claim Statements do not assume human understanding where supporting Evidence is absent.

Alignment should be sufficient to support safe, reliable, and traceable interaction with the declared Infrastructure Quality Object.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- human-machine interface reviews;
- control-room design reviews;
- alarm management records;
- procedure validation records;
- operating manuals;
- training materials;
- competency assessments;
- system walkdown records;
- field labeling reviews;
- operating mode descriptions;
- emergency response guides;
- management-of-change communication records;
- lessons-learned records;
- incident and near-miss reviews;
- operational readiness reviews.

4.9.6 Indicator 8.6 — Workplace Contextual Pressures Affecting Safety

Context-Specific Interpretation

Workplace contextual pressures may affect safety and infrastructure quality by influencing how people observe, decide, communicate, maintain, operate, or respond.

In LNG infrastructure, contextual pressures may include production pressure, schedule pressure, ship-loading or unloading pressure, truck or rail dispatch pressure, startup pressure, commissioning pressure, maintenance backlog, staffing constraints, fatigue, contractor coordination, simultaneous operations, weather constraints, emergency-response limitations, regulatory deadlines, commercial commitments, or pressure to close Unresolved Conditions.

Such pressures may increase the likelihood that Assumptions are accepted without verification, procedures are bypassed, degraded conditions are normalized, Evidence gaps are ignored, or Infrastructure Quality Claim Statements exceed the Evidence basis.

The purpose of this Indicator is not to judge organizational culture in general.

The purpose is to make visible workplace contextual pressures that affect the declared Infrastructure Quality Object, Critical Infrastructure Conditions, Evidence interpretation, or Infrastructure Quality Claim Statement validity.

Illustrative Context-Specific Quality Outcome Criteria

Workplace contextual pressures may be considered adequately addressed when:

- relevant contextual pressures affecting workplace interaction are identified;
- pressures affecting Critical Infrastructure Conditions are identified;
- pressures during commissioning, cooldown, transfer, loading, unloading, operation, maintenance, emergency response, modification, recommissioning, or decommissioning are considered where relevant;

- effects on procedure adherence, monitoring, communication, Evidence quality, decision-making, and response readiness are considered;
- controls or safeguards against unsafe pressure effects are identified where relevant;
- unresolved pressure-related limitations are documented;
- Infrastructure Quality Claim Statements do not hide limitations created by workplace pressures.

Contextual pressure interpretation should be sufficient to prevent infrastructure quality from being overstated where human interaction is materially affected by work conditions.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- operational readiness reviews;
- simultaneous operations reviews;
- staffing assessments;
- fatigue risk assessments;
- shift handover records;
- maintenance backlog records;
- commissioning pressure reviews;
- schedule risk reviews;
- contractor coordination records;
- incident and near-miss records;
- stop-work or escalation records;
- unresolved finding registers;
- management-of-change records;
- lessons-learned records;
- Infrastructure Quality Claim Statement limitation statements.

4.9.7 Indicator 8.7 — Retention of Workplace Interaction Safety Knowledge

Context-Specific Interpretation

Workplace interaction safety knowledge should be retained so that the declared LNG Infrastructure Quality Object can continue to be understood, operated, maintained, monitored, modified, and responded to safely across its lifecycle.

In LNG infrastructure, such knowledge may include operating experience, task knowledge, alarm interpretation, control-room knowledge, field access knowledge, maintenance knowledge, emergency-response knowledge, transfer and loading knowledge, interface knowledge, abnormal-condition knowledge, incident lessons, near-miss lessons, training records, competence records, contractor knowledge, and change-related knowledge.

Knowledge retention is quality-relevant because loss of workplace interaction knowledge may weaken operational reliability, safety, emergency readiness, monitoring interpretation, maintenance effectiveness, and Infrastructure Quality Claim Statement validity.

This is especially important for aging LNG infrastructure, modified LNG infrastructure, floating LNG infrastructure, multi-operator terminals, contractor-dependent operations, transportation interfaces, and lifecycle transitions such as recommissioning or repurposing.

Illustrative Context-Specific Quality Outcome Criteria

Workplace interaction safety knowledge may be considered adequately retained when:

- workplace interaction knowledge relevant to the declared Infrastructure Quality Object is identified;
- knowledge concerning routine, non-routine, abnormal, degraded, emergency, and lifecycle-transition conditions is retained;
- knowledge concerning Critical Infrastructure Conditions is retained;
- lessons from incidents, near misses, drills, maintenance, modifications, and operations are retained and accessible;
- knowledge remains connected to current infrastructure configuration, boundaries, interfaces, and lifecycle condition;
- training and competence records support knowledge continuity where relevant;
- loss, fragmentation, or inaccessibility of workplace interaction knowledge is identified as an Evidence limitation;
- Infrastructure Quality Claim Statements are not made beyond retained and traceable workplace interaction Evidence.

Knowledge retention should be sufficient to support safe and reliable human interaction over time.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- operating experience records;
- shift handover records;
- training records;
- competence records;
- procedure revision records;
- lessons-learned records;
- incident and near-miss records;
- emergency drill records;
- maintenance knowledge records;
- control-room guidance records;
- alarm response guidance records;
- transfer and loading operation records;
- contractor handover records;
- management-of-change communication records;
- document-control records;
- Infrastructure Quality Claim Statement Evidence files.

4.10 Factor 9 — Competence of Personnel

Purpose of the Factor

The authoritative IQC1 purpose is:

To ensure that personnel whose decisions, actions, omissions, judgment, or authority can affect Function Realization, Infrastructure Results, Infrastructure Outcomes, Evidence, Infrastructure Quality Claim Statements, or Critical Infrastructure Conditions possess and maintain Role-Appropriate Competence for the relevant Lifecycle and operating conditions.

Core architecture role: Examines competence-dependent conditions where human decisions, actions, or omissions can materially affect the Infrastructure Quality Object.

Definitions and Governing Terms

Governing terms. Infrastructure Quality Object, Infrastructure Work, Evidence, Critical Infrastructure Condition, and the Factor 4 definitions of Abnormal Operating Condition and Degraded Condition apply with their established meanings.

IQC1 Factor-specific terms. Personnel Competence, Infrastructure-Critical Role, Role-Appropriate Competence, Technical Competence, Contextual Competence, Authority, Expertise, Competence Limit, and Non-Routine Condition apply as defined in IQI_IQC1 and are not redefined in LNG1.

LNG1 context terms and anchors. process, cryogenic, storage, tank, structural, marine, transfer, loading, unloading, regasification, pipeline-Interface, MNT1 coordination, instrumentation, control, electrical, mechanical, inspection, maintenance, environmental, emergency-response, security, port, contractor, and management roles whose competence, authority, judgment, or omissions may affect LNG Function Realization, Evidence, or Critical Infrastructure Conditions. Their technical meaning, values, methods, and acceptance conditions depend on the declared Infrastructure Quality Object, applicable Context-Specific Quality Outcome Criteria, and the Reference Layer.

Context-specific boundary. Qualifications, licenses, credentials, experience levels, scopes of practice, staffing arrangements, and training requirements are controlled by the applicable authority, Context Guide, or Reference Layer. IQC1 does not create credentials or legal permissions.

Context-Specific Interpretation

Competence of Personnel concerns the ability of personnel whose work affects the declared LNG Infrastructure Quality Object to understand, perform, assess, control, maintain, respond to, and preserve quality-relevant infrastructure functions within the declared boundary, lifecycle condition, interfaces, Assumptions, limitations, Critical Infrastructure Conditions, and Evidence basis.

In the LNG context, personnel competence should be interpreted in relation to the declared Infrastructure Quality Object and the declared LNG-context realization pathway.

Competence may be relevant for personnel involved in planning, design, engineering, construction, commissioning, cooldown, operation, maintenance, inspection, testing, monitoring, transfer, loading, unloading, regasification, send-out, emergency response, environmental protection, modification, recommissioning, repurposing, decommissioning, conformity assessment, documentation, and Infrastructure Quality Claim Statement preparation.

Personnel competence is not demonstrated merely by job title, organizational position, certification, training attendance, years of experience, or assignment to a role.

Such Evidence may support interpretation.

However, competence under this Guide depends on whether personnel have role-appropriate technical and contextual understanding of LNG infrastructure behavior, boundaries, interfaces, lifecycle conditions, abnormal and degraded conditions, limits of authority, Critical Infrastructure Conditions, Evidence limitations, and Infrastructure Quality Claim Statement implications.

Core Quality Indicators

The following Core Quality Indicator titles are invariant and governed by IQI_IQC1. The clauses under each Indicator provide LNG1 Context-Specific Interpretation, illustrative Context-Specific Quality Outcome Criteria, and Evidence considerations; they do not reproduce or replace the normative Core Indicator Statement.

4.10.1 Indicator 9.1 — Identification of Infrastructure-Critical Roles

Context-Specific Interpretation

In LNG infrastructure, infrastructure-critical roles are roles whose actions, decisions, omissions, judgments, or loss of competence may affect realization of the invariant Core intended function, Critical Infrastructure Conditions, Evidence interpretation, or Infrastructure Quality Claim Statement validity.

Infrastructure-critical roles may include roles related to engineering, process design, cryogenic systems, storage, transfer, loading, unloading, regasification, send-out, boil-off gas management, operations, control-room monitoring, field operation, maintenance, inspection, testing, safety systems, emergency response, environmental monitoring, interface coordination, conformity assessment, management of change, documentation, and Infrastructure Quality Claim Statement preparation.

The identification of infrastructure-critical roles should depend on the declared LNG Infrastructure Quality Object and the declared LNG-context realization pathway.

For example, critical roles for an LNG storage facility may differ from those for a liquefaction facility, regasification terminal, FSRU, transfer system, satellite LNG facility, peak-shaving facility, or integrated LNG terminal.

Roles should also be considered where external interfaces affect the declared Infrastructure Quality Object, such as marine operations, truck or rail loading, pipeline coordination, emergency response, environmental monitoring, contractor work, or shared terminal responsibilities.

Illustrative Context-Specific Quality Outcome Criteria

Infrastructure-critical roles may be considered adequately identified when:

- roles affecting the declared LNG Infrastructure Quality Object are identified;
- roles affecting the declared LNG-context realization pathway are identified;
- roles affecting Critical Infrastructure Conditions are identified;
- roles affecting boundaries and interfaces are identified;
- roles affecting commissioning, cooldown, operation, maintenance, inspection, testing, monitoring, transfer, loading, unloading, regasification, send-out, emergency response, modification, recommissioning, repurposing, or decommissioning are considered where relevant;
- roles affecting Evidence generation, Evidence interpretation, conformity assessment, documentation, and Infrastructure Quality Claim Statements are identified;
- contractor, third-party, external-interface, and multi-operator roles are considered where relevant;
- role boundaries, responsibilities, and authority are sufficiently clear to support quality-relevant decisions.

Identification should be sufficient to make visible which personnel roles materially affect infrastructure behavior, Evidence sufficiency, and claim validity.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- role and responsibility matrices;
- organization charts;
- responsibility assignment matrices;
- operations staffing plans;
- maintenance staffing plans;
- commissioning role definitions;
- emergency-response role definitions;

- interface responsibility documents;
- contractor responsibility documents;
- control-room role descriptions;
- inspection and testing role descriptions;
- conformity assessment role descriptions;
- management-of-change role assignments;
- environmental monitoring role assignments;
- Infrastructure Quality Claim Statement responsibility records.

4.10.2 Indicator 9.2 — Role-Appropriate Technical and Contextual Competence

Context-Specific Interpretation

Role-appropriate technical and contextual competence means that personnel have competence appropriate to the quality-relevant role they perform in relation to the declared LNG Infrastructure Quality Object.

In LNG infrastructure, technical competence may involve understanding of cryogenic systems, phase transformation, pressure control, thermal behavior, storage, boil-off gas management, transfer, loading, unloading, regasification, send-out, utilities, instrumentation, control systems, safety systems, emergency systems, environmental controls, inspection, maintenance, and monitoring.

Contextual competence may involve understanding of the declared boundary, included and excluded interfaces, lifecycle condition, operating modes, connected infrastructure, environmental context, community context, Assumptions, limitations, Critical Infrastructure Conditions, Evidence limitations, and Infrastructure Quality Claim Statement scope.

A person may be generally qualified in one technical area while lacking context-specific competence for the declared LNG Infrastructure Quality Object.

Competence should therefore be interpreted in relation to role, context, lifecycle condition, and infrastructure-quality significance.

Illustrative Context-Specific Quality Outcome Criteria

Role-appropriate technical and contextual competence may be considered adequate when:

- competence expectations are defined for each infrastructure-critical role;
- competence is aligned with the declared LNG Infrastructure Quality Object;
- competence is aligned with the declared LNG-context realization pathway;
- personnel understand relevant boundaries, interfaces, lifecycle conditions, Assumptions, and limitations;
- personnel understand relevant cryogenic, thermal, pressure, storage, transfer, boil-off gas, regasification, send-out, monitoring, safety, emergency, environmental, and interface conditions where applicable;
- personnel understand Critical Infrastructure Conditions relevant to their role;
- competence is supported by appropriate training, qualification, experience, assessment, supervision, or demonstrated performance;
- competence limitations are identified and controlled where relevant;
- Infrastructure Quality Claim Statements do not assume competence beyond the Evidence basis.

Competence should be sufficient to support reliable performance of the role within the declared boundary and lifecycle condition.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- competence requirements;
- training records;
- qualification records;
- certification records where relevant;
- experience records;
- role-specific competence assessments;
- LNG-specific training records;
- control-room training records;
- emergency-response training records;
- maintenance and inspection competence records;
- environmental monitoring competence records;
- contractor competence records;
- supervision records;
- performance observations;
- competency gap assessments;
- Infrastructure Quality Claim Statement Evidence files.

4.10.3 Indicator 9.3 — Competence for Abnormal, Degraded, and Non-Routine Conditions

Context-Specific Interpretation

Personnel competence should include competence for abnormal, degraded, and non-routine conditions where such conditions may affect the declared LNG Infrastructure Quality Object.

In LNG infrastructure, abnormal, degraded, and non-routine conditions may include startup, cooldown, first LNG introduction, emergency shutdown, pressure upset, boil-off gas upset, transfer interruption, loading or unloading abnormality, regasification interruption, send-out disruption, utility loss, control-system failure, monitoring failure, fire or gas detection event, environmental event, extreme weather, equipment degradation, temporary bypass, maintenance under operating conditions, recommissioning, repurposing, or decommissioning.

Competence for such conditions is quality-relevant because infrastructure behavior may depend on timely recognition, correct interpretation, proper response, communication, escalation, isolation, recovery, and Evidence retention.

Normal-operation competence alone may be insufficient where personnel must make decisions under Uncertainty, time pressure, degraded visibility, changing interfaces, or emergency conditions.

Illustrative Context-Specific Quality Outcome Criteria

Competence for abnormal, degraded, and non-routine conditions may be considered adequate when:

- relevant abnormal, degraded, and non-routine conditions are identified;
- personnel roles required under those conditions are identified;
- personnel understand the relevant operating limits, response actions, escalation criteria, and limitations;
- competence covers cryogenic, pressure, transfer, boil-off gas, regasification, send-out, safety, emergency, environmental, monitoring, and interface conditions where relevant;
- competence for Critical Infrastructure Conditions is addressed;

- drills, simulations, exercises, supervised experience, or other Evidence support competence where relevant;
- contractor and external-interface competence are considered where relevant;
- lessons from abnormal events, incidents, near misses, and exercises are retained;
- Infrastructure Quality Claim Statements do not assume abnormal-condition competence where Evidence is insufficient.

Competence should be sufficient to support credible interpretation of infrastructure behavior under non-routine conditions included within the claim boundary.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- abnormal operation training records;
- emergency-response training records;
- cooldown and startup training records;
- transfer interruption response training;
- emergency shutdown drills;
- fire and gas response drills;
- tabletop exercises;
- simulator training records;
- incident and near-miss reviews;
- abnormal event response records;
- shift handover records;
- operating procedure validation records;
- emergency-response evaluation records;
- contractor emergency competence records;
- corrective action records;
- lessons-learned records.

4.10.4 Indicator 9.4 — Recognition of Limits of Authority and Expertise

Context-Specific Interpretation

Personnel should recognize the limits of their authority and expertise where their decisions or actions may affect the declared LNG Infrastructure Quality Object.

In LNG infrastructure, unclear limits of authority or expertise may affect operations, maintenance, inspection, transfer, loading, unloading, emergency isolation, environmental response, management of change, conformity assessment, documentation, and Infrastructure Quality Claim Statements.

A person may be competent to perform a task but not authorized or competent to approve a deviation, accept a non-conformity, change an operating envelope, override a control, close an unresolved finding, interpret a monitoring anomaly, or make an Infrastructure Quality Claim Statement.

Recognition of limits is especially important where LNG infrastructure involves multi-operator interfaces, contractor work, marine or transportation interfaces, emergency-response coordination, external specialists, regulatory interfaces, or complex technical Uncertainty.

Failure to recognize limits may cause unsupported Assumptions, unreviewed changes, unsafe decisions, hidden non-conformities, or misleading Infrastructure Quality Claim Statements.

Illustrative Context-Specific Quality Outcome Criteria

Recognition of limits of authority and expertise may be considered adequate when:

- authority limits are defined for infrastructure-critical roles;
- technical decision limits are defined where relevant;
- escalation requirements are defined;
- personnel understand when specialist review, management approval, engineering review, safety review, environmental review, or conformity reassessment is required;
- limits are clear for changes, deviations, bypasses, temporary operation, non-conformities, Unresolved Conditions, and Infrastructure Quality Claim Statements;
- contractor and external-interface authority limits are defined where relevant;
- Evidence shows that personnel do not act beyond defined authority or expertise without appropriate escalation;
- Infrastructure Quality Claim Statements are not made or expanded by personnel without appropriate authority and Evidence.

Recognition of limits should be sufficient to prevent unsupported decisions from affecting infrastructure quality or claim validity.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- delegation of authority documents;
- role responsibility matrices;
- approval matrices;
- escalation procedures;
- management-of-change procedures;
- deviation approval records;
- non-conformity disposition records;
- operating authority records;
- permit-to-work records;
- control-room authority procedures;
- contractor authority agreements;
- emergency-response authority records;
- conformity assessment approval records;
- Infrastructure Quality Claim Statement approval records;
- audit or review findings.

4.10.5 Indicator 9.5 — Evolution of Competence with Lifecycle and Context

Context-Specific Interpretation

Competence should evolve as the declared LNG Infrastructure Quality Object moves through lifecycle stages and as its context changes.

Competence needed during planning or design may differ from competence needed during construction, acceptance, commissioning, cooldown, first LNG introduction, operation, maintenance, inspection, transfer, loading, unloading, regasification, send-out, modification, temporary shutdown, conservation, recommissioning, repurposing, decommissioning, or post-operation residual conditions.

Competence may also need to evolve when infrastructure ages, operating modes change, throughput changes, gas composition changes, transfer modes change, emergency-response Assumptions change, environmental exposure changes, technology changes, automation changes, monitoring changes, regulatory expectations change, or organizational responsibilities change.

In the LNG context, competence that was adequate for an original facility configuration may not remain adequate after expansion, repurposing, FSRU integration, new loading modes, new send-out requirements, or changed connected-system interfaces.

Illustrative Context-Specific Quality Outcome Criteria

Evolution of competence with lifecycle and context may be considered adequate when:

- competence requirements are reviewed at lifecycle transitions;
- competence requirements are reviewed when infrastructure context changes;
- competence is updated for commissioning, cooldown, operation, maintenance, modification, recommissioning, repurposing, and decommissioning where relevant;
- competence is updated when boundaries, interfaces, operating modes, technologies, monitoring systems, or Critical Infrastructure Conditions change;
- training, qualification, supervision, or assessment is updated where needed;
- contractor and external-interface competence is updated where relevant;
- competence gaps are identified and controlled;
- Infrastructure Quality Claim Statements reflect lifecycle or context limitations where competence Evidence is incomplete.

Competence should remain aligned with the current condition and intended use of the declared Infrastructure Quality Object.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- lifecycle competence plans;
- training matrix updates;
- refresher training records;
- commissioning competence records;
- cooldown and first LNG introduction training records;
- modification training records;
- recommissioning training records;
- decommissioning training records;
- management-of-change competence reviews;
- contractor onboarding records;
- technology-change training records;
- emergency-response retraining records;
- competence gap records;
- lessons-learned records;
- Infrastructure Quality Claim Statement limitation statements.

4.10.6 Indicator 9.6 — Competence-Related Risk Awareness

Context-Specific Interpretation

Competence-related risk awareness means that personnel understand how their roles may affect infrastructure quality, risk controls, Critical Infrastructure Conditions, Evidence, and Infrastructure Quality Claim Statements.

In LNG infrastructure, personnel should understand not only task execution but also the risk significance of their decisions, observations, omissions, and communications.

For example, personnel may need to recognize the significance of abnormal boil-off gas behavior, unexplained pressure changes, transfer irregularities, alarm patterns, degraded monitoring, environmental anomalies, emergency-isolation limitations, deferred maintenance, non-conformities, or interface misunderstandings.

Competence-related risk awareness is especially important where conditions are abnormal, degraded, time-pressured, multi-operator, contractor-dependent, or not immediately visible.

Without risk awareness, personnel may complete tasks while failing to recognize quality-relevant Evidence, unresolved Critical Infrastructure Conditions, or limitations affecting Infrastructure Quality Claim Statements.

Illustrative Context-Specific Quality Outcome Criteria

Competence-related risk awareness may be considered adequate when:

- personnel understand risk significance relevant to their role;
- personnel understand how their actions may affect the declared Infrastructure Quality Object;
- personnel understand relevant Critical Infrastructure Conditions;
- personnel understand when observations or deviations require escalation;
- personnel understand how Evidence, documentation, and communication affect Infrastructure Quality Claim Statements where relevant;
- personnel understand interface-related and lifecycle-transition risks where relevant;
- competence programs include risk awareness, not only task instruction;
- incident, near-miss, and lessons-learned information is used to strengthen risk awareness;
- Infrastructure Quality Claim Statements do not assume risk awareness where supporting Evidence is absent.

Risk awareness should be sufficient to support recognition and communication of conditions that may affect infrastructure behavior or claim validity.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- risk awareness training records;
- toolbox meeting records;
- pre-job briefing records;
- shift handover records;
- operating experience records;
- incident and near-miss reviews;
- lessons-learned records;
- emergency drill records;
- abnormal condition recognition training;
- Critical Infrastructure Conditions communication records;
- interface coordination records;
- stop-work or escalation records;
- management-of-change communication records;
- audit and observation records;
- Infrastructure Quality Claim Statement Evidence files.

4.10.7 Indicator 9.7 — Retention of Competence-Relevant Knowledge

Context-Specific Interpretation

Competence-relevant knowledge should be retained so that the declared LNG Infrastructure Quality Object can continue to be understood, operated, maintained, assessed, changed, and claimed across its lifecycle.

In LNG infrastructure, competence-relevant knowledge may include technical knowledge, operating experience, maintenance knowledge, inspection knowledge, emergency-response knowledge, interface knowledge, contractor knowledge, lessons learned, incident history, near-miss history, abnormal-condition knowledge, control-room knowledge, environmental knowledge, management-of-change knowledge, and Infrastructure Quality Claim Statement interpretation knowledge.

Knowledge retention is especially important for aging LNG facilities, modified infrastructure, brownfield systems, floating LNG systems, FSRUs, multi-operator terminals, contractor-dependent operations, and lifecycle transitions such as recommissioning, repurposing, or decommissioning.

Loss of competence-relevant knowledge may cause repeated mistakes, weakened emergency response, poor monitoring interpretation, inadequate change evaluation, Assumption drift, or unsupported Infrastructure Quality Claim Statements.

Illustrative Context-Specific Quality Outcome Criteria

Competence-relevant knowledge may be considered adequately retained when:

- competence-relevant knowledge is identified and retained;
- knowledge concerning infrastructure-critical roles is retained;
- knowledge concerning Critical Infrastructure Conditions is retained;
- knowledge from operations, maintenance, inspection, incidents, near misses, emergencies, changes, and lifecycle transitions is retained;
- knowledge remains connected to current infrastructure configuration, boundaries, interfaces, lifecycle condition, and Assumptions;
- contractor, vendor, and external-interface knowledge is retained where relevant;
- knowledge is accessible to appropriate personnel;
- loss, fragmentation, or inaccessibility of competence-relevant knowledge is identified as an Evidence limitation;
- Infrastructure Quality Claim Statements are not made beyond retained and traceable competence Evidence.

Knowledge retention should be sufficient to support continued competent performance and responsible interpretation of infrastructure quality.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- competence records;
- training records;
- qualification records;
- operating experience records;
- lessons-learned databases;
- incident and near-miss records;
- emergency drill records;
- procedure revision records;
- shift handover records;

- maintenance knowledge records;
- contractor handover records;
- vendor training records;
- management-of-change communication records;
- knowledge transfer records;
- succession and staffing records;
- document-control records;
- Infrastructure Quality Claim Statement Evidence files.

4.11 Factor 10 — Regulatory and Standards Compliance

Purpose of the Factor

The authoritative IQC1 purpose is:

To ensure that Applicable Requirements from the Reference Layer are identified, interpreted, and supported by Evidence of Compliance for the declared Infrastructure Quality Object, Boundary, Lifecycle, and purpose, while preserving the distinction between Compliance, Conformity, and Infrastructure Quality.

Core architecture role: Examines alignment with the applicable Reference Layer while preserving the rule that compliance is necessary in context but not sufficient for quality.

Definitions and Governing Terms

Governing WQI and IQC1 terms. Reference Layer applies with its authoritative WQI_VOC1 meaning. Conformity and Conformity Statement apply as defined under Factor 3.

IQC1 Factor-specific terms. Applicable Requirement, Regulatory Obligation and Standards Obligation, Compliance Basis, Compliance, Compliance Statement, Compliance Limitation, Conflicting or Overlapping Requirements, and Continued Validity of Compliance apply as defined in IQI_IQC1 and are not redefined in LNG1.

LNG1 context terms and anchors. LNG facility, process-safety, cryogenic, pressure-equipment, storage-tank, fire, electrical, marine, port, transfer, transportation, pipeline, gas-quality, environmental, emissions, occupational-safety, emergency-response, security, land-use, construction, Commissioning, operating, and decommissioning obligations; overlapping jurisdictions; MNT1 Interface requirements; and the separation of downstream automotive LNG fuel-station requirements into LNGFS1. Their technical meaning, values, methods, and acceptance conditions depend on the declared Infrastructure Quality Object, applicable Context-Specific Quality Outcome Criteria, and the Reference Layer.

Context-specific boundary. Specific laws, codes, standards, jurisdictional hierarchy, legal interpretations, incorporation mechanisms, and evidentiary rules remain controlled by their authoritative Reference Layer sources. IQC1 does not make legal determinations.

Context-Specific Interpretation

Regulatory and Standards Compliance concerns the quality of identifying, integrating, demonstrating, maintaining, limiting, and tracing compliance with applicable regulatory and standards obligations relevant to the declared LNG Infrastructure Quality Object.

In the LNG context, regulatory and standards compliance should be interpreted in relation to the declared Infrastructure Quality Object, the declared LNG-context realization pathway, applicable lifecycle condition, boundaries, interfaces, Assumptions, limitations, Critical Infrastructure Conditions, and Evidence basis.

LNG infrastructure may be subject to regulatory and standards obligations related to safety, process safety, cryogenic storage, pressure equipment, fire protection, hazardous materials, environmental protection, emissions, discharges, maritime interfaces, port operations, transportation interfaces, pipeline interfaces, gas quality, occupational safety, emergency response, security, land use, construction, operation, modification, decommissioning, and other jurisdiction-specific requirements.

This Guide does not replace applicable laws, regulations, codes, standards, permits, approvals, operator procedures, or competent authority requirements.

Regulatory and standards obligations may provide important Evidence and boundary conditions for infrastructure-quality interpretation.

However, compliance with regulatory or standards requirements should not by itself be treated as complete proof of infrastructure quality under IQI_IQC1.

Compliance is quality-relevant Evidence, but it does not substitute for interpretation of the full set of applicable Core Quality Factors and Core Quality Indicators, the declared Infrastructure Quality Object, actual infrastructure behavior, Evidence limitations, Critical Infrastructure Conditions, and bounded Infrastructure Quality Claim Statement scope.

The applicable Reference Layer shall be selected for the declared midstream LNG1 object. Automotive LNG fuel-station and vehicle-dispensing obligations are not LNG1 requirements and are addressed in the downstream LNGFS1 context.

Core Quality Indicators

The following Core Quality Indicator titles are invariant and governed by IQI_IQC1. The clauses under each Indicator provide LNG1 Context-Specific Interpretation, illustrative Context-Specific Quality Outcome Criteria, and Evidence considerations; they do not reproduce or replace the normative Core Indicator Statement.

4.11.1 Indicator 10.1 — Identification of Applicable Regulatory and Standards Obligations

Context-Specific Interpretation

In LNG infrastructure, applicable regulatory and standards obligations should be identified in relation to the declared Infrastructure Quality Object and the declared LNG-context realization pathway.

The applicable obligations may differ depending on whether the declared object is a liquefaction facility, LNG storage facility, export terminal, import terminal, regasification facility, FSRU, floating LNG facility, transfer system, loading or unloading system, satellite LNG facility, peak-shaving facility, or integrated LNG terminal.

Applicable obligations may also differ depending on jurisdiction, lifecycle stage, facility location, marine or port interface, transportation interface, pipeline interface, environmental setting, occupational context, emergency-response arrangements, modification status, and claim boundary.

Identification should distinguish between obligations that apply directly to the declared LNG Infrastructure Quality Object and obligations that apply to connected systems or external interfaces.

Applicable obligations should not be assumed complete merely because a permit, approval, standard reference, or compliance matrix exists.

Illustrative Context-Specific Quality Outcome Criteria

Applicable regulatory and standards obligations may be considered adequately identified when:

- the declared LNG Infrastructure Quality Object is identified;
- the declared LNG-context realization pathway is identified;
- applicable lifecycle condition is identified;
- relevant regulatory obligations are identified;
- relevant standards, codes, specifications, permit conditions, approval conditions, and authority requirements are identified where applicable;
- obligations related to safety, process safety, environmental protection, emissions, discharges, occupational safety, emergency response, maritime, port, transportation, pressure equipment, cryogenic storage, pipeline interface, gas quality, and security are considered where relevant;
- obligations applying directly to the declared object are distinguished from obligations applying to connected systems or external interfaces;
- Assumptions, exclusions, and limitations in the identification of obligations are documented;
- Critical Infrastructure Conditions affected by regulatory or standards obligations are identified where relevant;
- the identified obligations are traceable to technical specifications, conformity assessment, monitoring, documentation, and Infrastructure Quality Claim Statements.

Identification should be sufficiently complete to support responsible compliance interpretation within the declared boundary and lifecycle condition.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- regulatory applicability registers;
- standards applicability matrices;
- permit registers;
- approval registers;
- compliance obligation registers;
- legal and regulatory reviews;
- authority correspondence;
- environmental permit basis documents;
- safety and process-safety requirement matrices;
- maritime, port, transportation, or pipeline-interface requirement records;
- occupational safety requirement records;
- emergency-response requirement records;
- security requirement records;
- standards cross-reference documents;
- Critical Infrastructure Conditions registers;
- Infrastructure Quality Claim Statement Evidence files.

4.11.2 Indicator 10.2 — Integration of Regulatory and Standards Requirements into Infrastructure Decisions

Context-Specific Interpretation

Regulatory and standards requirements should be integrated into infrastructure decisions where they affect the declared LNG Infrastructure Quality Object.

In the LNG context, integration may affect functional requirements, technical specifications, design decisions, material selection, cryogenic containment, storage, transfer, loading, unloading, boil-off gas management, regasification, send-out, process safety, environmental protection, occupational safety, emergency response, monitoring, documentation, construction, commissioning, operation, maintenance, modification, recommissioning, repurposing, and decommissioning.

Integration means that applicable obligations are not merely listed separately from infrastructure decisions.

They should be reflected where relevant in requirements, specifications, assessments, procedures, controls, monitoring, Evidence, and Infrastructure Quality Claim Statement Boundaries.

Failure to integrate regulatory and standards requirements may result in formal awareness of obligations without practical influence on infrastructure behavior.

Integration should also preserve the IQI distinction between compliance Evidence and infrastructure quality.

A requirement may be integrated and complied with, but the broader infrastructure-quality interpretation still depends on the full Core Quality Factors and Core Quality Indicators.

Illustrative Context-Specific Quality Outcome Criteria

Regulatory and standards requirements may be considered adequately integrated into infrastructure decisions when:

- applicable obligations are linked to functional requirements where relevant;
- applicable obligations are linked to technical specifications where relevant;
- applicable obligations are linked to conformity assessment, inspection, testing, commissioning, operation, monitoring, and documentation where relevant;
- obligations affecting cryogenic, thermal, pressure, storage, transfer, boil-off gas, regasification, send-out, safety, emergency, environmental, occupational, maritime, transportation, pipeline, security, and interface conditions are integrated where relevant;
- regulatory and standards obligations affecting Critical Infrastructure Conditions are reflected in infrastructure decisions;
- lifecycle-stage obligations are integrated into lifecycle decisions;
- Evidence shows how obligations were considered and implemented;
- integration limitations, exclusions, or unresolved obligations are documented;
- Infrastructure Quality Claim Statements distinguish integrated compliance Evidence from broader IQI infrastructure-quality interpretation.

Integration should be sufficient to make regulatory and standards obligations visible in the infrastructure-quality Evidence basis.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- requirement traceability matrices;
- regulatory-to-design crosswalks;
- standards-to-specification crosswalks;
- permit condition implementation records;
- design review records;
- technical specification records;
- engineering decision records;
- environmental control implementation records;
- safety-system requirement allocation records;
- emergency-response integration records;
- commissioning requirement records;

- operating procedure records;
- monitoring requirement records;
- management-of-change records;
- compliance implementation reports;
- Infrastructure Quality Claim Statement Evidence mapping.

4.11.3 Indicator 10.3 — Demonstration of Conformity with Applicable Requirements

Context-Specific Interpretation

Demonstration of conformity with applicable requirements concerns the Evidence showing that the declared LNG Infrastructure Quality Object, or relevant parts of it, conforms to identified regulatory and standards obligations within the declared boundary and lifecycle condition.

In the LNG context, conformity demonstration may involve design review, inspection, testing, verification, certification where applicable, commissioning Evidence, permit compliance Evidence, monitoring results, environmental reports, safety-system testing, emergency-response Evidence, operational records, maintenance records, audit records, or authority acceptance where applicable.

Demonstration of conformity should identify what requirement was assessed, what Evidence was used, what boundary was covered, what lifecycle condition was addressed, and what limitations remain.

A statement of compliance should not be interpreted as a universal Infrastructure Quality Claim Statement unless it is bounded, traceable, and supported by Evidence relevant to the Core Quality Factors and Core Quality Indicators.

Conformity with applicable requirements may be necessary and important, but it does not by itself prove that all infrastructure-quality outcomes are realized under IQI_IQC1.

Illustrative Context-Specific Quality Outcome Criteria

Demonstration of conformity with applicable requirements may be considered adequate when:

- applicable requirements are identified;
- the conformity basis is defined;
- assessment scope and boundary are stated;
- lifecycle condition is stated;
- Evidence supporting conformity is identified and retained;
- conformity Evidence addresses relevant LNG systems, interfaces, and obligations;
- deviations, exceptions, limitations, non-conformities, and Unresolved Conditions are documented;
- conformity Evidence is traceable to regulatory and standards obligations;
- conformity Evidence is not used to imply quality beyond its scope;
- Infrastructure Quality Claim Statements distinguish compliance conformity from broader infrastructure-quality interpretation.

Demonstration of conformity should be sufficiently specific, Evidence-based, and bounded to support responsible use in an Infrastructure Quality Claim Statement.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- compliance certificates;
- inspection records;
- test records;

- commissioning records;
- regulatory inspection records;
- permit compliance reports;
- environmental monitoring reports;
- emissions and discharge reports;
- safety-system test records;
- emergency-response exercise records;
- pressure equipment records;
- fire protection verification records;
- maritime or port compliance records;
- transportation interface compliance records;
- audit records;
- non-conformity records;
- authority acceptance records;
- compliance Evidence indexes;
- Infrastructure Quality Claim Statement Evidence files.

4.11.4 Indicator 10.4 — Treatment of Conflicting or Overlapping Requirements

Context-Specific Interpretation

LNG infrastructure may be subject to multiple regulatory, standards, contractual, engineering, environmental, safety, occupational, maritime, transportation, pipeline-interface, security, and organizational requirements.

These requirements may overlap, differ in terminology, differ in scope, apply to different lifecycle stages, or assign responsibilities differently.

In some cases, requirements may appear to conflict or create Uncertainty regarding which requirement applies, which boundary is covered, which interface is included, which Evidence is sufficient, or which authority has jurisdiction.

Treatment of conflicting or overlapping requirements is quality-relevant because unresolved conflicts may affect technical specifications, conformity assessment, process safety, environmental protection, operational reliability, monitoring, documentation, and Infrastructure Quality Claim Statements.

In the LNG context, overlapping requirements may be especially important at marine interfaces, truck or rail loading interfaces, pipeline send-out interfaces, emergency-response interfaces, environmental interfaces, multi-operator boundaries, and modified or repurposed facilities.

Illustrative Context-Specific Quality Outcome Criteria

Conflicting or overlapping requirements may be considered adequately treated when:

- overlapping requirements are identified where relevant;
- apparent conflicts are identified and documented;
- the applicable boundary, lifecycle condition, jurisdiction, authority, or standard scope is clarified where possible;
- responsibility for resolution is assigned;
- technical, safety, environmental, operational, and interface implications are considered;
- Critical Infrastructure Conditions affected by overlapping or conflicting requirements are reviewed;
- unresolved conflicts or overlaps are documented as limitations where they remain unresolved;

- Evidence shows how the final interpretation was selected or applied;
- Infrastructure Quality Claim Statements do not hide unresolved requirement conflicts or overlaps.

Treatment should be sufficient to prevent unclear or conflicting requirements from weakening infrastructure-quality interpretation.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- regulatory interpretation records;
- standards interpretation records;
- requirement conflict logs;
- applicability reviews;
- authority correspondence;
- legal or technical opinions where applicable;
- design review records;
- interface responsibility records;
- permit condition interpretation records;
- management-of-change records;
- risk assessment records;
- environmental review records;
- unresolved issue logs;
- compliance decision records;
- Infrastructure Quality Claim Statement limitation statements.

4.11.5 Indicator 10.5 — Continued Validity of Compliance Under Change

Context-Specific Interpretation

Compliance status should remain valid when LNG infrastructure changes.

Changes may include functional changes, technical changes, operational changes, lifecycle changes, ownership changes, organizational changes, interface changes, environmental changes, regulatory changes, standards revisions, permit changes, expansion, modification, repair, recommissioning, repurposing, or decommissioning.

In LNG infrastructure, continued validity of compliance may be affected by changed gas composition, changed throughput, changed storage use, changed boil-off gas management, changed transfer mode, added loading or unloading function, changed regasification or send-out condition, changed transportation interface, changed marine interface, changed environmental exposure, changed emergency-response arrangement, changed monitoring coverage, or changed downstream interface.

Compliance established for one configuration, lifecycle stage, or operating condition should not automatically be assumed valid for another.

Where an Infrastructure Quality Claim Statement relies on compliance Evidence, the continued validity of that Evidence should be reviewed when relevant changes occur.

Illustrative Context-Specific Quality Outcome Criteria

Continued validity of compliance under change may be considered adequately addressed when:

- changes affecting compliance obligations are identified;
- changes affecting the declared Infrastructure Quality Object are reviewed;
- changes affecting boundaries, interfaces, lifecycle condition, operating modes, and Critical Infrastructure Conditions are reviewed;

- regulatory, permit, standards, environmental, safety, occupational, maritime, transportation, pipeline-interface, and emergency-response implications are considered where relevant;
- compliance Evidence is updated where necessary;
- Assumptions and limitations are updated;
- unresolved compliance issues are documented;
- conformity or Compliance Statements are revised where necessary;
- Infrastructure Quality Claim Statements are revised, limited, withdrawn, or re-evidenced where compliance validity changes.

Compliance should not be presumed valid after change merely because prior approvals, permits, procedures, or conformity records remain in existence.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- management-of-change records;
- regulatory change reviews;
- standards change reviews;
- permit applicability reviews;
- compliance reassessment records;
- design change records;
- operating condition change records;
- environmental change assessments;
- interface change records;
- authority correspondence;
- revised compliance matrices;
- updated permit records;
- updated monitoring records;
- recommissioning records;
- unresolved compliance issue logs;
- revised Infrastructure Quality Claim Statements.

4.11.6 Indicator 10.6 — Recognition of Compliance Limitations

Context-Specific Interpretation

Recognition of compliance limitations means acknowledging that compliance with applicable regulatory or standards requirements may be necessary, important, and Evidence-relevant, but not sufficient by itself to establish infrastructure quality under IQI_IQC1.

Regulations and standards may define minimum requirements, specific technical criteria, jurisdictional obligations, documentation requirements, process requirements, approval conditions, or conformity expectations.

They may not fully address all context-specific infrastructure-quality questions concerning integrated asset behavior, boundaries, interfaces, lifecycle transitions, Critical Infrastructure Conditions, Uncertainty, Evidence sufficiency, monitoring limitations, organizational interfaces, cumulative risk, environmental interactions, stakeholder impacts, or Infrastructure Quality Claim Statement Boundaries.

In the LNG context, a facility may comply with applicable requirements while still having unresolved quality-relevant limitations, such as incomplete interface understanding, aging-related Uncertainty, degraded monitoring visibility, Assumption drift, unresolved non-conformities, cumulative risk, or Infrastructure Quality Claim Statement overreach.

Compliance limitations should therefore be explicit rather than hidden.

Illustrative Context-Specific Quality Outcome Criteria

Compliance limitations may be considered adequately recognized when:

- the scope of compliance Evidence is stated;
- the boundary of compliance Evidence is stated;
- lifecycle condition covered by compliance Evidence is stated;
- limitations, exclusions, deviations, waivers, Unresolved Conditions, and Evidence gaps are documented;
- compliance Evidence is distinguished from broader infrastructure-quality Evidence;
- minimum compliance is not treated as full infrastructure quality;
- regulatory or standards conformity is not used to substitute for interpretation of all applicable Core Quality Factors and Core Quality Indicators;
- Critical Infrastructure Conditions not fully addressed by compliance Evidence are identified;
- Infrastructure Quality Claim Statements state compliance limitations where relevant.

Recognition of compliance limitations should be sufficient to prevent misleading interpretation of compliance as complete infrastructure-quality proof.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- compliance scope statements;
- compliance limitation statements;
- permit limitation records;
- standards applicability notes;
- deviation and waiver records;
- non-conformity records;
- unresolved finding logs;
- Evidence-gap registers;
- regulatory correspondence;
- audit findings;
- compliance assessment reports;
- risk assessment records;
- Critical Infrastructure Conditions registers;
- Infrastructure Quality Claim Statement limitation statements;
- Evidence interpretation records.

4.11.7 Indicator 10.7 — Traceability of Compliance Statements

Context-Specific Interpretation

Compliance claims should be traceable to applicable obligations, assessment basis, Evidence, lifecycle condition, boundaries, interfaces, limitations, and Unresolved Conditions.

A compliance claim may state that the declared LNG Infrastructure Quality Object, a system, a component, an activity, an interface, a lifecycle stage, or a document conforms to applicable requirements.

Such a claim should not be confused with a broader IQI Infrastructure Quality Claim Statement unless it is explicitly bounded and supported by Evidence relevant to the full infrastructure-quality interpretation.

Traceability is especially important in LNG infrastructure because compliance Evidence may be distributed across permits, design records, inspection records, test records, commissioning records, monitoring reports, environmental records, operating records, maintenance records, emergency-response records, interface records, management-of-change records, and authority correspondence.

A compliance claim may be misleading if it does not identify what complies, with what requirement, during what lifecycle condition, within what boundary, based on what Evidence, and subject to what limitations.

Illustrative Context-Specific Quality Outcome Criteria

Traceability of Compliance Statements may be considered adequate when:

- the compliance claim identifies what is claimed to comply;
- the applicable requirement or obligation is identified;
- the assessment basis is identified;
- the Evidence supporting the claim is identified;
- the boundary and lifecycle condition are identified;
- included and excluded interfaces are identified where relevant;
- limitations, deviations, waivers, Unresolved Conditions, or Evidence gaps are identified;
- Compliance Statements are distinguished from IQI Infrastructure Quality Claim Statements;
- Compliance Statements are not used to imply quality beyond their scope;
- where compliance Evidence supports an Infrastructure Quality Claim Statement, its contribution and limitations are traceable.

Compliance claims should remain bounded, Evidence-based, transparent, and linked to the declared Infrastructure Quality Object.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- compliance certificates;
- permit compliance statements;
- regulatory submissions;
- standards conformity declarations;
- compliance matrices;
- Evidence indexes;
- inspection and test records;
- commissioning completion records;
- environmental reporting records;
- monitoring records;
- authority acceptance records;
- deviation and waiver records;
- non-conformity closeout records;
- unresolved finding records;
- management-of-change compliance reviews;
- Infrastructure Quality Claim Statement Evidence files.

4.12 Factor 11 — Stakeholder and Community Satisfaction

Purpose of the Factor

The authoritative IQC1 purpose is:

To ensure that Infrastructure Quality interpretation accounts for Infrastructure Impacts on Stakeholders and Communities, including relevant effects on Infrastructure Safety, Environmental Protection, accessibility, Operational Reliability, Declared Commitments, Relevant Stakeholder Expectations, and trust across the Lifecycle.

Core architecture role: Examines infrastructure effects, commitments, transparency, and responsiveness in relation to affected stakeholders and communities; it is not reduced to opinion polling.

Definitions and Governing Terms

Governing WQI terms. Stakeholder / Interested Party and Boundary Transparency apply with their authoritative WQI_VOC1 meanings.

IQC1 Factor-specific terms. Community, Affected Stakeholder, Affected Community, Infrastructure Impact, Declared Commitment, Relevant Stakeholder Expectation, Community Concern, Responsiveness, Stakeholder and Community Satisfaction, and Cumulative and Long-Term Community Effect apply as defined in IQI_IQC1 and are not redefined in LNG1.

LNG1 context terms and anchors. workers, contractors, terminal operators, pipeline operators, MNT1 operators, marine carriers, port authorities, road and rail bulk carriers, neighboring communities, landowners, fishers, businesses, emergency responders, regulators, Indigenous or tribal interests where applicable, environmental interests, vulnerable populations, and other parties affected by construction, traffic, noise, light, emissions, marine activity, safety zones, emergency planning, service continuity, or lifecycle change. Their technical meaning, values, methods, and acceptance conditions depend on the declared Infrastructure Quality Object, applicable Context-Specific Quality Outcome Criteria, and the Reference Layer.

Context-specific boundary. Consultation duties, benefit agreements, notification rules, social-impact methods, public-participation requirements, and acceptance criteria remain controlled by the Context Guide or applicable Reference Layer.

Context-Specific Interpretation

Stakeholder and Community Satisfaction concerns the quality of identifying, understanding, addressing, and transparently communicating infrastructure impacts that are relevant to affected stakeholders and communities.

In the LNG context, stakeholder and community satisfaction should be interpreted in relation to the declared LNG Infrastructure Quality Object, the declared LNG-context realization pathway, applicable lifecycle condition, boundaries, interfaces, Assumptions, limitations, Critical Infrastructure Conditions, and Evidence basis.

LNG infrastructure may affect or concern nearby communities, workers, emergency responders, regulators, port authorities, transportation operators, marine users, pipeline operators, industrial users, environmental groups, local governments, landowners, Indigenous or local communities where applicable, and other affected stakeholders.

Stakeholder and community satisfaction under this Guide should not be interpreted as popularity, public relations, approval by all stakeholders, or absence of complaints.

It concerns whether stakeholder- and community-relevant infrastructure impacts, commitments, concerns, limitations, and Evidence are identified, considered, retained, and communicated transparently within the declared Infrastructure Quality Claim Boundary.

Core Quality Indicators

The following Core Quality Indicator titles are invariant and governed by IQI_IQC1. The clauses under each Indicator provide LNG1 Context-Specific Interpretation, illustrative Context-Specific Quality

Outcome Criteria, and Evidence considerations; they do not reproduce or replace the normative Core Indicator Statement.

4.12.1 Indicator 11.1 — Identification of Affected Stakeholders and Communities

Context-Specific Interpretation

In LNG infrastructure, affected stakeholders and communities should be identified in relation to the declared Infrastructure Quality Object and its boundaries, interfaces, lifecycle condition, and realization pathway.

Affected stakeholders may include persons, groups, organizations, authorities, or connected infrastructure operators who may be affected by LNG infrastructure behavior or who may affect realization of the intended function.

In the LNG context, affected stakeholders and communities may include nearby residents, workers, contractors, emergency responders, regulators, local governments, port authorities, marine operators, truck or rail operators, pipeline operators, industrial users, environmental stakeholders, land users, community organizations, and other affected parties.

Identification should consider normal operation, abnormal conditions, emergency conditions, lifecycle transitions, environmental exposure, transportation interfaces, public-consequence conditions, and cumulative or long-term effects.

Affected stakeholders should not be limited to those who have already complained or formally participated in a process.

Illustrative Context-Specific Quality Outcome Criteria

Affected stakeholders and communities may be considered adequately identified when:

- stakeholders and communities relevant to the declared LNG Infrastructure Quality Object are identified;
- stakeholders affected by normal, abnormal, degraded, emergency, and lifecycle-transition conditions are considered;
- stakeholders affected by environmental, transportation, marine, port, pipeline, emergency-response, occupational, and public-consequence interfaces are considered where relevant;
- stakeholders affected by Critical Infrastructure Conditions are identified where relevant;
- stakeholder identification reflects the declared boundary and does not imply responsibility outside the claim boundary unless explicitly included;
- Assumptions and limitations in stakeholder identification are documented;
- stakeholder identification is reviewed when boundaries, interfaces, lifecycle conditions, or infrastructure behavior change;
- Infrastructure Quality Claim Statements do not imply stakeholder or community coverage beyond the identified scope.

Stakeholder identification should be sufficient to support interpretation of infrastructure impacts, commitments, concerns, communication, and claim limitations.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- stakeholder maps;
- community identification records;
- affected-party registers;

- emergency-response stakeholder lists;
- port, marine, truck, rail, and pipeline interface stakeholder records;
- local government and authority records;
- environmental stakeholder records;
- public meeting records;
- consultation records;
- community impact assessments;
- environmental justice or community vulnerability assessments where applicable;
- land-use and receptor maps;
- Infrastructure Quality Claim Boundary records.

4.12.2 Indicator 11.2 — Identification of Infrastructure Impacts Relevant to Stakeholders and Communities

Context-Specific Interpretation

Infrastructure impacts relevant to stakeholders and communities should be identified in relation to the declared LNG Infrastructure Quality Object and its context.

In the LNG context, relevant impacts may include safety concerns, emergency-response concerns, environmental exposure, emissions, discharges, vapor dispersion, fire or explosion consequence, traffic, marine activity, truck or rail movement, noise, light, visual effects, land-use effects, coastal or port effects, waterway effects, construction effects, operational changes, decommissioning effects, and cumulative or long-term effects.

Impacts may arise during planning, construction, commissioning, cooldown, operation, maintenance, transfer, loading, unloading, regasification, send-out, modification, temporary shutdown, recommissioning, repurposing, decommissioning, or abnormal and emergency conditions.

Identification of impacts should not be limited to regulatory impact categories or formal permit topics.

It should consider stakeholder- and community-relevant infrastructure behavior where it affects infrastructure-quality interpretation, Evidence, Critical Infrastructure Conditions, and Infrastructure Quality Claim Statement validity.

Illustrative Context-Specific Quality Outcome Criteria

Infrastructure impacts relevant to stakeholders and communities may be considered adequately identified when:

- relevant safety, environmental, operational, emergency, transportation, land-use, and public-consequence impacts are identified;
- normal, abnormal, degraded, emergency, and lifecycle-transition impacts are considered;
- LNG-specific impacts involving cryogenic storage, transfer, loading, unloading, boil-off gas, regasification, send-out, emissions, discharges, vapor dispersion, fire, emergency response, and transportation interfaces are considered where relevant;
- impacts associated with Critical Infrastructure Conditions are identified;
- affected stakeholder and community groups are linked to relevant impacts;
- Assumptions and Uncertainties affecting impact identification are documented;
- impact identification is updated when infrastructure conditions, boundaries, interfaces, or lifecycle stages change;
- Infrastructure Quality Claim Statements do not imply that unassessed stakeholder or community impacts have been addressed.

Impact identification should be sufficient to support transparent interpretation of infrastructure effects and claim limitations.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- community impact assessments;
- environmental impact assessments;
- safety consequence studies;
- emergency-response studies;
- traffic impact studies;
- marine or port impact studies;
- noise and light studies;
- air emissions assessments;
- discharge and water impact assessments;
- vapor dispersion studies;
- fire and explosion consequence studies;
- construction impact records;
- operational change assessments;
- decommissioning impact assessments;
- stakeholder concern logs;
- Infrastructure Quality Claim Statement limitation statements.

4.12.3 Indicator 11.3 — Alignment with Declared Commitments and Expectations

Context-Specific Interpretation

Declared commitments and expectations should be aligned with the actual behavior, limitations, Evidence, and claim boundaries of the declared LNG Infrastructure Quality Object.

In the LNG context, commitments and expectations may arise from permits, public statements, community agreements, environmental commitments, safety commitments, emergency-response commitments, transportation commitments, noise or traffic commitments, operating commitments, monitoring commitments, reporting commitments, or stakeholder engagement commitments.

Alignment means that commitments and expectations are not overstated, ignored, contradicted, or disconnected from infrastructure behavior and Evidence.

For example, a commitment concerning emergency response, emissions control, traffic management, environmental monitoring, community notification, or safe transfer operations should remain connected to the systems, interfaces, personnel, Evidence, and lifecycle condition needed to support that commitment.

Stakeholder expectations should not be treated as proof of quality by themselves.

However, misalignment between declared commitments and actual infrastructure conditions may affect trust, transparency, Evidence interpretation, and Infrastructure Quality Claim Statement validity.

Illustrative Context-Specific Quality Outcome Criteria

Alignment with declared commitments and expectations may be considered adequate when:

- declared stakeholder and community commitments are identified;

- expectations created by public, regulatory, operational, environmental, safety, or emergency-response communications are identified where relevant;
- commitments are traceable to infrastructure conditions, controls, monitoring, Evidence, or limitations;
- commitments are reviewed when boundaries, interfaces, lifecycle conditions, operating modes, or infrastructure behavior change;
- commitments affecting Critical Infrastructure Conditions are identified and monitored where relevant;
- limitations or changes affecting commitments are communicated transparently where appropriate;
- Infrastructure Quality Claim Statements do not imply commitments or outcomes that exceed the Evidence basis.

Alignment should be sufficient to prevent misleading interpretation of stakeholder and community satisfaction.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- commitment registers;
- permit commitment records;
- community agreement records;
- public communication records;
- stakeholder engagement records;
- environmental monitoring commitments;
- emergency-response commitments;
- transportation management commitments;
- traffic, noise, or light management records;
- reporting records;
- community notification records;
- management-of-change records;
- corrective action records;
- commitment closeout records;
- Infrastructure Quality Claim Statement Evidence files.

4.12.4 Indicator 11.4 — Consideration of Cumulative and Long-Term Community Effects

Context-Specific Interpretation

Stakeholder and community effects should be considered over time, not only as isolated events.

In LNG infrastructure, cumulative and long-term community effects may arise from repeated traffic, marine activity, emissions, discharges, noise, light, emergency drills, construction phases, maintenance activities, flaring or venting where applicable, stormwater impacts, visual presence, land-use constraints, perceived risk, or interaction with other nearby industrial activities.

Long-term effects may also arise from aging infrastructure, changed operating patterns, expansion, increased throughput, new transfer modes, changed transportation routes, changed environmental exposure, climate-related conditions, or community development around the infrastructure.

Cumulative and long-term community effects should not be ignored merely because individual events appear minor, permitted, or compliant.

In the LNG context, community satisfaction may be affected by whether such effects are monitored, understood, communicated, and reflected in Evidence and Infrastructure Quality Claim Statements.

Illustrative Context-Specific Quality Outcome Criteria

Cumulative and long-term community effects may be considered adequately addressed when:

- relevant cumulative community effects are identified;
- relevant long-term community effects are identified;
- repeated or chronic exposure pathways are considered where applicable;
- traffic, marine activity, noise, light, emissions, discharges, emergency response, land-use, public-consequence, and environmental effects are considered where relevant;
- community effects associated with Critical Infrastructure Conditions are considered;
- monitoring and trend information is reviewed where relevant;
- Assumptions and Uncertainties are documented;
- stakeholder and community concerns are retained and reviewed over time;
- Infrastructure Quality Claim Statements do not treat short-term absence of complaints or incidents as proof that cumulative or long-term effects are controlled.

Consideration should be sufficient to support lifecycle-aware interpretation of stakeholder and community impacts.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- cumulative impact assessments;
- long-term community impact assessments;
- environmental monitoring trends;
- traffic and transportation trend records;
- marine activity records;
- noise and light monitoring records;
- emissions and discharge trends;
- community complaint and response records;
- stakeholder engagement records;
- public meeting records;
- emergency drill records;
- land-use records;
- operating history records;
- expansion or modification assessments;
- Infrastructure Quality Claim Statement limitation statements.

4.12.5 Indicator 11.5 — Responsiveness to Infrastructure-Related Community Concerns

Context-Specific Interpretation

Responsiveness to infrastructure-related community concerns concerns how concerns are received, understood, evaluated, addressed, tracked, and reflected in infrastructure-quality interpretation.

In LNG infrastructure, community concerns may involve safety, emergency response, environmental protection, emissions, discharges, traffic, marine movement, truck or rail operations, noise, light, odor where relevant, visual effects, construction effects, operational changes, perceived risk, property effects, public communication, or trust in operator commitments.

Responsiveness does not mean that every concern must lead to the same outcome or that all stakeholders must be satisfied.

It means that concerns relevant to the declared Infrastructure Quality Object are not ignored, dismissed without evaluation, hidden from Evidence interpretation, or excluded from Infrastructure Quality Claim Statement limitations where they materially affect infrastructure-quality interpretation.

Community concerns may provide Evidence of visibility gaps, communication gaps, monitoring limitations, cumulative effects, or unresolved infrastructure impacts.

Illustrative Context-Specific Quality Outcome Criteria

Responsiveness to infrastructure-related community concerns may be considered adequate when:

- mechanisms exist for receiving infrastructure-related concerns;
- concerns are recorded and categorized;
- concerns relevant to the declared Infrastructure Quality Object are evaluated;
- concerns affecting safety, environmental protection, emergency response, transportation interfaces, public consequence, or Critical Infrastructure Conditions are escalated where relevant;
- responses, corrective actions, explanations, or limitations are documented;
- recurring concerns are analyzed for patterns;
- concern information is retained across lifecycle stages;
- Infrastructure Quality Claim Statements reflect unresolved community-relevant limitations where they affect claim validity.

Responsiveness should be sufficient to support transparent and Evidence-based interpretation of community-relevant infrastructure conditions.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- community concern logs;
- complaint registers;
- response records;
- corrective action records;
- stakeholder engagement records;
- public communication records;
- community liaison records;
- environmental monitoring follow-up records;
- emergency-response concern records;
- traffic or transportation concern records;
- noise, light, odor, or visual concern records;
- trend analyses;
- management review records;
- unresolved concern registers;
- Infrastructure Quality Claim Statement limitation statements.

4.12.6 Indicator 11.6 — Transparency of Infrastructure Impacts and Limitations

Context-Specific Interpretation

Transparency of infrastructure impacts and limitations means that stakeholder- and community-relevant impacts, Assumptions, Evidence, limitations, Uncertainties, unresolved concerns, and claim boundaries are communicated or made visible in a way appropriate to the context.

In LNG infrastructure, transparency may concern safety limitations, emergency-response Assumptions, environmental monitoring, emissions, discharges, traffic, marine operations, transfer operations, construction impacts, abnormal events, incident response, lifecycle changes, expansion, repurposing, or decommissioning.

Transparency does not require disclosure of every internal document or confidential detail.

It requires that infrastructure-quality interpretation does not depend on hidden Assumptions, hidden exclusions, hidden Evidence gaps, hidden unresolved conditions, or misleading statements about quality, safety, environmental protection, or community impact.

In the LNG context, transparency is especially important where public consequence, environmental exposure, emergency response, transportation interfaces, or stakeholder trust may be affected.

Illustrative Context-Specific Quality Outcome Criteria

Transparency of infrastructure impacts and limitations may be considered adequate when:

- relevant stakeholder and community impacts are described within the appropriate scope;
- relevant limitations and Assumptions are identified;
- unresolved concerns, Evidence gaps, and claim limitations are not hidden;
- monitoring and reporting information is communicated where appropriate;
- changes affecting stakeholders and communities are communicated where relevant;
- abnormal events and corrective actions are addressed transparently where appropriate;
- Critical Infrastructure Conditions affecting stakeholders or communities are not obscured by general claims;
- Infrastructure Quality Claim Statements clearly state their boundary and do not imply broader stakeholder or community satisfaction than supported by Evidence.

Transparency should be sufficient to prevent misunderstanding of the meaning, scope, and limitations of LNG Infrastructure Quality Claim Statements.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- public reports;
- stakeholder communication records;
- community meeting records;
- monitoring reports;
- environmental reports;
- emergency-response communication records;
- incident communication records;
- corrective action summaries;
- permit reporting records;
- website or public information records;
- community liaison records;

- management-of-change communication records;
- Infrastructure Quality Claim Boundary statements;
- Infrastructure Quality Claim Statement limitation statements.

4.12.7 Indicator 11.7 — Retention of Stakeholder and Community Impact Knowledge

Context-Specific Interpretation

Stakeholder and community impact knowledge should be retained so that community-relevant infrastructure conditions, concerns, commitments, impacts, limitations, and lessons remain visible across the lifecycle of the declared LNG Infrastructure Quality Object.

In LNG infrastructure, stakeholder and community impact knowledge may include stakeholder identification records, community concern records, public commitments, environmental monitoring records, emergency-response records, traffic and transportation records, public meeting records, consultation records, incident communication records, corrective action records, lessons learned, and Infrastructure Quality Claim Statement Evidence.

Retention is especially important where infrastructure is modified, expanded, repurposed, recommissioned, transferred between operators, or operated over long periods near communities or sensitive environmental receptors.

Loss of stakeholder and community impact knowledge may lead to repeated concerns, broken commitments, misunderstanding of cumulative effects, weak emergency communication, poor monitoring continuity, or misleading Infrastructure Quality Claim Statements.

Illustrative Context-Specific Quality Outcome Criteria

Stakeholder and community impact knowledge may be considered adequately retained when:

- stakeholder and community impact information is identified and retained;
- information concerning affected stakeholders and communities is retained;
- concerns, commitments, responses, monitoring results, unresolved issues, and limitations are retained;
- information concerning stakeholder- or community-relevant Critical Infrastructure Conditions is retained;
- information remains connected to current infrastructure configuration, boundaries, interfaces, lifecycle condition, and Assumptions;
- information is updated when infrastructure conditions or stakeholder conditions change;
- loss, fragmentation, or inaccessibility of stakeholder and community information is identified as an Evidence limitation;
- Infrastructure Quality Claim Statements are not made beyond retained and traceable stakeholder/community impact Evidence.

Retention should be sufficient to support continuity of understanding, communication, responsiveness, and claim transparency over time.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- stakeholder registers;
- community impact records;
- consultation records;
- public meeting records;

- community concern logs;
- complaint and response records;
- commitment registers;
- environmental monitoring records;
- traffic and transportation records;
- emergency-response communication records;
- incident communication records;
- corrective action records;
- community trend analyses;
- lessons-learned records;
- document-control records;
- Infrastructure Quality Claim Statement Evidence files.

4.13 Factor 12 — Monitoring and Performance Evaluation

Purpose of the Factor

The authoritative IQC1 purpose is:

To ensure that behavior, Infrastructure Results, and Infrastructure Outcomes of the declared Infrastructure Quality Object are monitored, evaluated, and interpreted so that Degradation and Aging, deviation, Uncertainty, and Emerging Risk are detected in time to prevent or limit unacceptable consequences.

Core architecture role: Examines whether infrastructure behavior remains sufficiently observable and interpretable to detect deviation, degradation, emerging risk, and loss of function.

Definitions and Governing Terms

Governing WQI and IQI terms. Data, Evidence, Evidence Sufficiency, Intended Result, Infrastructure Outcome, Infrastructure Operating Condition, and Degradation and Aging apply with their authoritative meanings. Systemic Risk applies as defined under Factor 5.

IQC1 Factor-specific terms. Monitoring, Performance Evaluation, Monitoring-Relevant Infrastructure Behavior, Monitoring Adequacy, Deviation, Emerging Risk, Performance Baseline, Expected Behavior, and Infrastructure Behavior apply as defined in IQI_IQC1 and are not redefined in LNG1.

LNG1 context terms and anchors. feed-gas composition and condition; process, refrigeration, temperature, pressure, flow, inventory, tank level, stratification, rollover, boil-off gas, vapor return, relief, flare, vent, transfer, loading, unloading, regasification, send-out, MNT1 Interface, gas-quality, utilities, controls, alarms, shutdowns, fire-and-gas, structural and foundation condition, environmental performance, data quality, model validity, trends, blind spots, and monitoring limitations. Their technical meaning, values, methods, and acceptance conditions depend on the declared Infrastructure Quality Object, applicable Context-Specific Quality Outcome Criteria, and the Reference Layer.

Context-specific boundary. Monitoring frequencies, alarm settings, thresholds, technologies, sensor coverage, baselines, and tolerances are established by Context-Specific Quality Outcome Criteria and the applicable Reference Layer. Monitoring Data are not automatically sufficient Evidence.

Context-Specific Interpretation

Monitoring and Performance Evaluation concerns the quality of observing, detecting, interpreting, evaluating, retaining, and acting upon information about the behavior of the declared LNG Infrastructure Quality Object.

In the LNG context, monitoring and performance evaluation should be interpreted in relation to the declared Infrastructure Quality Object, the declared LNG-context realization pathway, applicable lifecycle condition, boundaries, interfaces, Assumptions, limitations, Critical Infrastructure Conditions, and Evidence basis.

Monitoring may concern cryogenic conditions, pressure, temperature, flow, storage level, boil-off gas behavior, transfer behavior, loading and unloading, regasification, send-out, gas quality, emissions, discharges, environmental conditions, equipment condition, control-system behavior, safety-system status, emergency-system readiness, utility availability, interface conditions, and operational performance.

Performance evaluation should not be interpreted as simple collection of data.

It requires contextual interpretation of monitoring information in relation to functional intent, technical specifications, lifecycle condition, operating envelope, degradation, deviation, Uncertainty, Critical Infrastructure Conditions, and Infrastructure Quality Claim Statement validity.

Monitoring and Performance Evaluation is not demonstrated merely by the presence of instruments, alarms, control systems, dashboards, reports, or data archives.

It is demonstrated by the extent to which monitoring and performance information makes infrastructure behavior visible, understandable, traceable, and usable for responsible infrastructure-quality interpretation.

Monitoring at MNT1 receipt and send-out Interfaces and at bulk carrier-transfer Interfaces shall preserve direction, custody, time, material, condition, and Boundary meaning. Evidence from a connected object shall not be generalized beyond the supported Interface condition.

Core Quality Indicators

The following Core Quality Indicator titles are invariant and governed by IQI_IQC1. The clauses under each Indicator provide LNG1 Context-Specific Interpretation, illustrative Context-Specific Quality Outcome Criteria, and Evidence considerations; they do not reproduce or replace the normative Core Indicator Statement.

4.13.1 Indicator 12.1 — Identification of Monitoring-Relevant Infrastructure Behaviors

Context-Specific Interpretation

In LNG infrastructure, monitoring-relevant infrastructure behaviors are behaviors that should be observed or evaluated because they affect realization of the invariant Core intended function, Critical Infrastructure Conditions, Evidence sufficiency, or Infrastructure Quality Claim Statement validity.

Monitoring-relevant behaviors may include cryogenic containment behavior, thermal behavior, pressure behavior, storage behavior, boil-off gas behavior, transfer behavior, loading and unloading behavior, regasification behavior, send-out behavior, utility behavior, control-system behavior, safety-system behavior, emergency-system behavior, environmental behavior, emissions and discharge behavior, degradation behavior, and interface behavior.

The relevant behaviors depend on the declared LNG Infrastructure Quality Object and the declared LNG-context realization pathway.

For example, monitoring needs for a liquefaction facility may differ from those for an LNG storage facility, regasification terminal, FSRU, satellite LNG facility, peak-shaving facility, transfer system, or integrated LNG terminal.

Monitoring-relevant behaviors should be identified before monitoring Evidence is interpreted.

Otherwise, available data may be mistaken for sufficient visibility even where important infrastructure behavior remains unobserved.

Illustrative Context-Specific Quality Outcome Criteria

Monitoring-relevant infrastructure behaviors may be considered adequately identified when:

- behaviors relevant to the declared LNG Infrastructure Quality Object are identified;
- behaviors relevant to the declared LNG-context realization pathway are identified;
- behaviors affecting Critical Infrastructure Conditions are identified;
- behaviors involving cryogenic, thermal, pressure, storage, transfer, boil-off gas, regasification, send-out, utility, monitoring, control, safety, emergency, environmental, emissions, discharge, and interface conditions are considered where relevant;
- normal, abnormal, degraded, emergency, and lifecycle-transition behaviors are considered;
- behaviors affected by external interfaces are identified where relevant;
- Assumptions and limitations affecting monitoring relevance are documented;
- identified behaviors are traceable to functional requirements, technical specifications, Evidence interpretation, and Infrastructure Quality Claim Statements.

Identification should be sufficient to support monitoring that is relevant to infrastructure quality rather than merely available or convenient.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- monitoring basis documents;
- performance evaluation plans;
- monitoring strategy documents;
- operating envelope documents;
- process monitoring lists;
- Critical Infrastructure Conditions registers;
- alarm and trip basis documents;
- instrumentation lists;
- environmental monitoring plans;
- emissions and discharge monitoring plans;
- inspection and condition monitoring plans;
- control-system monitoring records;
- safety-system monitoring records;
- interface monitoring plans;
- Infrastructure Quality Claim Statement Evidence mapping.

4.13.2 Indicator 12.2 — Adequacy of Monitoring to Detect Degradation and Deviation

Context-Specific Interpretation

Monitoring should be adequate to detect degradation and deviation that may affect the declared LNG Infrastructure Quality Object.

Degradation may involve deterioration of materials, containment, insulation, equipment, instrumentation, control systems, safety systems, emergency systems, environmental controls, utilities, foundations, structures, or interface conditions.

Deviation may involve departure from functional requirements, technical specifications, operating envelope, expected process behavior, environmental expectations, monitoring Assumptions, interface Assumptions, or Infrastructure Quality Claim Statement limitations.

In LNG infrastructure, monitoring adequacy is especially important where degradation or deviation may be hidden, delayed, intermittent, or difficult to observe directly.

Examples may include insulation degradation, abnormal heat ingress, changing boil-off gas behavior, pressure instability, transfer irregularities, vaporization performance changes, send-out variability, environmental monitoring gaps, degraded emergency isolation, or loss of monitoring coverage.

Adequate monitoring does not require unlimited monitoring of every condition.

It requires monitoring sufficient to make quality-relevant degradation and deviation visible within the declared boundary and lifecycle condition.

Illustrative Context-Specific Quality Outcome Criteria

Monitoring may be considered adequate to detect degradation and deviation when:

- degradation and deviation mechanisms relevant to the declared Infrastructure Quality Object are identified;
- monitoring methods are aligned with those mechanisms;
- monitoring addresses Critical Infrastructure Conditions where relevant;
- monitoring addresses cryogenic, thermal, pressure, storage, transfer, boil-off gas, regasification, send-out, utility, control, safety, emergency, environmental, emissions, discharge, and interface conditions where relevant;
- monitoring coverage is appropriate to the lifecycle condition;
- monitoring limitations, blind spots, delays, or Uncertainties are identified;
- monitoring information is reviewed and interpreted rather than merely collected;
- degradation or deviation findings are traceable to evaluation, response, documentation, and Infrastructure Quality Claim Statements.

Monitoring should be sufficient to support credible understanding of whether infrastructure behavior remains within acceptable quality-relevant conditions.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- condition monitoring records;
- process trend records;
- alarm and trip records;
- inspection records;
- maintenance records;
- instrumentation calibration records;
- control-system records;
- safety-system test records;
- boil-off gas monitoring records;
- storage condition records;
- transfer monitoring records;
- regasification and send-out monitoring records;
- environmental monitoring records;
- emissions and discharge monitoring records;
- degradation assessments;

- deviation logs;
- corrective action records;
- monitoring limitation statements.

4.13.3 Indicator 12.3 — Interpretation of Monitoring Information in Context

Context-Specific Interpretation

Monitoring information should be interpreted in context.

In LNG infrastructure, the same monitoring value, trend, alarm, deviation, or event may have different meaning depending on operating mode, lifecycle condition, process configuration, gas composition, storage condition, ambient condition, transfer condition, regasification condition, send-out condition, interface condition, degradation history, and Critical Infrastructure Conditions.

Monitoring information should therefore not be interpreted as isolated data.

It should be interpreted in relation to functional requirements, technical specifications, operating envelope, boundaries, interfaces, Assumptions, Uncertainties, Evidence limitations, and Infrastructure Quality Claim Statement scope.

For example, a pressure trend, temperature trend, boil-off gas trend, alarm sequence, transfer interruption, emissions trend, or monitoring gap may be quality-relevant only when interpreted in relation to the declared LNG Infrastructure Quality Object and current operating condition.

Contextual interpretation is necessary to avoid both overstatement and understatement of infrastructure quality.

Illustrative Context-Specific Quality Outcome Criteria

Monitoring information may be considered adequately interpreted in context when:

- the operating mode and lifecycle condition are considered;
- the declared Infrastructure Quality Object and realization pathway are considered;
- boundaries and interfaces affecting the monitoring result are considered;
- relevant Assumptions and Uncertainties are considered;
- monitoring information is interpreted against functional requirements, technical specifications, operating limits, and Critical Infrastructure Conditions where relevant;
- abnormal, degraded, transient, and emergency conditions are distinguished from expected conditions;
- monitoring limitations and Evidence gaps are identified;
- monitoring interpretation is documented where relevant;
- Infrastructure Quality Claim Statements reflect the actual scope and limitations of monitoring interpretation.

Interpretation should be sufficient to support responsible infrastructure-quality conclusions rather than raw data presentation.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- monitoring interpretation records;
- performance evaluation reports;
- trend analyses;
- operating mode logs;

- shift logs;
- control-room logs;
- alarm analysis records;
- deviation investigation records;
- process performance reviews;
- environmental performance reviews;
- interface performance reviews;
- incident and near-miss reviews;
- management review records;
- corrective action records;
- Infrastructure Quality Claim Statement Evidence interpretation records.

4.13.4 Indicator 12.4 — Detection of Emerging and Systemic Risk

Context-Specific Interpretation

Monitoring and performance evaluation should support detection of emerging and systemic risk.

Emerging risk may develop gradually, intermittently, or through early indicators that do not initially appear to be failures.

Systemic risk may arise from interactions among systems, interfaces, lifecycle stages, operating modes, organizational responsibilities, environmental conditions, monitoring limitations, and Unresolved Conditions.

In LNG infrastructure, emerging or systemic risk may appear through repeated minor deviations, changing trends, recurring alarms, repeated transfer difficulties, increasing boil-off gas variation, recurring maintenance issues, degraded monitoring coverage, repeated emergency-system findings, environmental trend changes, interface coordination problems, or accumulation of Unresolved Conditions.

Detection of emerging and systemic risk requires more than response to individual alarms or isolated incidents.

It requires evaluation of patterns, trends, weak signals, cumulative effects, and cross-system interactions.

Illustrative Context-Specific Quality Outcome Criteria

Detection of emerging and systemic risk may be considered adequate when:

- monitoring and performance information is reviewed for trends and patterns;
- recurring deviations, alarms, failures, near misses, or Unresolved Conditions are evaluated collectively;
- interactions among systems, interfaces, lifecycle conditions, and operating modes are considered;
- emerging risks affecting Critical Infrastructure Conditions are identified;
- monitoring limitations that could hide emerging or systemic risk are identified;
- environmental, operational, safety, reliability, and interface information are considered together where relevant;
- emerging or systemic risk findings are documented and acted upon where appropriate;
- Infrastructure Quality Claim Statements do not ignore unresolved emerging or systemic risk indicators.

Detection should be sufficient to prevent fragmented monitoring Evidence from producing unsupported confidence in infrastructure quality.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- trend analysis records;
- recurring deviation reviews;
- alarm trend reviews;
- failure trend analyses;
- incident and near-miss trend analyses;
- maintenance backlog reviews;
- deferred action registers;
- monitoring gap assessments;
- environmental trend records;
- interface issue trend records;
- operational performance reviews;
- systemic risk reviews;
- management review records;
- corrective action records;
- Critical Infrastructure Conditions reviews;
- Infrastructure Quality Claim Statement limitation statements.

4.13.5 Indicator 12.5 — Monitoring Relevance Under Change

Context-Specific Interpretation

Monitoring should remain relevant when LNG infrastructure changes.

Changes may include functional changes, technical changes, operating changes, lifecycle changes, interface changes, environmental changes, regulatory changes, technology changes, automation changes, monitoring-system changes, expansion, modification, repair, recommissioning, repurposing, or decommissioning.

In LNG infrastructure, monitoring relevance may be affected by changed gas composition, changed throughput, changed storage use, changed transfer configuration, added loading or unloading mode, changed boil-off gas management, changed regasification or send-out conditions, changed environmental exposure, changed emergency-response Assumptions, changed interface responsibility, or changed Critical Infrastructure Conditions.

A monitoring arrangement that was adequate for one configuration, operating mode, or lifecycle condition may not remain adequate after change.

Monitoring relevance should therefore be reviewed when the declared Infrastructure Quality Object, its behavior, or its claim boundary changes.

Illustrative Context-Specific Quality Outcome Criteria

Monitoring relevance under change may be considered adequately preserved when:

- changes affecting monitoring needs are identified;
- affected monitoring-relevant behaviors are reviewed;
- effects on Critical Infrastructure Conditions are reviewed;
- effects on cryogenic, thermal, pressure, storage, transfer, boil-off gas, regasification, send-out, environmental, emissions, discharge, safety, emergency, utility, and interface monitoring are considered where relevant;

- monitoring coverage, alarm limits, data interpretation, Evidence retention, and performance evaluation are updated where necessary;
- Assumptions and Uncertainties are updated;
- monitoring gaps created by change are identified;
- Infrastructure Quality Claim Statements are revised, limited, withdrawn, or re-evidenced where monitoring relevance changes.

Monitoring should not be presumed adequate after change merely because instruments, procedures, or reports remain in place.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- management-of-change records;
- monitoring impact assessments;
- instrumentation change records;
- alarm setpoint review records;
- control-system modification records;
- environmental monitoring reassessments;
- emissions and discharge monitoring reassessments;
- operating envelope revisions;
- interface monitoring revisions;
- commissioning or recommissioning monitoring records;
- updated Critical Infrastructure Conditions registers;
- monitoring gap registers;
- revised performance evaluation plans;
- revised Infrastructure Quality Claim Statements.

4.13.6 Indicator 12.6 — Interpretation of Infrastructure Behavior in Relation to Intended Results

Context-Specific Interpretation

Monitoring and performance evaluation should interpret infrastructure behavior in relation to Infrastructure Intended Results.

In LNG infrastructure, Infrastructure Intended Results are not limited to production volume, storage availability, transfer completion, regasification capacity, or send-out quantity.

They also include preservation of functional intent, integrity, process safety, environmental protection, operational reliability, workplace safety, competence-dependent performance, compliance limitations, stakeholder and community impact, Evidence sufficiency, and Infrastructure Quality Claim Statement validity.

Infrastructure behavior should therefore be evaluated against the declared Infrastructure Quality Object, the declared LNG-context realization pathway, the applicable lifecycle condition, boundaries, interfaces, Assumptions, limitations, and Critical Infrastructure Conditions.

For example, successful LNG transfer may still require interpretation of transfer stability, cryogenic control, pressure behavior, emergency isolation readiness, environmental protection, interface responsibility, monitoring visibility, and Evidence continuity.

Likewise, stable send-out may still require interpretation of gas-quality compatibility, downstream interface Assumptions, environmental effects, reliability, and claim limitations.

Illustrative Context-Specific Quality Outcome Criteria

Infrastructure behavior may be considered adequately interpreted in relation to Infrastructure Intended Results when:

- Infrastructure Intended Results relevant to the declared Infrastructure Quality Object are identified;
- monitoring and performance information is evaluated against those outcomes;
- operational output is distinguished from infrastructure quality;
- cryogenic, thermal, pressure, storage, transfer, boil-off gas, regasification, send-out, safety, environmental, reliability, monitoring, interface, and stakeholder conditions are considered where relevant;
- Critical Infrastructure Conditions are evaluated in relation to Infrastructure Intended Results;
- Evidence limitations are identified;
- deviations between observed behavior and Infrastructure Intended Results are documented;
- Infrastructure Quality Claim Statements are bounded by the observed and interpreted infrastructure behavior.

Interpretation should be sufficient to support responsible conclusions about whether Infrastructure Intended Results are being realized within the declared boundary and lifecycle condition.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- performance evaluation reports;
- operating performance reviews;
- intended outcome matrices;
- process trend analyses;
- reliability reviews;
- safety performance reviews;
- environmental performance reviews;
- stakeholder impact reviews;
- interface performance reviews;
- monitoring interpretation records;
- deviation investigation records;
- corrective action records;
- management review records;
- Infrastructure Quality Claim Statement Evidence mapping;
- Infrastructure Quality Claim Statement limitation statements.

4.13.7 Indicator 12.7 — Retention of Monitoring and Performance Knowledge

Context-Specific Interpretation

Monitoring and performance knowledge should be retained so that infrastructure behavior can be understood, evaluated, compared, trended, reassessed, and claimed across the lifecycle of the declared LNG Infrastructure Quality Object.

In LNG infrastructure, monitoring and performance knowledge may include operating data, trend records, alarm records, trip records, inspection data, maintenance data, degradation data, environmental monitoring data, emissions and discharge records, control-system data, safety-system records, emergency-system records, interface monitoring records, incident records, abnormal-condition records, performance reviews, corrective actions, and Infrastructure Quality Claim Statement Evidence.

Retention is especially important where infrastructure is aging, modified, brownfield, floating, multi-operator, transportation-connected, interface-dependent, or subject to changing environmental conditions.

Loss or fragmentation of monitoring and performance knowledge may obscure trends, hide emerging risk, weaken reliability interpretation, prevent environmental interpretation, reduce change evaluation quality, or invalidate Infrastructure Quality Claim Statements.

Retention should preserve not only data, but also interpretation, context, Assumptions, limitations, and traceability.

Illustrative Context-Specific Quality Outcome Criteria

Monitoring and performance knowledge may be considered adequately retained when:

- monitoring and performance information relevant to the declared Infrastructure Quality Object is identified and retained;
- information concerning Critical Infrastructure Conditions is retained;
- operating, inspection, maintenance, environmental, emissions, discharge, alarm, trip, degradation, interface, and performance records are retained where relevant;
- monitoring information remains connected to operating mode, lifecycle condition, boundary, interface, Assumptions, and limitations;
- trend and interpretation records are retained, not only raw data;
- information remains accessible to appropriate users across lifecycle stages;
- loss, fragmentation, or inaccessibility of monitoring and performance knowledge is identified as an Evidence limitation;
- Infrastructure Quality Claim Statements are not made beyond retained and traceable monitoring and performance Evidence.

Retention should be sufficient to support future reassessment, lifecycle transition, change evaluation, performance evaluation, and bounded Infrastructure Quality Claim Statements.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- operating data archives;
- process historian records;
- trend reports;
- alarm and trip records;
- inspection and maintenance records;
- condition monitoring records;
- environmental monitoring records;
- emissions and discharge records;
- performance review reports;
- interface monitoring records;
- incident and near-miss records;
- abnormal operation records;
- corrective action records;
- management review records;
- document-control records;
- Evidence indexes;
- Infrastructure Quality Claim Statement Evidence files.

4.14 Factor 13 — Documentation and Traceability

Purpose of the Factor

The authoritative IQC1 purpose is:

To ensure that decisions, Assumptions, requirements, findings, determinations, claims, and changes affecting Infrastructure Quality are documented and traceable across the Lifecycle, enabling understanding of Infrastructure Configuration, Decision Rationale, Evidence, Uncertainty, and the basis of the current Infrastructure Quality State.

Core architecture role: Examines whether quality-relevant knowledge and Evidence remain available, connected, traceable, and usable across lifecycle and responsibility changes.

Definitions and Governing Terms

Governing WQI and IQI terms. Data, Evidence, Evidence Sufficiency, Unresolved Condition, and Infrastructure Evidence Continuity apply with their authoritative WQI_VOC1 and IQI_VOC1 meanings.

IQC1 Factor-specific terms. Documentation, Traceability, Decision Rationale, Quality-Critical Information, Information Accessibility, Information Usability and Interpretability, Information Retention, and Documentation Substitution for Quality apply as defined in IQI_IQC1 and are not redefined in LNG1.

LNG1 context terms and anchors. design bases; process-flow and piping-and-instrumentation information; material, fabrication, tank, containment, insulation, pressure-equipment, transfer, berth, marine, bulk-carrier, MNT1 Interface, utility, control, safety, Commissioning, cooldown, first-fill, cargo, inventory, gas-quality, operating, inspection, maintenance, modification, environmental, incident, emergency, Assumption, Uncertainty, and lifecycle records; and continuity of quality-critical information across owners and operators. Their technical meaning, values, methods, and acceptance conditions depend on the declared Infrastructure Quality Object, applicable Context-Specific Quality Outcome Criteria, and the Reference Layer.

Context-specific boundary. Document-control systems, record-management systems, retention periods, data platforms, access permissions, formats, and technology-specific controls remain governed by the Context Guide or Reference Layer.

Context-Specific Interpretation

Documentation and Traceability concerns the quality of recording, preserving, connecting, and making accessible information needed to understand the declared LNG Infrastructure Quality Object and support responsible infrastructure-quality interpretation.

In the LNG context, documentation and traceability should be interpreted in relation to the declared Infrastructure Quality Object, the declared LNG-context realization pathway, applicable lifecycle condition, boundaries, interfaces, Assumptions, limitations, Critical Infrastructure Conditions, and Evidence basis.

Documentation may include functional requirements, technical specifications, design decisions, Assumptions, Uncertainty records, interface records, conformity assessment records, inspection records, test records, commissioning records, cooldown records, operating records, monitoring records, maintenance records, environmental records, safety records, emergency-response records, stakeholder records, management-of-change records, Unresolved Conditions, and Infrastructure Quality Claim Statement Evidence.

Documentation is not quality by itself.

Documentation supports quality interpretation only when it remains accurate, traceable, accessible, current, connected to realized infrastructure behavior, and bounded by its limitations.

Traceability is especially important in LNG infrastructure because Evidence may be distributed across many systems, lifecycle stages, organizations, contractors, authorities, vendors, and interface owners.

Documentation shall distinguish LNG1 terminal or bulk-transfer records from MNT1 records, carrier records, and downstream LNGFS1 fueling records, while maintaining traceability of information transferred across each declared Interface.

Core Quality Indicators

The following Core Quality Indicator titles are invariant and governed by IQI_IQC1. The clauses under each Indicator provide LNG1 Context-Specific Interpretation, illustrative Context-Specific Quality Outcome Criteria, and Evidence considerations; they do not reproduce or replace the normative Core Indicator Statement.

4.14.1 Indicator 13.1 — Documentation of Infrastructure-Relevant Decisions and Assumptions

Context-Specific Interpretation

Infrastructure-relevant decisions and Assumptions should be documented where they affect the declared LNG Infrastructure Quality Object, its boundaries, interfaces, lifecycle condition, Critical Infrastructure Conditions, Evidence interpretation, or Infrastructure Quality Claim Statement validity.

In LNG infrastructure, relevant decisions may concern facility configuration, realization pathway, functional scope, technical design, material selection, cryogenic containment, storage strategy, boil-off gas management, transfer configuration, loading and unloading arrangements, regasification and send-out arrangements, environmental controls, safety systems, monitoring systems, emergency response, interface responsibilities, operating envelope, modification, recommissioning, repurposing, or decommissioning.

Relevant Assumptions may concern gas composition, operating mode, storage duration, transfer frequency, marine or transportation interface, downstream demand, environmental exposure, emergency-response capability, monitoring coverage, degradation mechanisms, lifecycle condition, or connected infrastructure behavior.

Undocumented decisions and Assumptions may later become invisible sources of Uncertainty, inconsistency, Evidence gaps, or misleading Infrastructure Quality Claim Statements.

Illustrative Context-Specific Quality Outcome Criteria

Documentation of infrastructure-relevant decisions and Assumptions may be considered adequate when:

- quality-relevant decisions are identified and documented;
- Assumptions affecting the declared Infrastructure Quality Object are identified and documented;
- decisions and Assumptions are connected to the declared LNG-context realization pathway;
- decisions and Assumptions affecting boundaries, interfaces, lifecycle conditions, and Critical Infrastructure Conditions are documented;
- Assumptions are distinguished from verified conditions;
- decision rationale is documented where relevant to quality interpretation;
- Assumptions are reviewed when lifecycle conditions, operating modes, interfaces, or infrastructure configuration change;

- Infrastructure Quality Claim Statements do not rely on undocumented Assumptions or unexplained decisions.

Documentation should be sufficient to allow later users to understand why infrastructure-quality-relevant decisions were made and what Assumptions supported them.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- decision registers;
- Assumptions registers;
- design-basis documents;
- operating basis documents;
- interface basis documents;
- technical decision records;
- engineering memoranda;
- risk assessment records;
- environmental basis documents;
- safety basis documents;
- management-of-change records;
- meeting minutes;
- unresolved issue logs;
- Critical Infrastructure Conditions registers;
- Infrastructure Quality Claim Statement Evidence files.

4.14.2 Indicator 13.2 — Traceability Between Functional Intent, Technical Requirements, and Realized Infrastructure

Context-Specific Interpretation

Traceability should connect functional intent, technical requirements, and realized infrastructure behavior.

In LNG infrastructure, functional intent may be translated into technical specifications, implemented through design and construction, verified during conformity assessment, made visible during commissioning and cooldown, and preserved or changed during operation, maintenance, modification, recommissioning, repurposing, or decommissioning.

Traceability is necessary because the declared Infrastructure Quality Object may include many systems and interfaces, including liquefaction, cryogenic storage, boil-off gas management, transfer, loading, unloading, regasification, send-out, utilities, monitoring, safety, emergency, environmental, and supporting systems.

A technical requirement may exist without clear connection to functional intent.

A realized infrastructure condition may exist without clear connection to the technical basis.

An Infrastructure Quality Claim Statement may be weakened where functional intent, technical requirements, and realized infrastructure behavior cannot be traced together.

Illustrative Context-Specific Quality Outcome Criteria

Traceability between functional intent, technical requirements, and realized infrastructure may be considered adequate when:

- functional requirements are traceable to technical requirements;

- technical requirements are traceable to realized infrastructure conditions;
- realized infrastructure Evidence is traceable back to functional intent;
- traceability includes relevant boundaries and interfaces;
- traceability includes lifecycle-stage Evidence where relevant;
- traceability includes cryogenic, thermal, pressure, storage, transfer, boil-off gas, regasification, send-out, monitoring, safety, emergency, environmental, and interface conditions where applicable;
- traceability includes Assumptions, Uncertainties, Critical Infrastructure Conditions, and Unresolved Conditions;
- Infrastructure Quality Claim Statements are traceable to the Evidence connecting intent, requirements, and realized behavior.

Traceability should be sufficient to show whether the declared LNG Infrastructure Quality Object realizes the intended function within the claimed boundary and lifecycle condition.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- requirements traceability matrices;
- functional-to-technical mapping;
- design-to-construction traceability records;
- construction completion records;
- inspection and test records;
- commissioning records;
- cooldown records;
- operating Evidence;
- monitoring Evidence;
- interface traceability records;
- management-of-change traceability records;
- configuration records;
- Evidence indexes;
- quality records;
- Infrastructure Quality Claim Statement traceability files.

4.14.3 Indicator 13.3 — Documentation of Uncertainty, Limitations, and Known Vulnerabilities

Context-Specific Interpretation

Uncertainty, limitations, and known vulnerabilities should be documented where they affect infrastructure-quality interpretation.

In LNG infrastructure, Uncertainty may concern gas composition, process behavior, cryogenic behavior, thermal conditions, pressure behavior, storage condition, boil-off gas behavior, transfer compatibility, regasification and send-out Assumptions, environmental exposure, degradation mechanisms, monitoring coverage, emergency-response Assumptions, interface conditions, lifecycle condition, or Evidence sufficiency.

Limitations may concern assessment scope, monitoring coverage, lifecycle stage, Unresolved Conditions, incomplete commissioning Evidence, temporary operating restrictions, degraded conditions, documentation gaps, compliance limitations, or Infrastructure Quality Claim Statement Boundaries.

Known vulnerabilities may concern Critical Infrastructure Conditions, aging mechanisms, interface weaknesses, emergency-system limitations, environmental exposure, monitoring blind spots, organizational handover weaknesses, or recurring deviations.

Documentation of Uncertainty, limitations, and known vulnerabilities prevents them from being hidden behind general statements of completion, compliance, operability, capacity, or absence of observed failure.

Illustrative Context-Specific Quality Outcome Criteria

Documentation of Uncertainty, limitations, and known vulnerabilities may be considered adequate when:

- relevant Uncertainties are identified and documented;
- relevant limitations are identified and documented;
- known vulnerabilities are identified and documented;
- Uncertainties, limitations, and vulnerabilities affecting Critical Infrastructure Conditions are identified;
- documentation distinguishes resolved issues from unresolved issues;
- Evidence gaps and monitoring limitations are documented;
- limitations are carried forward across lifecycle transitions where relevant;
- documentation is updated when infrastructure conditions change;
- Infrastructure Quality Claim Statements state relevant Uncertainty, limitations, and known vulnerabilities.

Documentation should be sufficient to prevent unsupported confidence in infrastructure quality or overextension of Infrastructure Quality Claim Statements.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- Uncertainty registers;
- limitation registers;
- vulnerability registers;
- Evidence-gap registers;
- risk assessment records;
- unresolved finding logs;
- non-conformity records;
- deviation and concession records;
- monitoring limitation statements;
- operating restriction records;
- degradation assessments;
- Critical Infrastructure Conditions registers;
- management review records;
- lifecycle transition records;
- Infrastructure Quality Claim Statement limitation statements.

4.14.4 Indicator 13.4 — Traceability of Assessments, Evaluations, and Conformity Statements

Context-Specific Interpretation

Assessments, evaluations, and Conformity Statements should be traceable to their basis, scope, Evidence, boundary, lifecycle condition, limitations, and Unresolved Conditions.

In LNG infrastructure, assessments and evaluations may include design reviews, engineering assessments, hazard studies, risk assessments, environmental assessments, integrity assessments, reliability assessments, competence assessments, monitoring evaluations, compliance assessments, conformity assessments, commissioning evaluations, operational readiness reviews, and Infrastructure Quality Claim Statement evaluations.

Conformity claims may concern components, systems, interfaces, lifecycle stages, technical specifications, regulatory requirements, standards, permits, or other defined requirements.

Traceability is necessary because assessment results may be used later as Evidence for infrastructure-quality interpretation.

A claim that a system is conforming, ready, safe, reliable, environmentally acceptable, or compliant may be misleading if the assessment basis, scope, Evidence, and limitations are not traceable.

Illustrative Context-Specific Quality Outcome Criteria

Traceability of assessments, evaluations, and Conformity Statements may be considered adequate when:

- the assessment or evaluation purpose is identified;
- the assessment basis is identified;
- the scope and boundary are identified;
- the lifecycle condition is identified;
- Evidence supporting the assessment is identified;
- findings, limitations, deviations, non-conformities, and unresolved issues are documented;
- claims based on assessments are bounded by the assessment scope;
- assessment Evidence is connected to applicable Core Quality Indicators where relevant;
- Conformity Statements are distinguished from broader Infrastructure Quality Claim Statements;
- Infrastructure Quality Claim Statements are traceable to supporting assessments and their limitations.

Traceability should be sufficient to support responsible use of assessment and conformity Evidence within infrastructure-quality interpretation.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- assessment reports;
- evaluation reports;
- conformity assessment records;
- inspection and test reports;
- commissioning evaluation records;
- operational readiness review records;
- integrity assessment reports;
- risk assessment reports;
- environmental assessment reports;

- compliance assessment reports;
- monitoring evaluation reports;
- Evidence indexes;
- finding closeout records;
- limitation statements;
- Infrastructure Quality Claim Statement Evidence files.

4.14.5 Indicator 13.5 — Documentation of Changes and Their Rationale

Context-Specific Interpretation

Changes affecting the declared LNG Infrastructure Quality Object should be documented together with their rationale.

In LNG infrastructure, changes may affect functional requirements, technical specifications, operating modes, lifecycle conditions, boundaries, interfaces, equipment, materials, process configuration, storage use, boil-off gas management, transfer configuration, loading and unloading, regasification, send-out, monitoring, control systems, safety systems, emergency systems, environmental controls, organizational responsibilities, compliance obligations, or Infrastructure Quality Claim Statements.

Documentation of change should make clear what changed, why it changed, what conditions were affected, what Evidence supports the change, what Assumptions were revised, what risks were considered, and whether the Infrastructure Quality Claim Statement remains valid.

Change documentation should not be limited to administrative tracking.

It should preserve the quality-relevant meaning of the change.

In LNG infrastructure, even a local change may affect integrated infrastructure behavior, Critical Infrastructure Conditions, Evidence sufficiency, or claim validity.

Illustrative Context-Specific Quality Outcome Criteria

Documentation of changes and their rationale may be considered adequate when:

- changes affecting the declared Infrastructure Quality Object are identified and documented;
- the rationale for change is documented;
- affected functional requirements and technical specifications are identified;
- affected boundaries, interfaces, lifecycle conditions, Assumptions, and Critical Infrastructure Conditions are identified;
- effects on integrity, process safety, environmental protection, reliability, workplace interaction, competence, monitoring, compliance, and documentation are considered where relevant;
- Evidence supporting the change is retained;
- approval, review, and verification records are retained where relevant;
- Infrastructure Quality Claim Statements are reviewed and revised where change affects claim validity.

Change documentation should be sufficient to preserve continuity between prior infrastructure conditions, modified conditions, Evidence, and claim boundaries.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- management-of-change records;
- engineering change requests;
- change rationale documents;

- design change records;
- operating change records;
- interface change records;
- environmental change records;
- safety change records;
- monitoring change records;
- revised Assumptions registers;
- revised Critical Infrastructure Conditions registers;
- approval records;
- commissioning or recommissioning records;
- verification records;
- revised Infrastructure Quality Claim Statements.

4.14.6 Indicator 13.6 — Accessibility and Continuity of Quality-Critical Information

Context-Specific Interpretation

Quality-critical information should remain accessible and continuous across the lifecycle of the declared LNG Infrastructure Quality Object.

In LNG infrastructure, quality-critical information may be held by different organizations, contractors, vendors, operators, regulators, port authorities, transportation interfaces, emergency-response organizations, or document-control systems.

Information may become inaccessible because of organizational change, contractor turnover, system migration, outdated formats, poor document control, fragmented databases, loss of vendor records, incomplete handover, or unclear ownership of records.

Information continuity is quality-relevant because infrastructure-quality interpretation depends on the ability to understand functional intent, technical basis, realized conditions, Assumptions, limitations, Critical Infrastructure Conditions, monitoring history, change history, and Evidence basis over time.

Loss of accessibility or continuity may prevent credible reassessment, maintenance, operation, modification, recommissioning, decommissioning, or Infrastructure Quality Claim Statement preparation.

Illustrative Context-Specific Quality Outcome Criteria

Accessibility and continuity of quality-critical information may be considered adequate when:

- quality-critical information is identified;
- information ownership and responsibility are defined;
- information remains accessible to appropriate users;
- information remains traceable across lifecycle stages;
- information remains connected to the declared Infrastructure Quality Object, boundaries, interfaces, lifecycle condition, and Critical Infrastructure Conditions;
- information transfer is addressed during organizational, contractor, operator, or lifecycle transitions;
- loss, fragmentation, inaccessibility, or obsolescence of information is identified as an Evidence limitation;
- Infrastructure Quality Claim Statements are not made beyond accessible and continuous Evidence.

Information accessibility and continuity should be sufficient to support responsible infrastructure-quality interpretation across time.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- document-control systems;
- records management plans;
- information handover records;
- data retention schedules;
- Evidence indexes;
- document registers;
- vendor document registers;
- commissioning handover records;
- operations handover records;
- management-of-change records;
- lifecycle transition records;
- access control records;
- archival records;
- information gap assessments;
- Infrastructure Quality Claim Statement Evidence files.

4.14.7 Indicator 13.7 — Prevention of Documentation Substitution for Quality

Context-Specific Interpretation

Documentation should not be substituted for infrastructure quality.

In LNG infrastructure, complete documentation may exist while the declared Infrastructure Quality Object still has unresolved quality-relevant issues.

Documentation may show that a requirement was stated, a test was performed, a certificate was issued, a permit was obtained, a procedure exists, or a report was completed.

However, such documentation does not by itself demonstrate that infrastructure behavior realizes the invariant Core intended function within the declared boundary, lifecycle condition, interfaces, Assumptions, limitations, Critical Infrastructure Conditions, and Evidence basis.

Documentation becomes quality-relevant when it accurately reflects realized infrastructure condition, supports traceability, preserves Evidence, identifies limitations, and enables responsible interpretation.

Documentation substitution may occur when paperwork, compliance files, certificates, design packages, inspection reports, operating procedures, or dashboards are treated as proof of quality without sufficient connection to actual infrastructure behavior.

Illustrative Context-Specific Quality Outcome Criteria

Prevention of documentation substitution for quality may be considered adequate when:

- documentation is treated as Evidence, not as quality itself;
- documentation is checked against realized infrastructure behavior where relevant;
- documentation completeness is distinguished from Evidence sufficiency;
- certificates, permits, procedures, reports, and compliance records are not used to imply quality beyond their scope;
- documentation limitations and Evidence gaps are identified;

- documentation is connected to functional intent, technical requirements, conformity assessment, monitoring, and Infrastructure Quality Claim Statements;
- absence of observed failure is not combined with documentation alone as proof of quality;
- Infrastructure Quality Claim Statements state what documentation supports and what it does not support.

Prevention should be sufficient to avoid misleading Infrastructure Quality Claim Statements based only on records rather than infrastructure behavior.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- Evidence sufficiency reviews;
- document-to-field verification records;
- as-built verification records;
- commissioning verification records;
- operational verification records;
- monitoring interpretation records;
- assessment limitation statements;
- compliance limitation statements;
- non-conformity records;
- unresolved finding logs;
- document quality reviews;
- field walkdown records;
- management review records;
- Infrastructure Quality Claim Statement limitation statements;
- Infrastructure Quality Claim Statement Evidence interpretation records.

4.15 Factor 14 — Adaptability and Innovation Readiness

Purpose of the Factor

The authoritative IQC1 purpose is:

To ensure that the declared Infrastructure Quality Object can undergo responsible Adaptation and Innovation without compromising Infrastructure Safety, Structural or Functional Integrity, Operational Reliability, Environmental Protection, Infrastructure Intended Results, Evidence, Critical Infrastructure Conditions, or claim validity.

Core architecture role: Examines whether change and innovation can occur without loss of functional alignment, safety, integrity, Evidence Sufficiency, or claim validity.

Definitions and Governing Terms

Governing WQI and IQI terms. Technology, Technology Governance, Infrastructure Technology Governance, Intended Function, Intended Result, Boundary, Interface, Infrastructure Configuration, and Infrastructure Quality Object apply with their authoritative WQI_VOC1 and IQI_VOC1 meanings.

IQC1 Factor-specific terms. Adaptation, Adaptability, Innovation, Innovation Readiness, Adaptability Constraint, Adaptability Opportunity, Reversibility, Recoverability of Adaptation, and Learning from Adaptation and Innovation apply as defined in IQI_IQC1 and are not redefined in LNG1.

LNG1 context terms and anchors. debottlenecking, expansion, export-import role change, floating LNG and FSRU integration, new refrigeration or liquefaction technology, alternative heat sources, new tank or containment concepts, advanced insulation, digital twins, automation, remote operation, advanced sensing, emissions reduction, boil-off gas recovery, carbon-management interfaces, changed gas composition, changed carrier or bulk-transport modes, MNT1 Interface change, repurposing, and adaptation without importing downstream LNGFS1 vehicle-dispensing functions into LNG1. Their technical meaning, values, methods, and acceptance conditions depend on the declared Infrastructure Quality Object, applicable Context-Specific Quality Outcome Criteria, and the Reference Layer.

Context-specific boundary. Technology-readiness levels, pilot requirements, modularity criteria, spare-capacity requirements, roadmaps, commercialization criteria, and technology-specific acceptance thresholds remain in this Guide or the Reference Layer.

Context-Specific Interpretation

Adaptability and Innovation Readiness concerns the ability of the declared LNG Infrastructure Quality Object to accommodate, evaluate, control, learn from, and preserve quality during adaptation, innovation, modernization, repurposing, or changed infrastructure conditions.

In the LNG context, adaptability and innovation readiness should be interpreted in relation to the declared Infrastructure Quality Object, the declared LNG-context realization pathway, applicable lifecycle condition, boundaries, interfaces, Assumptions, limitations, Critical Infrastructure Conditions, and Evidence basis.

Adaptation or innovation may involve new technology, new operating modes, changed liquefaction arrangements, changed storage use, modified boil-off gas management, new transfer systems, added loading or unloading modes, regasification changes, send-out changes, floating LNG applications, FSRU integration, automation, digital monitoring, emissions-reduction technology, alternative fuels, changed gas composition, changed environmental requirements, changed safety systems, or repurposing of infrastructure.

Adaptability and Innovation Readiness is not demonstrated merely by willingness to adopt new technology, modernization plans, digital systems, pilot projects, vendor proposals, or future-oriented statements.

It is demonstrated by the extent to which adaptation and innovation remain compatible with the invariant Core intended function, declared boundaries, lifecycle conditions, interfaces, Critical Infrastructure Conditions, Evidence limitations, and bounded Infrastructure Quality Claim Statements.

Adaptation that adds automotive vehicle dispensing changes the intended function and Context. Such a function shall be treated as a separately bounded downstream LNGFS1 object or Interface rather than being absorbed silently into LNG1.

Core Quality Indicators

The following Core Quality Indicator titles are invariant and governed by IQI_IQC1. The clauses under each Indicator provide LNG1 Context-Specific Interpretation, illustrative Context-Specific Quality Outcome Criteria, and Evidence considerations; they do not reproduce or replace the normative Core Indicator Statement.

4.15.1 Indicator 14.1 — Identification of Adaptability-Relevant Constraints and Opportunities

Context-Specific Interpretation

In LNG infrastructure, adaptability-relevant constraints and opportunities should be identified before adaptation or innovation is interpreted as quality-positive.

Constraints may arise from cryogenic behavior, material limits, storage configuration, pressure limits, boil-off gas management, transfer compatibility, loading and unloading interfaces, regasification or send-out limits, gas-quality requirements, environmental obligations, safety systems, emergency-response arrangements, monitoring capability, regulatory requirements, stakeholder commitments, lifecycle condition, or connected infrastructure Assumptions.

Opportunities may arise from improved monitoring, improved emissions control, improved boil-off gas management, increased reliability, improved transfer compatibility, better environmental protection, digital tools, improved emergency response, energy efficiency, modernization, modularization, floating infrastructure options, or better lifecycle Evidence continuity.

The identification of constraints and opportunities should be specific to the declared LNG Infrastructure Quality Object and realization pathway.

A general opportunity for innovation should not be assumed suitable for every LNG infrastructure context.

Illustrative Context-Specific Quality Outcome Criteria

Adaptability-relevant constraints and opportunities may be considered adequately identified when:

- constraints affecting the declared LNG Infrastructure Quality Object are identified;
- opportunities relevant to the declared LNG-context realization pathway are identified;
- constraints and opportunities affecting boundaries and interfaces are identified;
- constraints and opportunities affecting Critical Infrastructure Conditions are identified;
- cryogenic, thermal, pressure, storage, transfer, boil-off gas, regasification, send-out, environmental, safety, emergency, monitoring, utility, and interface conditions are considered where relevant;
- lifecycle-stage and lifecycle-transition constraints are considered;
- Assumptions and Uncertainties affecting adaptation are documented;
- Infrastructure Quality Claim Statements do not treat adaptation or innovation as beneficial without Evidence of suitability within the declared context.

Identification should be sufficient to support responsible evaluation of whether adaptation or innovation can preserve or improve infrastructure quality.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- adaptability assessments;
- innovation readiness reviews;
- technology screening records;
- constraint registers;
- opportunity registers;
- interface compatibility reviews;
- lifecycle assessments;
- risk assessments;
- environmental opportunity assessments;

- emissions-reduction assessments;
- monitoring improvement assessments;
- vendor technology evaluations;
- pilot project evaluations;
- management-of-change records;
- Critical Infrastructure Conditions registers;
- Infrastructure Quality Claim Statement limitation statements.

4.15.2 Indicator 14.2 — Preservation of Safety and Integrity During Adaptation

Context-Specific Interpretation

Safety and integrity should be preserved during adaptation, innovation, modernization, modification, expansion, repurposing, recommissioning, or changed operation of LNG infrastructure.

In the LNG context, adaptation may affect cryogenic containment, thermal behavior, pressure control, storage integrity, boil-off gas management, transfer integrity, loading and unloading safety, regasification and send-out behavior, monitoring coverage, control systems, safety systems, emergency systems, environmental protection, workplace interaction, competence, documentation, and interface conditions.

An innovation may improve one aspect of infrastructure performance while introducing new Uncertainty, new failure modes, new interface dependencies, or new Evidence limitations.

Preservation of safety and integrity therefore requires explicit evaluation of how adaptation affects the declared Infrastructure Quality Object and its Critical Infrastructure Conditions.

Adaptation should not be interpreted as quality-positive merely because it is new, efficient, automated, digital, lower-emission, or commercially attractive.

Illustrative Context-Specific Quality Outcome Criteria

Safety and integrity during adaptation may be considered preserved when:

- safety and integrity implications of adaptation are identified;
- effects on Critical Infrastructure Conditions are evaluated;
- effects on cryogenic, thermal, pressure, storage, transfer, boil-off gas, regasification, send-out, monitoring, control, safety, emergency, environmental, and interface systems are considered where relevant;
- new failure modes and new Uncertainties are identified;
- conformity assessment, testing, commissioning, monitoring, and Evidence needs are defined where relevant;
- personnel competence and workplace interaction implications are considered;
- unresolved adaptation-related safety or integrity limitations are documented;
- Infrastructure Quality Claim Statements are revised, limited, withdrawn, or re-evidenced where adaptation affects safety or integrity Assumptions.

Safety and integrity should remain demonstrable within the declared boundary and lifecycle condition before adaptation is used to support an Infrastructure Quality Claim Statement.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- management-of-change records;

- safety impact assessments;
- integrity impact assessments;
- hazard study updates;
- process safety reviews;
- technology qualification records;
- pilot test records;
- commissioning and recommissioning records;
- safety-system verification records;
- emergency-system verification records;
- interface reassessment records;
- competence and training updates;
- monitoring coverage reassessments;
- updated Critical Infrastructure Conditions registers;
- revised Infrastructure Quality Claim Statements.

4.15.3 Indicator 14.3 — Compatibility with Functional Intent, Boundaries, and Interfaces

Context-Specific Interpretation

Adaptation and innovation should remain compatible with the declared functional intent and system boundaries of the LNG Infrastructure Quality Object.

A proposed change may be technically possible but incompatible with the declared functional scope, realization pathway, lifecycle condition, included interfaces, excluded interfaces, connected infrastructure Assumptions, environmental context, stakeholder commitments, or Infrastructure Quality Claim Boundary.

In LNG infrastructure, compatibility may be affected by changed liquefaction function, changed storage role, changed transfer mode, added loading or unloading function, changed regasification or send-out role, changed gas composition, changed pipeline interface, changed marine or transportation interface, changed environmental requirements, or changed emergency-response Assumptions.

Compatibility should also consider whether adaptation changes the declared Infrastructure Quality Object itself.

Where adaptation creates a new functional pathway or substantially changes the claim boundary, the Infrastructure Quality Claim Statement should be revised rather than carried forward unchanged.

Illustrative Context-Specific Quality Outcome Criteria

Compatibility with functional intent and system boundaries may be considered adequate when:

- the functional intent affected by adaptation is identified;
- the declared Infrastructure Quality Object boundary is reviewed;
- included and excluded interfaces are reviewed;
- the declared LNG-context realization pathway is reviewed;
- compatibility with connected infrastructure Assumptions is evaluated;
- compatibility with lifecycle condition is evaluated;
- compatibility with Critical Infrastructure Conditions is evaluated;
- Assumptions and limitations are updated;
- changes to the Infrastructure Quality Claim Boundary are identified;

- Infrastructure Quality Claim Statements are revised, limited, withdrawn, or re-evidenced where adaptation changes functional intent or system boundaries.

Compatibility should be sufficient to prevent adaptation from silently changing the meaning of the declared LNG Infrastructure Quality Object or Infrastructure Quality Claim Statement.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- functional compatibility reviews;
- boundary reassessment records;
- interface compatibility reviews;
- system integration reviews;
- operating philosophy revisions;
- design-basis updates;
- management-of-change records;
- gas-quality compatibility assessments;
- pipeline interface assessments;
- marine or transportation interface assessments;
- environmental compatibility reviews;
- emergency-response compatibility reviews;
- lifecycle transition reviews;
- updated Assumptions registers;
- revised Infrastructure Quality Claim Statements.

4.15.4 Indicator 14.4 — Treatment of Uncertainty Introduced by Innovation

Context-Specific Interpretation

Innovation may introduce Uncertainty that should be identified, evaluated, monitored, and transparently reflected in Evidence interpretation and Infrastructure Quality Claim Statements.

In LNG infrastructure, innovation-related Uncertainty may arise from new equipment, new materials, new process arrangements, new digital systems, new automation, new monitoring methods, new emissions-control technologies, new boil-off gas management strategies, new transfer methods, floating applications, repurposed infrastructure, new gas compositions, new safety systems, new environmental controls, or new interface arrangements.

Innovation-related Uncertainty may affect performance, safety, integrity, environmental protection, operational reliability, workplace interaction, competence, monitoring interpretation, documentation, compliance, stakeholder impact, and claim validity.

Uncertainty introduced by innovation should not be hidden by vendor claims, pilot success, generic technology readiness statements, or compliance with selected standards.

The question under this Guide is whether Uncertainty is understood and bounded within the declared LNG Infrastructure Quality Object and lifecycle condition.

Illustrative Context-Specific Quality Outcome Criteria

Uncertainty introduced by innovation may be considered adequately treated when:

- innovation-related Uncertainties are identified;
- Uncertainties affecting Critical Infrastructure Conditions are identified;

- effects on functional requirements, technical specifications, integrity, process safety, environmental protection, operational reliability, workplace interaction, competence, monitoring, documentation, compliance, and stakeholder impact are considered where relevant;
- Assumptions are distinguished from verified Evidence;
- testing, monitoring, commissioning, or operational Evidence needs are identified where relevant;
- limitations in technology maturity, operating experience, or Evidence are documented;
- Uncertainty is tracked across lifecycle stages;
- Infrastructure Quality Claim Statements are bounded to reflect innovation-related Uncertainty.

Treatment should be sufficient to prevent innovation from creating unsupported confidence in infrastructure quality.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- technology qualification records;
- pilot project records;
- innovation risk assessments;
- Uncertainty registers;
- technology readiness assessments;
- vendor Evidence reviews;
- independent technical reviews;
- test and commissioning records;
- monitoring plans;
- performance evaluation records;
- incident and near-miss reviews;
- lessons-learned records;
- Evidence-gap registers;
- updated Critical Infrastructure Conditions registers;
- Infrastructure Quality Claim Statement limitation statements.

4.15.5 Indicator 14.5 — Reversibility and Recoverability of Adaptation

Context-Specific Interpretation

Adaptation and innovation should be interpreted with consideration of reversibility and recoverability where failure, degradation, Uncertainty, or incompatibility may affect infrastructure quality.

Reversibility concerns whether an adaptation can be undone, isolated, bypassed, discontinued, or returned to a prior state where appropriate.

Recoverability concerns whether the declared LNG Infrastructure Quality Object can restore acceptable infrastructure behavior after adaptation-related disruption, malfunction, underperformance, or unintended consequence.

In LNG infrastructure, reversibility and recoverability may be relevant where adaptation affects cryogenic systems, storage, transfer, loading, unloading, boil-off gas management, regasification, send-out, automation, monitoring, safety systems, emergency response, environmental controls, or connected interfaces.

Not every adaptation must be fully reversible.

However, where adaptation affects Critical Infrastructure Conditions or high-consequence infrastructure behavior, lack of reversibility or recoverability should be recognized as a quality-relevant limitation.

Illustrative Context-Specific Quality Outcome Criteria

Reversibility and recoverability of adaptation may be considered adequately addressed when:

- adaptation-related failure or underperformance scenarios are identified;
- reversibility needs are identified where relevant;
- recoverability needs are identified where relevant;
- effects on Critical Infrastructure Conditions are considered;
- effects on cryogenic, thermal, pressure, storage, transfer, boil-off gas, regasification, send-out, monitoring, safety, emergency, environmental, utility, and interface systems are considered where relevant;
- recovery actions, fallback conditions, isolation methods, or contingency arrangements are defined where relevant;
- limitations in reversibility or recoverability are documented;
- Infrastructure Quality Claim Statements reflect adaptation-related reversibility or recoverability limitations where relevant.

Reversibility and recoverability should be sufficient to support responsible use of adaptation within the declared boundary and lifecycle condition.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- adaptation contingency plans;
- rollback plans;
- bypass or isolation plans;
- recovery procedures;
- emergency-response updates;
- failure scenario analyses;
- commissioning and recommissioning records;
- pilot test exit criteria;
- technology qualification records;
- operating procedure updates;
- control-system recovery records;
- monitoring plans;
- management-of-change records;
- lessons-learned records;
- Infrastructure Quality Claim Statement limitation statements.

4.15.6 Indicator 14.6 — Learning from Adaptation and Innovation Results and Outcomes

Context-Specific Interpretation

LNG infrastructure should learn from adaptation and innovation Results and Outcomes so that realized experience informs future infrastructure-quality interpretation.

Learning should include not only successful outcomes, but also limitations, unexpected behavior, near misses, abnormal conditions, underperformance, monitoring gaps, human interaction difficulties, interface issues, environmental effects, maintenance implications, and Infrastructure Quality Claim Statement limitations.

In the LNG context, adaptation outcomes may involve changes in cryogenic performance, boil-off gas behavior, transfer reliability, emissions, monitoring visibility, safety-system behavior, operational reliability, maintenance demand, competence needs, emergency response, stakeholder effects, or Evidence sufficiency.

Learning is quality-relevant because innovation Results and Outcomes often become fully visible only after commissioning, operation, modification, abnormal events, or lifecycle transitions.

If learning is not retained and applied, the same Uncertainty may be repeated, hidden, or wrongly treated as resolved.

Illustrative Context-Specific Quality Outcome Criteria

Learning from adaptation and innovation Results and Outcomes may be considered adequate when:

- adaptation and innovation Results and Outcomes are evaluated;
- successful and unsuccessful outcomes are documented;
- unexpected behavior and limitations are documented;
- effects on Critical Infrastructure Conditions are evaluated;
- lessons affecting functional requirements, technical specifications, safety, integrity, environmental protection, reliability, monitoring, competence, documentation, compliance, stakeholder impact, and Infrastructure Quality Claim Statements are captured where relevant;
- learning is used to update Assumptions, procedures, monitoring, training, specifications, and future adaptation decisions where needed;
- learning is retained across lifecycle stages;
- Infrastructure Quality Claim Statements reflect actual adaptation outcomes rather than intended or predicted outcomes alone.

Learning should be sufficient to support continuous improvement of infrastructure-quality interpretation without substituting general improvement language for Evidence.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- post-implementation reviews;
- lessons-learned records;
- pilot project evaluations;
- technology performance reports;
- commissioning closeout reports;
- operational performance reviews;
- incident and near-miss reviews;
- maintenance feedback records;
- monitoring performance reviews;
- environmental performance reviews;
- stakeholder feedback records;
- updated Assumptions registers;
- updated procedures and training records;
- management review records;
- revised Infrastructure Quality Claim Statement Evidence files.

4.15.7 Indicator 14.7 — Retention of Adaptation and Innovation Knowledge

Context-Specific Interpretation

Adaptation and innovation knowledge should be retained so that future users of the declared LNG Infrastructure Quality Object can understand what changed, why it changed, how it was evaluated, what Evidence supported it, what limitations remain, and how it affects Infrastructure Quality Claim Statements.

In LNG infrastructure, adaptation and innovation knowledge may include technology selection records, qualification records, pilot records, design changes, risk assessments, Uncertainty records, commissioning records, monitoring records, performance evaluations, lessons learned, vendor information, operating experience, maintenance implications, competence updates, interface updates, environmental effects, and Infrastructure Quality Claim Statement limitations.

Retention is especially important where innovation involves new technology, automation, digital monitoring, emissions-reduction systems, modified boil-off gas management, changed transfer systems, floating infrastructure, repurposed infrastructure, or changed interface arrangements.

Loss of adaptation and innovation knowledge may cause future users to repeat Uncertainty, misunderstand technology limitations, overlook new failure modes, misinterpret monitoring results, or make unsupported Infrastructure Quality Claim Statements.

Illustrative Context-Specific Quality Outcome Criteria

Adaptation and innovation knowledge may be considered adequately retained when:

- adaptation and innovation information is identified and retained;
- rationale, Assumptions, Uncertainties, Evidence, limitations, and outcomes are retained;
- information concerning Critical Infrastructure Conditions is retained;
- qualification, testing, commissioning, monitoring, performance, and lessons-learned records are retained where relevant;
- knowledge remains connected to the current infrastructure configuration, boundaries, interfaces, lifecycle condition, and Infrastructure Quality Claim Statement scope;
- knowledge remains accessible to appropriate users;
- loss, fragmentation, or inaccessibility of adaptation knowledge is identified as an Evidence limitation;
- Infrastructure Quality Claim Statements are not made beyond retained and traceable adaptation and innovation Evidence.

Retention should be sufficient to support future reassessment, change evaluation, lifecycle transition, and responsible Infrastructure Quality Claim Statements.

Illustrative Evidence Considerations

Illustrative Evidence considerations may include:

- adaptation records;
- innovation registers;
- technology qualification records;
- pilot project records;
- vendor Evidence files;
- design change records;
- management-of-change records;
- Uncertainty registers;

- testing and commissioning records;
- monitoring records;
- performance evaluation records;
- lessons-learned records;
- training and competence update records;
- interface update records;
- document-control records;
- Infrastructure Quality Claim Statement Evidence files.

5. Determination Architecture: Failure-Mode Families, Quality Outcome Criteria, Evidence, Findings, and Interpretation

5.1 Determination Sequence

LNG1 applies the invariant IQI_IQC1 determination sequence to the declared Liquefied Natural Gas Infrastructure Quality Object. The sequence begins only after the Infrastructure Quality Object Description and Structural Checkpoints are sufficiently complete.

Failure-Mode Families -> Core Quality Factors -> Core Quality Indicators -> Context-Specific Quality Outcome Criteria -> Evidence -> Evidence-Supported Findings -> Quality Factor Interpretation -> Critical-Condition and Non-Compensability Review -> Infrastructure Quality State -> Infrastructure Quality Claim Statement

The sequence preserves traceability from the resulting Infrastructure Quality State and any Infrastructure Quality Claim Statement back to the declared object, Scale, LNG realization pathway, midstream classification, composition, Boundaries, Interfaces, Infrastructure Intended Functions and Infrastructure Intended Results, lifecycle and operating conditions, applicable criteria, Evidence, Assumptions, Uncertainty, Unresolved Conditions, and limitations.

LNG1 does not prescribe a universal numerical score, facility grade, terminal rating, averaging method, certificate, or fixed verbal category. Favorable findings concerning production capacity, tank inventory, cargo throughput, send-out capacity, availability, or one subsystem shall not offset a failed, prohibited, unresolved, insufficiently evidenced, or non-compensable condition elsewhere in the declared object.

5.2 LNG1 Failure-Mode Families

Failure-Mode Families organize the principal ways in which the declared LNG1 Infrastructure Quality Object may fail to realize or sustain its Infrastructure Intended Functions and Infrastructure Intended Results. They support interpretation of the invariant Core Quality Factors and Core Quality Indicators; they do not replace them and do not constitute a fixed list of critical equipment.

LNG1 Failure-Mode Families may include:

- functional-definition, technical-translation, conformity-demonstration, object-description, Scale, Boundary, Interface, or responsibility failure;
- feed-gas receipt, conditioning, pressure, composition, contamination, measurement, custody, isolation, control, or MNT1-to-LNG1 transfer failure;

- liquefaction, pretreatment, refrigeration, compression, heat-exchange, phase-transformation, thermal-control, utility, power, or process-control failure;
- loss of cryogenic containment from tanks, process vessels, piping, pumps, valves, seals, flanges, loading arms, hoses, transfer lines, marine systems, road, rail, or ISO-container Interfaces;
- brittle fracture, thermal shock, differential contraction, insulation failure, frost or ice formation, rollover, stratification, rapid phase transition, vapor generation, or other cryogenic or phase-behavior failure;
- boil-off gas, vapor-return, pressure-control, relief, vent, flare, gas-recovery, recondenser, compressor, or inventory-management failure;
- overfill, underfill, level-measurement, density, composition, custody-transfer, inventory-accounting, or storage-availability failure;
- loading, unloading, berth, jetty, ship-shore link, emergency-release, marine-carrier, truck, railcar, ISO-container, scheduling, communication, or transfer-control failure;
- regasification, vaporization, heating, send-out compression, pressure regulation, gas-quality control, odorization-status verification where applicable, measurement, or LNG1-to-MNT1 transfer failure;
- emergency shutdown, isolation, fire and gas detection, fire protection, spill containment, drainage, impoundment, emergency power, alarm, communication, security, or emergency-response failure;
- environmental, marine, land, air, water, noise, light, thermal-discharge, methane, combustion-emission, waste, biodiversity, or community-Interface failure;
- monitoring, automation, alarm rationalization, instrumentation, calibration, cybersecurity, model, records, Evidence, visibility, Traceability, or uncertainty-control failure;
- worker-interaction, competence, contractor, control-room, permit-to-work, simultaneous-operations, fatigue, emergency-command, public-warning, or organizational-responsibility failure;
- commissioning, drying, inerting, cooldown, initial fill, startup, shutdown, warm-up, maintenance, repair, modification, expansion, conversion, recommissioning, repurposing, or Decommissioning/Transition failure;
- failure to maintain the declared separation between LNG1 bulk midstream infrastructure and the downstream LNGFS1 vehicle-fueling Infrastructure Quality Object;
- systemic, cumulative, common-cause, interacting, or cascading failure across liquefaction trains, storage tanks, boil-off gas systems, transfer systems, utilities, MNT1 Interfaces, marine or land transportation Interfaces, environmental systems, and the wider energy system-of-systems.

The applicable Failure-Mode Families shall be selected and refined for the declared LNG realization pathway, object, Scale, Infrastructure Configuration, Infrastructure Operating Medium, Infrastructure Operating Conditions, lifecycle transition, Boundaries, Interfaces, marine or land-transfer arrangement, surrounding environmental and community conditions, and Reference Layer. A single failure mode may affect several Core Quality Factors, and several failure modes may combine into one Critical Infrastructure Condition.

5.3 Context-Specific Quality Outcome Criteria

Context-Specific Quality Outcome Criteria define the expected condition, result, relationship, threshold, prohibited condition, tolerance, or Evidence-supported state against which a Core Quality Indicator is interpreted for the declared LNG1 object. The Core Quality Indicator identifies what is examined; the criterion identifies what the Evidence must support for the stated LNG context.

Each applicable criterion shall be traceable to the declared object, Scale, LNG realization pathway, Infrastructure Intended Functions and Infrastructure Intended Results, Failure-Mode Families, lifecycle and operating conditions, Infrastructure Operating Medium, applicable Reference Layer, and determination question. Criteria may be qualitative, quantitative, binary, conditional, comparative, time-bound, operating-mode-specific, or Interface-specific.

A criterion shall not be selected merely because data are available, because it is convenient to score, or because it produces a favorable result. Where different criteria apply to different trains, tanks, transfer systems, phases, operating modes, marine or land Interfaces, or jurisdictions, those differences shall remain visible.

A criterion used for one object, Scale, lifecycle stage, operating condition, cargo arrangement, or MNT1 Interface shall not be generalized to another without demonstrated applicability.

5.4 Evidence Sources and Evidence Sufficiency

Evidence may include design and process bases; hazard studies; specifications; conformity records; material, fabrication, welding, insulation, pressure, leak, and functional-test records; commissioning, drying, inerting, cooldown, and initial-fill records; operating and maintenance data; tank, piping, process, relief, flare, boil-off gas, loading, unloading, regasification, and send-out records; monitoring, alarm, inspection, integrity, calibration, corrosion, and condition data; environmental and community information; incidents, anomalies, near misses, releases, and emergency exercises; models and calculations; MNT1 and carrier-interface records; and other relevant sources.

Evidence Sufficiency is not established by document volume or the existence of a data system. Evidence shall be evaluated for relevance, credibility, coverage, representativeness, timeliness, accuracy, traceability, consistency, independence where needed, sensitivity, detection capability, continuity, accessibility, and adequacy for the declared object, Scale, lifecycle and operating condition, and claim.

Evidence from one train, tank, loading arm, berth, cargo, operating period, test, inspection, or successful transfer shall not automatically represent the whole facility, terminal, tank population, transfer system, floating unit, or system-of-systems. Sampling, exclusions, inaccessible areas, instrument ranges, alarm suppression, model dependence, data gaps, and contradictory findings shall remain visible.

Evidence shall distinguish the condition of the LNG1 object from the condition of connected MNT1, marine-carrier, truck, rail, ISO-container, utility, port, environmental, emergency-response, or LNGFS1 objects. Interface Evidence may support an LNG1 determination but does not establish the Infrastructure Quality State of the connected object unless it is expressly included within the declared Infrastructure Quality Claim Boundary.

5.5 Evidence-Supported Findings

An Evidence-Supported Finding is a bounded conclusion derived from Evidence against a stated Core Quality Indicator and applicable Context-Specific Quality Outcome Criterion. It shall identify what was examined, the Evidence used, the relevant Scale, Boundary, Interface, lifecycle and operating condition, and the extent to which the Evidence supports the conclusion.

Findings may be favorable, adverse, mixed, conditional, incomplete, indeterminate, conflicting, spatially or systemically variable, operating-mode-specific, cargo-specific, or time-limited. A finding shall not be made more favorable through unsupported inference, averaging, omission of contradictory Evidence, or substitution of compliance, capacity, throughput, or Absence of Observed Failure for demonstrated condition.

Where Evidence is insufficient, the finding shall state that limitation and identify the affected object, criterion, Factor interpretation, Critical Infrastructure Condition, and claim consequence.

5.6 Quality Factor Interpretation

Quality Factor Interpretation integrates the Evidence-Supported Findings associated with the Core Quality Indicators within a Factor and explains what they mean for Function Realization of the declared LNG1 object.

The interpretation shall preserve distinctions among liquefaction, cryogenic containment, boil-off gas management, transfer, regasification, utilities, control, safety, environmental, human, informational, and Interface conditions. It shall identify interactions, dependencies, contradictions, uncertainty, lifecycle effects, and limitations without converting the Factor into a numerical average or checklist score.

A favorable Factor interpretation shall not be made where an applicable non-compensable or Critical Infrastructure Condition remains failed, prohibited, unresolved, or insufficiently evidenced.

5.7 Critical-Condition and Non-Compensability Review

After Quality Factor Interpretation, the determination shall review all applicable Critical Infrastructure Conditions and non-compensable relationships. A Critical Infrastructure Condition is a condition whose failure, prohibition, unresolved status, insufficient Evidence, or loss of visibility prevents, narrows, qualifies, suspends, or invalidates a responsible positive Infrastructure Quality State or Infrastructure Quality Claim Statement.

Illustrative LNG1 Critical Infrastructure Conditions may concern cryogenic containment, tank integrity, process safety, pressure relief, boil-off gas control, overfill prevention, emergency shutdown and isolation, fire and gas detection, impoundment, transfer emergency release, ship-shore or land-transfer coordination, MNT1 pressure and gas-quality compatibility, utility continuity, regasification and send-out control, environmental protection, security, monitoring visibility, or unresolved conditions affecting unacceptable risk.

The review shall identify the condition, affected object and Boundary, Evidence basis, status, Uncertainty, responsible Interface, consequences for Function Realization, and whether the condition can be compensated. Favorable findings elsewhere shall not offset a non-compensable condition.

Where a Critical Infrastructure Condition cannot be responsibly resolved or bounded, the resulting Infrastructure Quality State shall remain adverse, indeterminate, conditional, restricted, or otherwise qualified, and any Infrastructure Quality Claim Statement shall reflect that limitation.

5.8 Evidence for Feed-Gas Receipt, Conditioning, Liquefaction, and Refrigeration

Evidence for feed-gas receipt and liquefaction should address the declared MNT1-to-LNG1 transfer Interface, feed-gas composition and pressure, pretreatment and contaminant removal, metering and custody, conditioning, compression, refrigeration, heat exchange, phase transformation, product specification, utility dependencies, operating envelopes, control logic, alarms, trips, relief, startup, shutdown, and abnormal or degraded conditions.

Installed nameplate capacity or production of LNG does not establish quality. The Evidence should support whether the relevant process functions remain aligned with the intended results, technical assumptions, actual feed-gas conditions, available utilities, equipment condition, control performance, and applicable safety and environmental constraints.

5.9 Evidence for Cryogenic Storage, Inventory, Containment, and Thermal Behavior

Evidence for storage should address tanks, foundations, secondary containment, insulation, piping, penetrations, pumps, valves, level and temperature measurement, density and composition, inventory, stratification, rollover potential, thermal gradients, cooldown and warm-up history, settlement, leakage detection, overfill protection, pressure-vacuum behavior, and the condition of associated structures and systems.

A tank-level finding shall not automatically determine the Infrastructure Quality State of the storage system or terminal. Evidence shall address population effects, common-cause conditions, shared systems, unavailable or inaccessible areas, aging, repair history, and interactions with boil-off gas, transfer, fire protection, impoundment, and emergency systems.

5.10 Evidence for Boil-Off Gas, Vapor, Pressure, Relief, Vent, and Flare Management

Evidence should address vapor generation under normal, transient, cargo-transfer, weather, maintenance, and abnormal conditions; pressure control; vapor return; boil-off gas compression, recovery, recondenser or fuel use; relief capacity and routing; vent and flare behavior; emissions; instrumentation; alarms; trips; availability; and consequences of unavailable equipment or utilities.

The absence of overpressure or visible venting does not demonstrate adequate management unless generation rates, detection capability, relief and control availability, operating history, maintenance condition, alarm response, and abnormal scenarios are sufficiently evidenced.

5.11 Evidence for LNG Transfer, Loading, Unloading, and Transportation Interfaces

Evidence should address loading arms, hoses, transfer piping, pumps, valves, emergency-release systems, dry-break or disconnect functions, ship-shore links, communication, custody transfer, vapor return, pressure and flow compatibility, mooring and berth conditions, weather and marine limits, truck, rail, or ISO-container conditions, simultaneous operations, isolation, spill control, emergency response, and responsibility transfer.

The declared LNG1 Boundary shall identify whether a marine, road, rail, or ISO-container system is included or is a connected object. Successful cargo or vehicle loading or unloading does not establish the Infrastructure Quality State of either object without a bounded determination supported by object-specific Evidence.

Automotive LNG dispensing is excluded from LNG1 and belongs to the downstream LNGFS1 context. Evidence concerning bulk transfer to a road tanker or ISO container shall not be used as Evidence of vehicle-fueling quality, and LNGFS1 findings shall not be generalized to the LNG1 terminal or facility.

5.12 Evidence for Regasification, Send-Out, and the LNG1-to-MNT1 Interface

Evidence should address withdrawal from storage, pumps, vaporization, heat source and heat-exchange performance, pressure and temperature control, send-out compression, metering, gas quality, odorization status where applicable to the receiving system, isolation, overpressure protection, controls, alarms, utilities, environmental discharges, and the declared LNG1-to-MNT1 transfer Interface.

Send-out capacity or successful gas delivery does not establish quality. Evidence shall support compatibility with the receiving MNT1 object, including pressure, flow, composition, temperature, measurement, custody, communication, control, responsibility, and Evidence transfer. A finding for LNG1 shall not be represented as a finding for MNT1 unless MNT1 is included within the declared object and claim Boundary.

5.13 Evidence for Utility, Control, Safety, Emergency, and Security Dependencies

Evidence should address electrical power, backup power, fuel gas, water, cooling, heating, nitrogen, instrument air, communications, control systems, cybersecurity, fire and gas detection, fire protection, emergency shutdown, isolation, drainage, impoundment, emergency command, access control, security, emergency-response arrangements, and dependencies on external providers.

Availability of a backup system does not establish resilience unless capacity, independence, common-cause exposure, transition behavior, testing, maintenance, fuel or resource availability, operating limits, human interaction, and restoration capability are sufficiently evidenced.

5.14 Evidence and Boundary and Interface Verification

Evidence shall support the declared physical, functional, operational, organizational, custody, responsibility, information, environmental, marine, land, lifecycle, and Infrastructure Quality Claim Boundaries. It shall distinguish intended, documented, realized, verified, degraded, temporary, shared, and uncertain Boundaries and Interfaces.

Particular attention should be given to MNT1-to-LNG1 feed-gas transfer, LNG1-to-MNT1 send-out, marine and land bulk-transfer Interfaces, shared port and utility systems, multi-operator responsibilities, floating LNG and FSRU Interfaces, and the declared exclusion of LNGFS1 automotive dispensing.

A contract, drawing, ownership line, custody point, or regulatory classification may support Boundary interpretation but does not by itself demonstrate the realized quality-relevant Boundary or the continuity of responsibility, control, and Evidence across it.

5.15 Lifecycle Evidence Continuity

Evidence shall be interpreted across Design, Construction, Commissioning, Operation, Maintenance, Repair/Modification, and Decommissioning/Transition, including context-specific stages such as fabrication, transport, installation, drying, inerting, cooldown, initial fill, startup, cargo introduction, shutdown, warm-up, tank entry, recommissioning, expansion, conversion, floating-unit relocation, repurposing, and abandonment.

Earlier-stage Evidence does not automatically remain valid after changes in feed gas, product specification, process configuration, capacity, tank use, operating mode, cargo pattern, carrier type, utilities, control systems, environmental conditions, MNT1 arrangement, ownership, responsibility, or Reference Layer.

The determination shall identify lost, superseded, inaccessible, contradictory, or non-transferable Evidence and any lifecycle transition at which assumptions, acceptance bases, or claim validity require renewed verification.

5.16 Environmental, Public-Consequence, Infrastructure-Protection, and Community Evidence

Evidence should address releases of LNG, natural gas, refrigerants, chemicals, combustion products, methane, wastewater, thermal discharges, noise, light, traffic, dredging, marine interaction, land use, habitat, groundwater and surface water, waste, emergency zones, public exposure, security, infrastructure protection, community commitments, complaints, incidents, and cumulative or long-term effects.

The absence of a recorded incident or complaint is not sufficient where monitoring, reporting, accessibility, baseline quality, community access, exposure pathways, or cumulative effects are incomplete or uncertain. Evidence shall remain bounded to the declared object and affected Context.

5.17 Monitoring, Models, Automation, Visibility, and Uncertainty

Monitoring and models may include process data, tank instrumentation, leak and gas detection, fire detection, structural and settlement monitoring, corrosion monitoring, vibration, thermal imaging, alarm histories, inspection, integrity models, dispersion models, consequence models, reliability models, digital twins, inventory models, and environmental monitoring.

Monitoring volume, automation, or model sophistication does not establish Evidence Sufficiency. Detection thresholds, coverage, blind zones, calibration, data quality, alarm suppression, sensor failure, common-mode error, model assumptions, validation, representativeness, cybersecurity, data retention, and uncertainty shall remain visible.

Where cryogenic systems, tank internals, buried or insulated piping, foundations, floating-unit systems, or marine Interfaces are inaccessible or indirectly observable, the determination shall distinguish observation from inference and shall qualify the Infrastructure Quality State accordingly.

5.18 Absence of Observed Failure

Continued production, storage, cargo transfer, send-out, or operation without an observed major failure may provide limited Evidence of behavior under the conditions actually experienced. It is not proof of satisfactory Infrastructure Quality.

Absence of Observed Failure shall be interpreted in relation to exposure, operating envelope, cargo and weather conditions, detection capability, monitoring coverage, reporting quality, inspection access, elapsed time, degradation mechanisms, abnormal-condition experience, and the possibility of latent or unobserved conditions.

5.19 Evidence Basis for Determinations and Claims

The determination record shall identify the Evidence used, its source, date, coverage, relevance, credibility, limitations, contradictions, exclusions, and relationship to the applicable criteria, findings, Quality Factor Interpretations, Critical Infrastructure Conditions, and resulting Infrastructure Quality State.

An Infrastructure Quality Claim Statement shall not cite LNG1, a regulation, a standard, a facility name, a capacity figure, a cargo record, a compliance result, or a monitoring system as a substitute for the supporting Evidence and determination record. The claim shall state the material Evidence basis and Evidence Sufficiency limitations in a form appropriate to its audience and decision purpose.

6. Infrastructure Quality State Determination and Infrastructure Quality Claim Statements

6.1 Establishing the LNG1 Infrastructure Quality State

The LNG1 Infrastructure Quality State is established by integrating the Evidence-Supported Findings and Quality Factor Interpretations for the declared object and then applying the Critical-Condition and Non-Compensability Review.

The Infrastructure Quality State communicates the Evidence-supported condition and Function Realization of the declared LNG1 object within its stated Scale, Infrastructure Quality Claim Boundary, realization pathway, lifecycle and operating conditions, Infrastructure Operating Medium, time or evaluation period, Assumptions, Uncertainty, Unresolved Conditions, limitations, and Critical Infrastructure Conditions.

The determination shall state what is supported, what is adverse, what is conditional or indeterminate, what has not been examined, and what cannot be responsibly claimed.

6.2 Required Determination Record

The determination record shall identify at least:

- the declared LNG1 Infrastructure Quality Object, Scale, purpose, LNG realization pathway, midstream classification, composition, and included and excluded systems;
- the Infrastructure Quality Object Description and status of the Structural Checkpoints;
- the physical, functional, operational, organizational, custody, responsibility, information, environmental, marine, land, lifecycle, and claim Boundaries and Interfaces;
- the Infrastructure Intended Functions, Infrastructure Intended Results, and relevant Work-Result-Outcome relationships;
- the lifecycle stage or transition, Infrastructure Operating Medium, Infrastructure Operating Conditions, cargo or send-out mode, and time or evaluation period;
- the applicable Failure-Mode Families, Core Quality Factors, Core Quality Indicators, and Context-Specific Quality Outcome Criteria;
- the Evidence sources, Evidence Sufficiency evaluation, gaps, contradictions, exclusions, model dependencies, monitoring limits, and Uncertainty;
- the Evidence-Supported Findings and Quality Factor Interpretations;
- the Critical-Condition and Non-Compensability Review;
- the resulting Infrastructure Quality State and any narrower conclusions;
- Assumptions, limitations, Unresolved Conditions, excluded conditions, and conditions of continued validity; and
- the persons or bodies responsible for the determination, date, edition of IQI_IQC1 and LNG1 used, and applicable Reference Layer anchors.

6.3 Determination Form and Limits

LNG1 does not require a single universal verbal category, numerical score, rating, or certificate. The determination form shall be appropriate to the decision purpose and shall preserve the underlying findings, Quality Factor Interpretations, non-compensable conditions, Evidence limitations, and Uncertainty.

A summary conclusion shall not conceal variation among trains, tanks, transfer systems, berths, operating modes, lifecycle stages, Interfaces, or time periods. Where a positive conclusion is not supportable, the determination may be adverse, mixed, conditional, indeterminate, restricted, or otherwise qualified.

6.4 Relationship Between Infrastructure Quality State Determination and Claim

An Infrastructure Quality Claim Statement communicates a conclusion derived from the Infrastructure Quality State determination. The claim shall not exceed, simplify away, broaden, or silently extend the supporting determination.

A claim may address a whole facility, terminal, train, tank population, loading or unloading system, regasification system, floating unit, Interface, lifecycle program, or other bounded object only when the determination supports that Scale and Boundary.

6.5 Infrastructure Quality Claim Boundary

The Infrastructure Quality Claim Boundary defines the precise extent of the object, conditions, Evidence, and conclusion communicated. It shall identify, as applicable:

- the facility, terminal, train, tank, transfer system, berth, jetty, pipeline segment, regasification system, floating LNG unit, FSRU, subsystem, asset population, Interface, program, or system-of-systems included;
- the LNG realization pathway and included functions, such as feed-gas receipt, conditioning, liquefaction, storage, boil-off gas management, loading, unloading, regasification, send-out, or supporting systems;
- the included and excluded MNT1, marine-carrier, truck, rail, ISO-container, port, utility, environmental, emergency-response, community, security, and LNGFS1 Interfaces;
- the lifecycle stage or transition, Infrastructure Operating Medium, Infrastructure Operating Conditions, cargo, operating mode, time or evaluation period, and relevant abnormal or degraded conditions;
- the Evidence basis, criteria, Assumptions, Uncertainty, Unresolved Conditions, Critical Infrastructure Conditions, limitations, and conditions of continued validity.

A corporate, site, license, property, security, custody, contract, or ownership Boundary shall not be assumed to be the Infrastructure Quality Claim Boundary unless the quality-relevant object, Interfaces, conditions, and Evidence align with it.

6.6 Facility, Terminal, Train, Tank, Transfer System, Floating Unit, and Interface Meaning

A claim at one Scale does not automatically apply at another. A finding for a component, instrument, loading arm, tank, train, berth, cargo operation, or MNT1 Interface may support but shall not determine a claim for the whole facility, terminal, floating unit, tank population, transfer network, or connected system-of-systems.

Where the object includes several trains, tanks, berths, carriers, operating modes, or locations, the determination shall address representativeness, shared systems, common-cause conditions, exclusions, unavailable systems, outliers, and interactions.

6.7 Declared, Realized, Verified, and Evolving Boundaries and Interfaces

The determination shall distinguish declared, designed, documented, realized, verified, degraded, temporary, shared, transferred, uncertain, and evolving Boundaries and Interfaces.

Changes in physical configuration, custody, responsibility, port or carrier arrangement, MNT1 connection, utility supply, operating mode, floating-unit location, LNGFS1 separation, or Evidence availability may change the relevant Boundary and invalidate an earlier claim unless reviewed.

6.8 Lifecycle and Infrastructure Operating Conditions Covered

The determination and claim shall identify the lifecycle stage or transition and the Infrastructure Operating Conditions covered, including normal, startup, shutdown, cooldown, warm-up, initial fill, cargo transfer, peak load, turndown, standby, maintenance, degraded, emergency, preservation, recommissioning, modification, conversion, repurposing, and Decommissioning/Transition conditions as applicable.

A claim based on one operating mode, season, cargo pattern, feed-gas composition, send-out condition, or utility arrangement shall not be implied to cover another.

6.9 LNG Realization Pathway and Infrastructure Operating Medium

The determination shall identify the LNG realization pathway and relevant Infrastructure Operating Medium, including feed gas, treated gas, refrigerants, LNG, boil-off gas, vapor, regasified gas, fuel gas, inert gas, water, chemicals, and other media where they affect Function Realization.

An import-terminal, export-terminal, peak-shaving, satellite storage, floating LNG, FSRU, bulk-transfer, liquefaction-only, storage-only, regasification-only, or integrated-terminal conclusion shall not be generalized to a different pathway without a new applicability review.

6.10 Evidence Basis and Evidence Sufficiency

The determination and claim shall identify the material Evidence basis and whether it is sufficient for the stated conclusion. Known gaps, contradictory Evidence, inaccessible areas, unverified assumptions, model dependencies, monitoring limits, data-quality issues, and excluded periods or systems shall be disclosed.

Where Evidence is sufficient only for a narrower object, period, operating mode, lifecycle stage, or Interface, the Infrastructure Quality State and claim shall be narrowed accordingly.

6.11 Assumptions, Limitations, and Unresolved Conditions

Material Assumptions, limitations, and Unresolved Conditions shall be stated, including assumptions concerning feed-gas and LNG composition, process performance, tank behavior, cargo compatibility, carrier or port conditions, utility availability, MNT1 acceptance, model validity, monitoring capability, responsibility, environmental exposure, and future operating conditions.

An assumption shall not be presented as a verified condition. Where the conclusion depends materially on an unresolved assumption, the Infrastructure Quality State and claim shall be conditional, restricted, indeterminate, or otherwise qualified.

6.12 Critical Infrastructure Conditions and Validity of the Infrastructure Quality Claim Statement

A failed, prohibited, unresolved, or insufficiently evidenced Critical Infrastructure Condition may prevent, narrow, qualify, suspend, or invalidate an Infrastructure Quality Claim Statement.

The claim shall identify any Critical Infrastructure Condition material to interpretation and shall not conceal it through aggregate language, favorable capacity or throughput figures, compliance statements, or findings from another system.

6.13 Relationship Between Conformity and Infrastructure Quality State Determination

Conformity Findings against specified requirements may provide important Evidence. They do not by themselves establish the Infrastructure Quality State of the assembled LNG1 object.

The determination shall integrate conformity with actual condition, Function Realization, Boundaries and Interfaces, lifecycle and operating conditions, Evidence Sufficiency, Uncertainty, Critical Infrastructure Conditions, and Non-Compensability. Non-conformity shall remain visible and its consequences shall be interpreted.

6.14 Traceability and Transparency

The Infrastructure Quality State and claim shall be traceable to the object description, criteria, Evidence, findings, Quality Factor Interpretations, critical review, limitations, and responsible determination record.

The communication shall be sufficiently clear for a reader to understand what object and conditions are covered, what is excluded, what Evidence supports the conclusion, what remains uncertain or unresolved, and what changes would require review.

6.15 Required Content of an LNG1 Infrastructure Quality Claim Statement

An LNG1 Infrastructure Quality Claim Statement shall identify at least:

- the declared LNG1 Infrastructure Quality Object, Scale, LNG realization pathway, and Infrastructure Quality Claim Boundary;
- the midstream classification of LNG1 and the included and excluded MNT1, carrier, land-transport, utility, port, environmental, emergency-response, and LNGFS1 Interfaces;
- the lifecycle stage or transition, Infrastructure Operating Medium, Infrastructure Operating Conditions, operating mode, cargo or send-out condition, time or evaluation period, and relevant abnormal or degraded conditions;
- the editions of IQI_IQC1 and LNG1 used and the applicable Reference Layer anchors;
- the Core Quality Factors and Core Quality Indicators examined and any Indicator not examined;
- the applicable Context-Specific Quality Outcome Criteria;
- the Evidence basis, Evidence Sufficiency, and known gaps, contradictions, model dependencies, inaccessible conditions, or monitoring limitations;
- the Evidence-Supported Findings and Quality Factor Interpretations;
- the Critical-Condition and Non-Compensability Review;
- the resulting Infrastructure Quality State or narrower Evidence-supported conclusion communicated;

- material Assumptions, Uncertainty, Unresolved Conditions, limitations, and excluded conditions;
- the date or evaluation period and conditions of continued validity; and
- a statement that the claim does not constitute IQI certification, approval, endorsement, accreditation, regulatory approval, engineering acceptance, legal compliance, guaranteed capacity or throughput, guaranteed cargo performance, or a conformity assessment performed by IQI.

6.16 Conditions of Continued Validity

An Infrastructure Quality Claim Statement remains valid only while its supporting Infrastructure Quality State determination remains valid.

Continued validity shall be reviewed when there is a material change in feed gas or LNG composition; process, refrigeration, tank, boil-off gas, transfer, regasification, utility, control, safety, environmental, or security configuration; capacity or operating envelope; cargo or carrier arrangement; MNT1 connection or acceptance conditions; LNGFS1 Boundary; ownership or responsibility; monitoring or model basis; incident, anomaly, release, fire, loss of containment, environmental or community condition; Reference Layer; or Critical Infrastructure Condition.

The claim shall identify any monitoring, inspection, testing, verification, time limit, operating restriction, cargo condition, MNT1 coordination requirement, carrier or port condition, Evidence-retention condition, or external dependency required for continued validity.

Where the supporting Infrastructure Quality State changes, becomes unsupported, or loses validity, the Infrastructure Quality Claim Statement shall be revised, narrowed, suspended, withdrawn, or replaced as appropriate.

6.17 Prohibition of Implied or Rolling Claims

An Infrastructure Quality Claim Statement shall not silently roll forward across time, lifecycle stages, operating seasons, cargoes, carrier types, feed-gas compositions, tank inventories, process configurations, operating modes, MNT1 arrangements, utility conditions, environmental conditions, modifications, responsibility transfers, or changes in Evidence availability.

A Design, Construction, testing, Commissioning, Operation, capacity, storage, cargo-transfer, regasification, Maintenance, repair, modification, recommissioning, conversion, repurposing, or Decommissioning/Transition claim applies only to the stated scope and Evidence basis.

Earlier-stage or earlier-operating-period Evidence-Supported Findings or Infrastructure Quality Claim Statements shall not justify a later-stage Infrastructure Quality State without reassessment against the current object, criteria, Evidence, Critical Infrastructure Conditions, Infrastructure Operating Medium, and Infrastructure Operating Conditions.

7. Determination Limits, Infrastructure Non-Substitutability, and Non-Prescriptive Interpretation

7.1 General

LNG1 provides a context-specific method for interpreting the invariant IQI_IQC1 Core. It does not prescribe site selection, LNG technology, process configuration, storage-tank type, marine or land-transfer arrangement, operating limits, inspection method, integrity-management method, risk model, maintenance program, emergency plan, or organizational system.

A determination shall remain within the declared object, Scale, Boundary, lifecycle and operating conditions, Evidence basis, and competence of the persons performing the interpretation. The Guide shall not be used to convert incomplete knowledge into certainty or to substitute a framework statement for technical work required by the Reference Layer.

7.2 Infrastructure Non-Substitutability Across Core Quality Factors and Core Quality Indicators

Infrastructure Non-Substitutability means that distinct quality-relevant functions, conditions, Evidence needs, Core Quality Factors, and Core Quality Indicators shall not be treated as interchangeable where each is independently necessary to Function Realization or responsible determination.

For example, the following shall not be treated as substitutes:

- installed liquefaction capacity for demonstrated process safety;
- tank inventory for verified cryogenic containment;
- successful cargo transfer for transfer-system integrity and emergency-release readiness;
- send-out capability for gas-quality and MNT1 Interface compatibility;
- a passed component test for continued integrity of the assembled system;
- alarm or sensor quantity for Evidence Sufficiency;
- automation or model agreement for verified physical behavior;
- regulatory compliance for Infrastructure Quality State determination;
- historical successful operation for current operating-envelope validity;
- emergency response capability for prevention of loss of containment;
- carrier conformity for LNG1 transfer quality;
- MNT1 acceptance for LNG1 quality or LNG1 performance for MNT1 quality;
- bulk road-tanker loading for downstream LNGFS1 vehicle-fueling quality;
- documentation for realized physical condition.

The determination shall identify which conditions are independently necessary, which are supportive, and which cannot compensate for one another.

7.3 Non-Substitutability Across LNG Process, Containment, Transfer, and Support Functions

Favorable condition of one LNG function cannot compensate for failure of another independently necessary function. Reliable liquefaction cannot compensate for deficient storage containment; robust tanks cannot compensate for uncontrolled boil-off gas; successful loading cannot compensate for unavailable emergency isolation; adequate regasification cannot compensate for incompatible MNT1 send-out; strong automation cannot compensate for failed utilities, competence, or physical integrity.

Feed-gas receipt, conditioning, liquefaction, cryogenic storage, boil-off gas management, transfer, regasification, utilities, control, safety, emergency, environmental, human, information, and external Interface functions shall be interpreted as interacting but non-interchangeable contributors to Function Realization.

7.4 Prohibition of Averaging, Offsetting, and Hidden Compensation

LNG1 shall not use averaging, aggregate scoring, weighted ratings, portfolio treatment, favorable-train or favorable-tank substitution, or high-level summary language to conceal a failed, prohibited, unresolved, insufficiently evidenced, or non-compensable condition.

A favorable majority of systems, successful majority of cargoes, high availability, large inventory, or strong performance in one train, tank, berth, or operating mode shall not offset a critical condition affecting another system or Interface within the declared claim Boundary.

Where an aggregate measure is used for a limited analytical purpose, the underlying distribution, outliers, exclusions, uncertainty, and non-compensable conditions shall remain visible and the aggregate shall not determine the Infrastructure Quality State by itself.

7.5 Non-Prescriptive Interpretation

LNG1 identifies what must be made visible for responsible quality interpretation; it does not prescribe a single technical realization pathway. Different liquefaction technologies, storage types, transfer systems, regasification methods, floating arrangements, utility architectures, control systems, monitoring strategies, and regulatory approaches may support Function Realization when the applicable criteria and Evidence are satisfied.

Non-prescriptive interpretation does not permit unsupported discretion. The selected criteria, methods, models, Evidence, assumptions, and conclusions shall remain traceable to the declared object, Intended Functions and Intended Results, Failure-Mode Families, Reference Layer, and determination question.

7.6 Limitations of Cryogenic, Insulated, Buried, Marine, Floating, Aging, and Inaccessible Visibility

Tank internals, insulation systems, foundations, buried or insulated piping, marine structures, floating-unit systems, loading equipment, relief paths, and other quality-critical conditions may be inaccessible or only indirectly observable. Aging, incomplete records, changing service, harsh environments, and model dependence may further limit visibility.

A determination shall identify the limits of observation and inference and shall not represent monitoring silence, sensor stability, successful operation, or absence of detected anomalies as proof of satisfactory condition unless detection capability, coverage, sensitivity, and representativeness are established.

Where sufficient visibility cannot be achieved, the Infrastructure Quality State shall remain indeterminate, narrower, conditional, or qualified as appropriate.

7.7 Limitations of Design-, Test-, Acceptance-, Compliance-, and Activity-as-Proof Interpretation

Design completion, construction completion, commissioning, regulatory authorization, conformity, pressure or leak testing, tank inspection, functional testing, cargo acceptance, monitoring activity, maintenance, repair, or documentation may provide Evidence but do not by themselves demonstrate continued Function Realization of the assembled LNG1 object.

The determination shall distinguish Work from Result and Outcome and shall address whether the intended condition was realized, remains valid, and is evidenced under the current lifecycle and operating conditions.

7.8 Limitations of Capacity, Inventory, Production, Cargo Transfer, and Send-Out as Proof

Installed capacity, actual production, stored inventory, cargo count, loading or unloading rate, send-out rate, availability, utilization, or commercial performance may be relevant Evidence but do not by themselves establish Infrastructure Quality.

Such measures shall be interpreted with containment, integrity, safety, environmental, reliability, Interface, monitoring, human, lifecycle, and uncertainty conditions. Performance achieved by exceeding margins, suppressing alarms, deferring maintenance, relying on temporary controls, or transferring risk outside the declared Boundary shall not support a favorable determination.

7.9 Limitations of Monitoring, Automation, Documentation, and Models

Monitoring, automation, digital systems, inspection databases, models, and documentation are supporting means, not substitutes for physical condition or Function Realization. Their limitations, blind zones, calibration status, cybersecurity, assumptions, validation, data quality, accessibility, and continuity shall be examined.

A model or control system shall not be treated as independent Evidence of the condition it assumes unless it is supported by appropriate observation, validation, and uncertainty treatment.

7.10 Limitations of Component-, Train-, Tank-, Cargo-, Berth-, or Program-to-System Generalization

A favorable finding for a component, train, tank, cargo, loading arm, berth, inspection program, or operating period shall not be generalized to the facility, terminal, floating unit, storage population, transfer system, or system-of-systems without Evidence of representativeness and interaction.

The determination shall identify shared systems, common-cause exposures, exclusions, unavailable systems, outliers, and differences in age, design, service, operating history, environment, or Interface conditions.

7.11 Context Dependence of Quality Outcome Criteria

Context-Specific Quality Outcome Criteria depend on the declared LNG realization pathway, object, Scale, technology, operating medium, lifecycle and operating conditions, cargo and Interface arrangement, environment, jurisdiction, and Reference Layer. A criterion shall not be transferred to another context without demonstrated applicability.

LNG1 does not establish universal acceptance values, design margins, inspection intervals, capacity thresholds, emission limits, exclusion distances, or regulatory classifications.

7.12 Relationship to IQI_IQC1

IQI_IQC1 remains the authoritative invariant Core. LNG1 interprets the Core for the bounded LNG context and shall not rename, redefine, omit, or replace the Core Intended Function architecture, Core Quality Factors, Core Quality Indicators, determination requirements, lifecycle applicability, or claim rules.

Where wording in LNG1 is incomplete or appears inconsistent with IQI_IQC1, the current controlled edition of IQI_IQC1 and the governing WQI_VOC1 and IQI_VOC1 definitions control.

8. Reference Layer: Regulatory Frameworks and Other Standards

8.1 Reference Layer Purpose and Limits

Applicable laws, regulations, permits, codes, technical and engineering standards, contracts, design bases, operating procedures, maritime and port requirements, environmental requirements, emergency-response arrangements, security requirements, scientific knowledge, operator standards, and professional guidance form the Reference Layer for the declared LNG1 Infrastructure Quality Object and Context.

Reference Layer sources may support interpretation of Infrastructure Intended Functions and Infrastructure Intended Results, Context-Specific Quality Outcome Criteria, technical meaning, responsibilities, Evidence, Critical Infrastructure Conditions, lifecycle controls, and Infrastructure Quality Claim Statements. They do not redefine WQI Root Concepts, IQI Applied Concepts, or the invariant IQC1 Core architecture.

Compliance with a Reference Layer source may provide Evidence or a Conformity Finding, but it does not by itself establish a positive Infrastructure Quality State. The determination shall still address actual LNG infrastructure behavior, Boundaries and Interfaces, lifecycle and operating conditions, Evidence Sufficiency, Uncertainty, Non-Compensability, and claim limitations.

Where Reference Layer sources differ by jurisdiction, facility type, marine or land-transfer arrangement, floating or onshore configuration, lifecycle stage, or connected-system arrangement, the determination shall identify the applicable source and edition and shall not imply universal applicability.

8.2 Relationship to LNG Safety and Process-Safety Regulatory Frameworks

LNG safety and process-safety regulatory frameworks may address siting, design, construction, operation, process hazards, loss of containment, fire, explosion, vapor dispersion, emergency shutdown, impoundment, separation, emergency planning, security, reporting, inspection, and enforcement.

Such frameworks may define mandatory requirements or prohibited conditions within their jurisdiction. Their requirements form part of the applicable Reference Layer and may identify Critical Infrastructure Conditions. Compliance findings remain narrower than an Infrastructure Quality State determination and shall be integrated with the broader LNG1 object, Evidence, and claim architecture.

8.3 Relationship to LNG Facility, Cryogenic, Pressure-Equipment, Storage, and Process Standards

Technical standards may address liquefaction and refrigeration, cryogenic materials, pressure equipment, storage tanks, foundations, insulation, piping, welding, valves, pumps, compressors, heat exchangers, relief systems, boil-off gas management, instrumentation, electrical systems, fire protection, and mechanical integrity.

These standards may support technical criteria, design and conformity Evidence, inspection interpretation, operating limits, and failure-mode analysis. A standard-compliant component or subsystem does not by itself establish the Infrastructure Quality State of the assembled LNG1 object or the continued validity of an earlier determination.

8.4 Relationship to Marine, Port, Ship-Shore, Road, Rail, ISO-Container, and Bulk-Transfer Requirements

Marine, port, transportation, and bulk-transfer requirements may address ship-shore compatibility, berth and mooring conditions, loading arms, hoses, emergency release, vapor return, communications, cargo custody, weather limits, navigation, traffic, road tankers, railcars, ISO containers, transfer procedures, simultaneous operations, and emergency coordination.

The applicable requirements and responsibility boundaries shall be identified for each declared Interface. Carrier, vehicle, port, or terminal compliance does not establish the Infrastructure Quality State of the other connected object. Automotive vehicle dispensing remains outside LNG1 and is addressed through LNGFS1.

8.5 Relationship to Pipeline, Gas-Quality, MNT1 Receipt, and MNT1 Send-Out Requirements

Pipeline and gas-quality requirements may address feed-gas receipt, pressure, composition, measurement, custody, contamination, moisture, sulfur, carbon dioxide, oxygen, nitrogen, temperature, heating value, send-out quality, pressure regulation, overpressure protection, control, communication, and transfer responsibility.

MNT1 and LNG1 are separately bounded midstream objects. Requirements and Evidence at the MNT1-to-LNG1 and LNG1-to-MNT1 Interfaces support Interface interpretation but do not merge the objects or allow the Infrastructure Quality State of one to substitute for the other.

8.6 Relationship to Environmental, Emissions, Water, Marine, and Climate-Related Frameworks

Environmental frameworks may address methane and combustion emissions, refrigerants, flaring and venting, wastewater, thermal discharges, stormwater, spills, waste, noise, light, dredging, marine and terrestrial habitat, groundwater and surface water, climate resilience, reporting, monitoring, remediation, and cumulative effects.

Environmental compliance may provide Evidence but shall be interpreted with actual pathways, baseline quality, monitoring coverage, abnormal conditions, cumulative effects, uncertainty, and the declared environmental and community Boundaries.

8.7 Relationship to Occupational Safety, Emergency Response, Public Consequence, and Security Frameworks

Occupational-safety, emergency-response, public-consequence, and security frameworks may address hazardous work, cryogenic exposure, confined spaces, hot work, simultaneous operations, control-room interaction, training, personal protective equipment, emergency command, evacuation, mutual aid, public notification, access control, cybersecurity, and physical security.

The existence of procedures, equipment, plans, or exercises does not establish their adequacy or realized effectiveness. Evidence shall address readiness, competence, interoperability, resource availability, response time, degradation, change, and lessons from actual events and exercises.

8.8 Relationship to Integrity Management, Risk Management, Organizational Management Systems, and Contracts

Integrity management, risk management, organizational management systems, contracts, operating agreements, and assurance programs may support responsibilities, controls, competence, documentation, change management, monitoring, maintenance, audit, and Evidence retention.

LNG1 is not a quality-management-system standard. Certification, audit results, risk registers, contractual allocation, or organizational procedures may provide Evidence but shall not substitute for the demonstrated condition and Function Realization of the declared Infrastructure Quality Object.

8.9 Relationship to Lifecycle Activities, Boundaries, Interfaces, MNT1, and LNGFS1

Reference Layer sources shall be applied to the correct lifecycle stage, transition, Boundary, Interface, operating condition, and object. Requirements for Design, Construction, Commissioning, Operation, Maintenance, Repair/Modification, or Decommissioning/Transition shall not be assumed to establish another stage.

LNG1 shall remain clearly separated from MNT1 and LNGFS1. MNT1 addresses onshore natural gas main pipeline transportation as a midstream object. LNG1 addresses midstream LNG conversion, storage, bulk transfer, terminal, regasification, and send-out functions. LNGFS1 addresses the separately bounded downstream automotive LNG fuel-station and vehicle-dispensing context.

An Interface may be relevant to more than one Context Guide, but each determination and claim shall state which object, side of the Interface, responsibilities, Evidence, and conditions are included.

8.10 Limits of Regulatory and Standards Substitution for IQI Quality Interpretation

No regulation, permit, code, standard, certification, audit, contract, design approval, inspection result, operating authorization, or absence of enforcement action shall be represented as equivalent to an LNG1 Infrastructure Quality State determination unless the IQI_IQC1 determination sequence has been applied to the declared object.

Conversely, use of LNG1 does not establish or imply legal compliance, regulatory approval, engineering acceptance, certification, or conformity with a Reference Layer source. Those conclusions require their own authorized bases and responsible decision processes.

9. Informative Annexes

9.1 General

The Annexes are informative and do not create requirements independent of IQI_IQC1 or the normative parts of this Guide. They provide illustrative support for applying the object, Boundary, Interface, lifecycle, Evidence, determination, and claim architecture to Liquefied Natural Gas Infrastructure.

Annexes A through G preserve LNG1-specific object, realization-pathway, cryogenic, phase-transformation, storage, boil-off gas, transfer, regasification, environmental, and community interpretation. Annex H illustrates Critical Infrastructure Conditions and Non-Compensability. Annex I clarifies the relationship among MNT1, LNG1, and LNGFS1. Annexes J and K illustrate Evidence, findings, Factor interpretation, Infrastructure Quality State determination, and bounded Infrastructure Quality Claim Statements.

The examples do not prescribe designs, technologies, operating limits, engineering methods, monitoring programs, acceptance values, priorities, regulatory classifications, management systems, audits, or certification schemes. Application remains bounded by the declared Infrastructure Quality Object, applicable IQI_IQC1 requirements, Context-Specific Quality Outcome Criteria, Evidence, and Reference Layer.

9.2 Annex A (Informative) — Illustrative LNG Infrastructure Quality Object and Boundary Interpretation

An LNG Infrastructure Quality Object may be declared at different levels of scope.

Illustrative declared objects may include:

- a complete integrated LNG terminal;
- an LNG liquefaction train and associated supporting systems;
- an LNG cryogenic storage system;
- an LNG import and regasification terminal;
- an LNG export terminal;
- an LNG transfer, loading, or unloading system;
- an LNG satellite storage and vaporization facility;
- an LNG peak-shaving facility;
- a floating LNG facility;
- an FSRU and its connected interface systems;
- a defined LNG send-out system;
- a defined LNG boil-off gas management system.

The declared object should not be assumed from the facility name alone.

For example, "LNG terminal" may include different combinations of storage, transfer, regasification, send-out, liquefaction, marine interface, truck interface, rail interface, pipeline interface, utility systems, environmental controls, and emergency systems.

The Quality Claim should identify what is included and excluded.

Illustrative boundary questions include:

- Is liquefaction included?
- Is LNG storage included?
- Is boil-off gas management included?
- Is regasification included?
- Is send-out included?
- Are marine, truck, rail, or pipeline interfaces included?
- Are utilities included?
- Are emergency systems included?
- Are environmental controls included?
- Are monitoring and control systems included?
- Are connected external systems included, excluded, or assumed?
- Which lifecycle condition is being claimed?

The boundary should be specific enough to prevent the Quality Claim from being broader than the evidence.

9.3 Annex B (Informative) — Illustrative LNG Context Realization Pathways

LNG infrastructure may realize the invariant Core intended function through different LNG-context realization pathways.

These pathways do not create different Core Factors or Indicators.

They affect how the Core Quality Factors and Core Quality Indicators are interpreted.

Illustrative LNG-context realization pathways include:

- liquefaction pathway;
- cryogenic storage pathway;
- LNG export pathway;
- LNG import pathway;
- regasification pathway;
- send-out pathway;
- transfer, loading, and unloading pathway;
- satellite LNG pathway;
- peak-shaving LNG pathway;
- floating LNG pathway;
- FSRU pathway;
- integrated terminal pathway.

For a liquefaction pathway, interpretation may emphasize feed-gas conditions, liquefaction process stability, refrigerant systems, cryogenic transition, production reliability, process safety, emissions, and interface with storage and export systems.

For a storage pathway, interpretation may emphasize tank integrity, insulation, low-temperature behavior, pressure control, boil-off gas management, storage duration, monitoring, emergency isolation, and environmental exposure.

For a transfer pathway, interpretation may emphasize compatibility between systems, loading and unloading connections, emergency shutdown, vapor management, transfer monitoring, communication, interface responsibility, and transportation interface conditions.

For a regasification and send-out pathway, interpretation may emphasize vaporization behavior, send-out reliability, gas-quality compatibility, downstream interface assumptions, environmental effects, and monitoring.

For floating LNG or FSRU pathways, interpretation may emphasize marine exposure, mooring, ship-shore or ship-pipeline interfaces, shared responsibilities, operational limits, weather conditions, emergency response, and evidence boundaries.

A Quality Claim should identify the pathway or pathways covered.

9.4 Annex C (Informative) — Illustrative Cryogenic and Phase-Transformation Interpretation

LNG infrastructure quality depends on cryogenic and phase-transformation conditions.

These conditions should be interpreted across the relevant Core Quality Factors and Core Quality Indicators.

Illustrative cryogenic and phase-transformation considerations include:

- low-temperature containment;
- material suitability for cryogenic conditions;
- thermal contraction and expansion;
- cooldown and warm-up behavior;
- heat ingress;
- insulation performance;
- pressure behavior;
- liquid-gas phase change;
- boil-off gas generation;
- vapor handling;
- regasification behavior;
- vaporizer performance;
- thermal effects on connected systems;
- emergency conditions involving LNG release or vapor dispersion;
- monitoring limitations affecting cryogenic visibility.

Cryogenic and phase-transformation conditions may be Critical Infrastructure Conditions where they affect intended function realization, safety, integrity, environmental protection, reliability, monitoring, or Quality Claim validity.

Illustrative evidence may include design basis records, material records, tank records, insulation records, cooldown records, commissioning records, temperature and pressure trends, boil-off gas records, vaporizer records, alarm records, abnormal operation records, inspection records, monitoring records, and change records.

The absence of observed cryogenic failure should not be treated as proof that cryogenic and phase-transformation behavior is fully understood or controlled.

9.5 Annex D (Informative) — Illustrative LNG Storage and Boil-Off Gas Management Interpretation

LNG storage and boil-off gas management may be central to many LNG Infrastructure Quality Objects.

Illustrative storage considerations include:

- tank or containment integrity;
- insulation condition;
- storage temperature;
- storage pressure;
- storage duration;
- liquid level;
- stratification or rollover-related concerns where applicable;
- foundation and structural conditions;
- emergency isolation;
- spill containment;
- monitoring coverage;
- inspection and maintenance history;
- lifecycle condition of storage systems.

Illustrative boil-off gas management considerations include:

- boil-off gas generation rates;
- pressure-control strategy;
- vapor handling;
- compression or recovery systems where applicable;
- reliquefaction where applicable;
- flaring or venting where applicable;
- interaction with storage duration and operating mode;
- abnormal boil-off gas behavior;
- monitoring and alarm interpretation;
- environmental and emissions implications;
- utility dependency;
- change in operating envelope.

Storage and boil-off gas evidence should be interpreted in relation to the declared object, lifecycle condition, operating envelope, monitoring limitations, abnormal conditions, environmental effects, and Critical Infrastructure Conditions.

A Quality Claim should not treat storage capacity or successful storage alone as proof of full storage quality.

9.6 Annex E (Informative) — Illustrative Transfer, Loading, Unloading, and Transportation Interface Interpretation

LNG transfer, loading, unloading, and transportation interfaces may involve multiple systems and organizations.

Illustrative transfer and loading/unloading considerations include:

- transfer compatibility;
- loading arm or hose condition;
- connection integrity;
- emergency shutdown compatibility;
- emergency release or isolation;
- vapor return or vapor management where applicable;
- communication between parties;
- custody transfer boundaries;
- pressure and temperature compatibility;
- transfer rate limitations;
- simultaneous operations;
- monitoring and alarm response;
- spill and vapor dispersion response;
- environmental protection;
- personnel competence;
- documentation and traceability.

Illustrative transportation interfaces may include:

- marine vessel interface;
- port and berth interface;
- truck loading interface;
- rail loading interface;
- pipeline interface;
- road, rail, or marine traffic effects;
- external emergency-response coordination;
- interface responsibility allocation.

Transfer completion should not be treated as proof of infrastructure quality by itself.

A Quality Claim involving transfer, loading, unloading, or transportation interfaces should identify included and excluded interfaces, responsibility boundaries, communication assumptions, emergency-response assumptions, monitoring evidence, and unresolved Critical Infrastructure Conditions.

9.7 Annex F (Informative) — Illustrative Regasification and Send-Out Interface Interpretation

Regasification and send-out functions may be central to LNG import terminals, FSRUs, satellite LNG facilities, peak-shaving facilities, and other LNG contexts.

Illustrative regasification considerations include:

- vaporizer performance;
- heating medium availability;
- thermal stability;
- pressure control;
- flow control;
- process safety;
- environmental effects of heating or cooling media where applicable;
- monitoring of regasification conditions;
- abnormal or degraded vaporizer performance;
- maintenance and inspection evidence;
- emergency shutdown and isolation.

Illustrative send-out considerations include:

- send-out pressure;
- send-out flow;
- gas-quality compatibility;
- metering;
- downstream pipeline interface;
- downstream user interface;
- odorization where applicable;
- pressure regulation;
- communication with downstream operators;
- utility dependency;
- reliability under variable demand;
- emergency isolation;
- monitoring and documentation.

A Quality Claim involving regasification and send-out should not rely only on send-out volume or flow.

It should consider whether regasification and send-out behavior remain compatible with the declared functional intent, downstream interface assumptions, environmental conditions, monitoring evidence, operating envelope, and Critical Infrastructure Conditions.

9.8 Annex G (Informative) — Illustrative Environmental and Community Interaction Interpretation

LNG infrastructure may interact with environmental receptors and affected communities.

Illustrative environmental interactions include:

- air emissions;
- methane emissions;
- combustion emissions;
- flaring or venting where applicable;
- refrigerant releases where applicable;
- wastewater discharges;
- stormwater pathways;
- spill pathways;
- firewater and emergency-response runoff;
- marine or coastal effects;
- thermal effects where applicable;
- waste generation;
- soil and groundwater exposure;
- noise, light, and traffic effects;
- cumulative and long-term effects.

Illustrative community interactions include:

- nearby residents;
- workers and contractors;
- emergency responders;
- port or marine users;
- truck or rail route communities;
- local governments;
- environmental stakeholders;
- connected infrastructure operators;
- affected land users;
- other affected parties.

Environmental and community evidence should be interpreted in relation to actual infrastructure behavior, abnormal and degraded conditions, cumulative effects, monitoring limitations, stakeholder concerns, commitments, and claim boundaries.

Permits, reports, or absence of complaints may support interpretation, but should not substitute for full environmental and community-impact interpretation.

9.9 Annex H (Informative) — Illustrative Critical Infrastructure Conditions and Non-Compensability Review

This Annex illustrates how Critical Infrastructure Conditions and Non-Compensability may be made visible for an LNG1 determination. The examples are informative and shall be refined for the declared object, LNG realization pathway, Scale, lifecycle and operating conditions, Interfaces, and Reference Layer.

H.1 Illustrative Critical Infrastructure Conditions

Illustrative conditions may include:

- unverified or degraded cryogenic containment, tank integrity, foundation condition, secondary containment, or overfill prevention;
- uncontrolled or insufficiently evidenced boil-off gas, vapor, pressure, relief, vent, flare, or vapor-return behavior;
- unavailable or inadequately independent emergency shutdown, isolation, emergency release, fire and gas detection, fire protection, impoundment, emergency power, communication, or emergency-response functions;
- feed-gas, LNG, refrigerant, or send-out composition, pressure, temperature, contamination, or compatibility outside the declared operating basis;
- unresolved brittle-fracture, thermal-shock, rollover, stratification, rapid-phase-transition, corrosion, settlement, fatigue, vibration, or other material or physical-behavior concern;
- unsafe or uncontrolled ship-shore, road, rail, ISO-container, MNT1, port, utility, or responsibility Interface;
- loss of visibility caused by inaccessible systems, failed instruments, unverified models, missing records, alarm suppression, insufficient monitoring, cybersecurity compromise, or contradictory Evidence;
- an unresolved condition with potential for unacceptable worker, public, environmental, marine, community, security, or cascading system-of-systems consequence;
- failure to maintain the declared Boundary between LNG1 bulk midstream functions and LNGFS1 downstream vehicle dispensing.

H.2 Illustrative Non-Compensability Questions

The review may ask whether:

- high production or send-out capacity is being used to offset deficient containment, process safety, or emergency isolation;
- successful cargo history is being used to offset an unresolved transfer, berth, carrier, emergency-release, or weather-limit condition;
- regulatory compliance or component conformity is being used to offset insufficient Evidence of actual system behavior;
- strong performance in one train, tank, berth, or operating mode is being used to conceal a critical condition elsewhere in the declared Boundary;
- automation, alarms, or models are being used to offset inadequate physical condition, monitoring coverage, competence, or utility resilience;

- MNT1 acceptance, carrier readiness, or LNGFS1 performance is being used to substitute for LNG1 quality, or vice versa.

H.3 Illustrative Review Record

For each applicable condition, record the condition, affected object and Boundary, Failure-Mode Family, relevant Core Quality Indicators and criteria, Evidence and Evidence Sufficiency, status, Assumptions and Uncertainty, potential consequences, compensability determination, actions or restrictions, and effect on the Infrastructure Quality State and claim.

9.10 Annex I (Informative) — Illustrative Relationship Among MNT1, LNG1, and LNGFS1

I.1 MNT1 and LNG1 as Separate Midstream Objects

MNT1 addresses onshore natural gas main pipeline transportation. LNG1 addresses LNG conversion, liquefaction, cryogenic storage, bulk transfer, terminal operation, regasification, and send-out. Both are midstream segments, but they have different declared objects, Intended Functions, Boundaries, Failure-Mode Families, Evidence, Critical Infrastructure Conditions, and claim bases.

A typical export pathway may include MNT1 feed-gas transfer to LNG1, treatment and liquefaction within LNG1, cryogenic storage, and bulk transfer to a marine carrier. A typical import pathway may include marine unloading to LNG1, cryogenic storage, regasification, and send-out from LNG1 to MNT1. These pathways do not merge the MNT1 and LNG1 objects.

I.2 LNG1 and LNGFS1 Separation

Bulk transfer of LNG to or from a road tanker, railcar, ISO container, or other transport unit may be included in LNG1 when it forms part of the declared bulk terminal or logistics Interface. Automotive vehicle dispensing, retail fueling, public access, dispenser operation, vehicle connection, and fuel-station conditions are excluded from LNG1 and belong to the downstream LNGFS1 context.

A bulk transport unit may therefore connect a midstream LNG1 object to a downstream LNGFS1 object without making the two objects one system. The transfer Boundary, custody, product condition, responsibility, Evidence, and claim scope shall be declared.

I.3 Interface Evidence and Claim Limits

Evidence at an MNT1-LNG1 or LNG1-LNGFS1 Interface shall identify the side of the Interface examined, the included equipment and functions, transfer conditions, custody and responsibility, measurement, product quality, control and communication, emergency arrangements, and Evidence continuity. A finding for one object shall not be communicated as a finding for the connected object unless both are expressly included in the determination.

9.11 Annex J (Informative) — Illustrative Evidence, Evidence-Supported Findings, and Quality Factor Interpretation

J.1 Evidence Register

An illustrative Evidence register may identify the source, date, owner, object and Scale, lifecycle and operating condition, LNG realization pathway, relevant Boundary or Interface, Core Quality Indicator, applicable criterion, coverage, credibility, representativeness, detection or measurement limits, model dependence, traceability, accessibility, gaps, contradictions, and retention condition.

J.2 Evidence-Supported Finding Form

An illustrative finding may state: for the declared object and condition, the identified Evidence supports, does not support, partially supports, or is insufficient to determine the stated criterion; the finding applies only to the identified Scale, Boundary, Interface, lifecycle and operating condition, and period; and the listed limitations, assumptions, uncertainty, and unresolved conditions remain.

J.3 Quality Factor Interpretation Form

An illustrative Factor interpretation may summarize the applicable findings, interactions among Indicators, LNG-specific failure mechanisms, dependencies on MNT1, carriers, utilities, environmental systems, or LNGFS1, adverse or contradictory conditions, Evidence Sufficiency, uncertainty, and the implications for Function Realization. It should state whether the Factor interpretation is favorable, adverse, mixed, conditional, incomplete, or indeterminate without reducing the Factor to a score.

J.4 Preservation of Adverse and Indeterminate Findings

Adverse, incomplete, contradictory, operating-mode-specific, cargo-specific, or indeterminate findings shall remain visible through the Critical-Condition and Non-Compensability Review. They shall not be omitted because other findings are favorable or because the facility remains in operation.

9.12 Annex K (Informative) — Illustrative LNG1 Infrastructure Quality State Determination and Infrastructure Quality Claim Statement Elements

K.1 Object and Determination Purpose

Identify the declared LNG1 object, Scale, LNG realization pathway, midstream classification, included and excluded functions and systems, determination purpose, decision context, and responsible persons or bodies.

K.2 Boundaries and Interfaces

Identify the physical, functional, operational, organizational, custody, responsibility, information, environmental, marine, land, lifecycle, and claim Boundaries and Interfaces, including MNT1 receipt and send-out, carrier and bulk-transfer Interfaces, shared port and utility systems, and the LNGFS1 exclusion.

K.3 Intended Functions, Intended Results, and Failure-Mode Families

State the applicable Infrastructure Intended Functions and Infrastructure Intended Results, relevant Work-Result-Outcome relationships, and selected LNG1 Failure-Mode Families.

K.4 Lifecycle, Operating Conditions, and Infrastructure Operating Medium

State the lifecycle stage or transition, operating mode, cargo or send-out condition, time or evaluation period, Infrastructure Operating Conditions, relevant abnormal or degraded conditions, and Infrastructure Operating Medium, including feed gas, refrigerants, LNG, boil-off gas, vapor, regasified gas, fuel gas, inert gas, water, and chemicals as applicable.

K.5 Core Quality Indicators and Quality Outcome Criteria

Identify the Core Quality Factors and Core Quality Indicators examined, applicable Context-Specific Quality Outcome Criteria, and the basis for any Indicator not examined.

K.6 Evidence Basis and Evidence Sufficiency

Describe the Evidence nature, source, coverage, relevance, credibility, traceability, representativeness, timeliness, model dependence, accessibility, consistency, limitations, gaps, contradictions, and the basis for concluding that Evidence is or is not sufficient.

K.7 Evidence-Supported Findings and Quality Factor Interpretations

Summarize the bounded findings and Quality Factor Interpretations. Preserve adverse, conflicting, incomplete, indeterminate, train-specific, tank-specific, cargo-specific, Interface-specific, operating-mode-specific, and time-limited results and identify what the Evidence does not support.

K.8 Critical-Condition and Non-Compensability Review

Identify all applicable Critical Infrastructure Conditions, their status, Evidence basis, affected object and Boundary, and whether any condition prevents, narrows, qualifies, suspends, or invalidates a positive Infrastructure Quality State or Infrastructure Quality Claim Statement. Confirm that favorable findings were not used to offset non-compensable conditions.

K.9 Resulting Infrastructure Quality State

State the Evidence-supported condition and Function Realization of the declared LNG1 object within its Scale, Boundary, realization pathway, lifecycle and operating conditions, Infrastructure Operating Medium, time, Assumptions, Uncertainty, limitations, Unresolved Conditions, and Critical Infrastructure Conditions. State what has not been determined.

K.10 Bounded Infrastructure Quality Claim Statement

Communicate only the conclusion supported by the Infrastructure Quality State determination. Identify the object, Scale, Infrastructure Quality Claim Boundary, lifecycle and operating conditions, Evidence basis and Evidence Sufficiency, criteria, Quality Factor Interpretations, critical review, Assumptions, Uncertainty, limitations, Unresolved Conditions, and conditions of continued validity.

K.11 Illustrative Claim-Limitation Language

Illustrative language may state that the conclusion applies only to the declared LNG1 object, LNG realization pathway, included trains, tanks, transfer, regasification, utility, safety, and MNT1 Interface systems, lifecycle stage, operating and cargo conditions, Infrastructure Operating Medium, time or evaluation period, and Evidence basis; excludes LNGFS1 vehicle dispensing and other stated systems; does not address future performance; and is subject to the stated uncertainty, limitations, unresolved conditions, critical conditions, and conditions of continued validity.

K.12 Conditions of Continued Validity and Non-Certification

Identify changes requiring review and state that use of IQI_IQC1 and LNG1 and communication of an Infrastructure Quality State or Infrastructure Quality Claim Statement do not constitute IQI certification, approval, endorsement, accreditation, regulatory approval, engineering acceptance, legal compliance, guaranteed capacity or throughput, guaranteed cargo performance, or performance of a conformity assessment by IQI.

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