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TERMOZULIA - UNIT 07

A Case Study of Technical Restoration and Sustainable Operational Performance

Asset Integrity, Transition Risks, Operational Readiness, and the Cost of Non-Readiness in the Context of Venezuela's Energy Industry Recovery

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ICxA - Technical Committees | Case Study Series

Executive Summary

The recovery of Venezuela's energy industry requires the rehabilitation of infrastructure affected by prolonged deterioration, deferred maintenance, and successive interventions. This challenge extends beyond physical restoration, demanding the re-establishment of the technical, human, and organizational capabilities necessary to sustain reliable operations. The effectiveness of rehabilitation programs should therefore be assessed not only by the installed capacity returned to service, but also by their contribution to the availability, reliability, and long-term performance of the energy system.

Termozulia Unit 07 (TZ7), located within the Termozulia thermal power generation complex in Venezuela's Zulia State, provides a relevant case. Following a major rehabilitation, its synchronization with the National Electric System was announced on October 6, 2026, with a nominal generating capacity of approximately 150 MW. Only six days later, the unit was taken out of service again, requiring further technical assessments (Angulo, 2026).

This case study examines four interdependent dimensions: the restoration of technical integrity, the risks associated with the transition to operations, Operational Readiness, and the economic consequences of an unsustainable recovery. The analysis integrates the standards of the Institute of Commissioning & Assurance (ICxA) with the conceptualization of Operational Readiness as an organizational capability for managing uncertainty, responding to emerging conditions, and converting project execution outcomes into sustained operational performance (Tain, 2026a, 2026b). The Cost of Non-Readiness (CoNR) further connects preventable readiness gaps with additional costs, asset availability, effective generation, cash flows, and the realization of investment value, introducing a financial dimension to the assessment of industrial recovery.

The central premise is that restoring an asset's technical functionality is necessary, but successful rehabilitation ultimately depends on demonstrating its ability to operate reliably and sustain the benefits that justified the investment.

Venezuela's Energy Industry Recovery: Rebuilding Capabilities and Managing Interdependencies

The recovery of Venezuela's energy industry represents a process of industrial reconstruction involving asset deterioration, infrastructure constraints, and the availability of technical and organizational resources. The country retains an extensive base of oil, gas, petrochemical, and electricity infrastructure; however, nominal capacity does not necessarily reflect immediately available productive potential. Deferred maintenance, technological obsolescence, accumulated modifications, and the loss of specialized competencies can create substantial differences between installed infrastructure and its ability to contribute sustainably to production.

The challenge is compounded by the interdependencies within the energy system. Oil production requires pumping, artificial lift, treatment, and transportation systems; gas production and processing depend on compression, separation, and conditioning facilities; and refineries and petrochemical complexes rely on dependable utilities to sustain their operations. All these systems require electricity, making power availability an essential enabling condition for restoring production. An industrial facility may successfully complete its rehabilitation while remaining constrained by insufficient generating capacity, transmission limitations, inadequate fuel supply, or unavailable supporting infrastructure. These dependencies introduce risks that extend beyond individual project boundaries, as the performance of each facility depends partly on the readiness and reliability of the wider operational environment.

In Zulia State, historically associated with Venezuela's oil industry and the industrial activity of the country's western region, thermal power generation recovery is essential to restoring productive continuity. This relationship is captured in the observation that "recovery will not be sustainable without a firm electricity supply" (Cabeza Rodríguez, 2026b; translated from Spanish), emphasizing the dependence of industrial rehabilitation on reliable energy infrastructure.

These interdependencies carry economic implications beyond individual assets. Restoring a generating unit may create value through its direct output while also reducing constraints on other facilities and enabling complementary investments. Such benefits, however, depend on the restored capacity remaining available over a sufficient operational horizon. A temporary recovery may represent technical progress, but its contribution to productive activity will remain limited if power supply continuity cannot be sustained. Energy industry recovery should therefore be approached as an integrated process of rebuilding capabilities, in which technical integrity, risk management, organizational readiness, and outcome assurance converge to transform investments into sustainable value.

The Termozulia Thermal Power Complex and Unit TZ7

The Termozulia Thermal Power Complex is located in La Cañada de Urdaneta municipality, south of Maracaibo, in Zulia State. It forms part of Venezuela's National Electric System *(Sistema Eléctrico Nacional, SEN*) and operates under the responsibility of the National Electric Corporation (*Corporación Eléctrica Nacional*, Corpoelec). The complex was developed to strengthen electricity generation in western Venezuela and complement the supply transmitted from the country's major hydroelectric facilities in the Lower Caroní region.

The complex comprises several generating developments, including Termozulia I, II, and III, incorporating gas turbine technology and combined-cycle projects. In open-cycle operation, combustion produces high-energy gases that drive a turbine coupled to an electrical generator. In combined-cycle operation, residual exhaust heat is recovered to produce steam and generate additional electricity, improving overall efficiency. Termozulia III was designed to integrate two gas turbine generators with heat recovery systems and steam generation, providing a higher design capacity than the gas turbines operating independently (Inelectra, 2012).

TZ7 belongs to Termozulia III and is a gas turbine generating unit with a nominal capacity of approximately 150 MW. Its operation depends on the integration of the compressor, combustion systems, turbine, electrical generator, lubrication and cooling systems, instrumentation, controls, and protective devices. Adequate fuel supply, auxiliary services, and grid interconnection conditions are also necessary. From an asset management perspective, the unit must be understood as an integrated technical system whose performance depends on interactions among components operating under varying temperatures, speeds, vibration levels, and loads.

Repairing a major component may restore its individual integrity, but reliable operation requires demonstrating that the assembled system remains fit for service. This requirement becomes particularly important when an asset has undergone successive interventions, configuration changes, or extended periods of unavailability.

The evaluation of rehabilitation outcomes must also distinguish between installed capacity, available capacity, and actual electricity generation. Installed capacity reflects nominal equipment characteristics; available capacity represents the power that can be delivered under defined conditions; and actual generation measures the electrical energy produced over time. Restoring nominal capacity is an important technical achievement, but its operational value depends on actual availability, reliability, efficiency, and the ability to meet the system's requirements consistently.

Background and Evolution of Termozulia Unit 07 Rehabilitation

TZ7 has undergone successive recovery efforts. In May 2016, the unit reportedly regained its nominal capacity of approximately 150 MW following maintenance activities that included interventions on its combustion systems. Additional programs were undertaken in subsequent years to rehabilitate other units within the complex and restore generating capacity (Diario República, 2016; Ocando Alex, 2026).

A relevant precedent involves TZ01, another Termozulia unit that returned to service in September 2018 but experienced a further shutdown approximately three months later. That intervention involved technical configuration, component integration, and compatibility issues. During the same period, a contractual program valued at approximately US$55 million was identified for interventions involving seven turbines (Ocando Alex, 2019). These circumstances illustrate how successive repairs can increase the complexity of restoring existing assets. Each intervention may alter equipment condition, introduce components, or create additional integration requirements, making configuration traceability, procedural consistency, and preservation of technical information essential to reliability management.

A further rehabilitation of TZ7 was announced in December 2025. By May 2026, physical progress had reportedly exceeded 70%, as part of a regional program involving other thermal generating units and electrical infrastructure (Ocando Alex, 2026).

The intervention advanced during September with specialized components supplied from Houston, United States, including a part identified as the turbine's fourth-stage wheel, weighing approximately one tonne. Its installation formed part of the work required to complete assembly and proceed toward functional testing (Banca y Negocios, 2026). Slow-roll operation began on September 30, followed by announced testing protocols before synchronization, with verification activities continuing into early October (Ciudad CCS, 2026a, 2026b).

On October 6, TZ7 was reported to have synchronized with the SEN at a nominal capacity of 150 MW, within a program intended to restore approximately 300 MW through the combined recovery of TZ5 and TZ7 (CASS, 2026). On October 12, however, the unit returned to an out-of-service condition, prompting technical assessments that included borescope inspections of the turbine (Angulo, 2026). Subsequent activities continued to include TZ7 among the units requiring intervention as part of the regional generation stabilization program during the final quarter of the year (Diario República, 2026).

This sequence illustrates a fundamental distinction: completing repair, assembly, testing, and synchronization milestones does not necessarily demonstrate sustained operational reliability. Between restored functionality and stable operation lies a transition in which the technical condition of the asset, integrated system behavior, organizational capabilities, and risks associated with increasingly demanding operating conditions converge.

The effectiveness of rehabilitation should therefore be assessed through post-intervention performance, complementing conventional measures of physical progress, budget, and schedule with indicators of availability, reliability, maintenance requirements, and the ability to sustain the intended operational outcomes.

Technical Integrity and Transition Risks: From Repair to Sustained Operations

Restoring existing industrial assets presents challenges different from those encountered in new installations. Equipment may exhibit uneven deterioration, modifications, and component replacements that alter its original condition. A major repair must establish a technically consistent configuration and demonstrate that the integrated system can perform under the intended operating conditions.

For a gas turbine, this includes verifying the rotor, compressor, combustion and expansion sections, bearings, clearances, balancing, and alignment, together with lubrication, fuel, cooling, instrumentation, and protection systems. Technical integrity must encompass the interfaces among these components because operational performance depends on their combined behavior rather than individual conformity alone.

Recommissioning brings these verifications together through progressive testing, from static conditions to startup, acceleration, synchronization, and operation at different loads. Transient conditions require particular attention because they introduce dynamic changes in temperature, speed, mechanical stresses, and control system response. Technical acceptance should therefore follow defined criteria for each operational state, incorporating operating limits, condition monitoring, and responses to deviations.

The transition from rehabilitation to operations also changes the nature of risk. During maintenance and repair, many systems remain isolated or operate under controlled conditions. As startup progresses, equipment, operators, external infrastructure, auxiliary systems, and organizational processes begin interacting simultaneously. These interactions can generate emerging conditions that may not become apparent during individual system verification and that require timely decisions under uncertainty (Tain, 2026a). Transition risks may involve technical deviations, functional incompatibilities, control and protection system interactions, inadequately adapted procedures, competency limitations, or fragmented responsibilities. Their consequences can propagate across the system: a technical anomaly may affect adjacent equipment, procedural limitations may hinder its interpretation, and inadequate coordination may delay an effective response. This complexity requires dynamic risk assessment and continuous adjustment of controls as new evidence becomes available during testing and early operations.

Transition Risk Management cannot be limited to identifying threats before startup. Inspection results, functional tests, load behavior, and condition monitoring must inform progressive decisions, updating the criteria for advancing toward more demanding operational states. The objective is to reduce uncertainty, control deviations, and ensure residual risks are accepted with an adequate understanding of their technical and operational consequences.

Sustainability also requires converting technical evidence into capabilities available to the operating organization. Approved configurations, maintenance instructions, operating limits, response procedures, and monitoring requirements must be transferred in a controlled manner. Restored integrity is a necessary condition; preserving it requires the ability to interpret deviations and respond as operating conditions change.

Operational Readiness: Capabilities for Managing Uncertainty and Sustaining Outcomes

Operational Readiness is an organizational capability that integrates the conditions and resources required to assume and sustain responsibility for operating an asset. Its structural dimension comprises four fundamental capabilities: People, Assets, Processes & Systems, and Organization. Its developmental dimension considers the progressive states of Awareness, Preparedness, and Readiness (Tain, 2026b).

The structural dimension establishes which capabilities must exist. People encompasses competencies, staffing, and response capabilities; Assets addresses integrity, functionality, and maintainability; Processes & Systems includes procedures, technical information, controls, maintenance, and management of change; and Organization covers governance, coordination, and resources. The developmental dimension assesses how these capabilities progress from understanding requirements to implementing and demonstrating them. Together, the two dimensions provide a basis for evaluating readiness as an integrated condition linked to operational requirements rather than merely the availability of individual resources.

The presence of repaired equipment, trained personnel, or approved procedures provides relevant evidence, but its sufficiency depends on how those capabilities interact. An organization may possess all three and still experience difficulties during transition if mechanisms for integrating information, coordinating responsibilities, or responding to emerging conditions are inadequate. Operational Readiness must therefore be demonstrated through assessment criteria linked to specific requirements and supported by objective evidence. ICxA standards reinforce this approach by connecting capabilities, requirements, acceptance criteria, and readiness decisions (ICxA, 2025).

The relationship between transition risks and Operational Readiness can be expressed through two complementary questions: What could happen during the transition? and What capabilities must exist to respond effectively if it does? The first guides the identification of threats and uncertainties; the second addresses the development of capabilities to prevent, absorb, or manage their consequences.
Identifying risks does not, by itself, establish the capacity to control them (Tain, 2026a, 2026b).

This relationship is particularly important after a major repair. The operating organization must interpret the behavior of a restored configuration, recognize anomalies, and respond to situations that may differ from previous operational experience. Organizational maturity is reflected in both prevention and response, as "the ability to respond to unplanned interruptions is the true measure of an organization's maturity" (Cabeza Rodríguez, 2026a; translated from Spanish). In complex installations, recognizing early warning signals, mobilizing resources, and adapting decisions are fundamental capabilities for preserving reliability and controlling consequences.

Applied to TZ7, this approach integrates repair and recommissioning results with the readiness of personnel, supporting systems, and the receiving organization.
Operational acceptance must consider demonstrated integrity, operating conditions, residual risks, outstanding restrictions, and response mechanisms. Synchronization represents a functional milestone, whereas Operational Readiness encompasses the capability required to sustain performance under actual operating conditions.

Operational Readiness and Transition Risk Management thus converge in an assurance process whose purpose extends beyond enabling startup to establishing the conditions for reliable and sustainable operations.

Cost of Non-Readiness: Transition Risks and Protection of Financial Value

The Economics of Asset Recovery

Industrial asset rehabilitation is an investment whose outcome depends on the capital committed, operating costs, and benefits realized during the restored service life. Expenditures generally precede the recovery of benefits, while subsequent economic performance depends on the availability, reliability, and duration of restored capacity. Traditional indicators—budget, physical progress, scope, and schedule—support execution control but do not fully describe economic

performance.

A repair completed within budget may deliver lower-than-expected benefits if stabilization takes longer than anticipated, additional interventions become necessary, or the asset cannot sustain availability. The cost of restoring an installation must therefore be considered alongside the operational capability achieved and the period over which that capability can be maintained.

The *Cost of Non-Readiness (CoNR)* provides a framework for identifying economic and financial consequences associated with preventable readiness gaps, including additional recovery costs, unavailability, delayed benefits, and exposure affecting dependent operations (ICxA, n.d.). Its value lies in connecting readiness conditions and transition decisions with the realization of the rehabilitation investment's expected economic benefits.

Economic Structure and Attribution of CoNR

Assessing CoNR requires understanding how readiness conditions can generate or amplify economic consequences. Direct costs may include additional inspections, disassembly, repairs, spare parts, specialist services, and repeated testing. Indirect costs may encompass prolonged supporting activities, immobilized resources, and maintenance rescheduling. Although these consequences generally appear as operating or capital expenditures, their origins may lie in integration, acceptance, or readiness conditions preceding the return to service.

A second dimension concerns benefits not realized during unavailability. In electricity generation, these must be linked to the energy the asset could reasonably have produced under justified demand, dispatch, fuel availability, and system constraints. Economic valuation depends on the net benefit associated with that generation and the available alternatives for replacing it, distinguishing nominal capacity from technically deliverable power and energy.

The third dimension is the financial effect of time. Rehabilitation commits capital in anticipation of future benefits. When stabilization is delayed, expected cash flows may shift into later periods while certain expenditures are accelerated or increased. The financial impact consequently depends on both the magnitude and timing of these effects.

Consequences may also extend to industrial facilities dependent on electricity supply, requiring the perspectives of the operator, electricity system, and end users to be distinguished. CoNR represents the portion of additional costs and unrealized net benefits attributable to preventable readiness gaps, rather than necessarily the entire cost of a failure. This distinction supports economically sound assessment by avoiding double counting and the automatic conversion of technical quantities into financial losses.

Availability, CAPEX, OPEX, and Value Creation

Availability directly connects technical reliability with economic outcomes. For TZ7, with a nominal capacity of approximately 150 MW, generation depends on effective output and operating hours, subject to dispatch conditions, fuel availability, and grid constraints. Evaluating unavailability requires comparing generation expected under technically justified conditions with actual generation and determining the corresponding net economic benefit.

The scale of investment needed to restore thermal generation infrastructure can be illustrated through Termozulia's rehabilitation history. A contractual program of approximately US$55 million identified in 2019 covered seven turbines at the complex (Ocando Alex, 2019). In August 2026, a proposal by the Zulia College of Engineers estimated approximately US$168 million to recover six thermal generating units and add around 700 MW of regional capacity (Zambrano, 2026). These programs had different scopes, but they demonstrate the magnitude of the resources involved and the importance of safeguarding expected benefits.

Financially, CAPEX represents capital committed to restoring or improving asset capabilities, whereas OPEX covers fuel, maintenance, personnel, consumables, and services required for operations. A rehabilitation that delivers low reliability may increase both through reinvestment and corrective maintenance while simultaneously reducing or delaying the benefits associated with restored capacity.

This relationship explains why the lowest initial rehabilitation cost is not necessarily the most economically advantageous option. Reducing inspections, validation, or readiness activities may decrease execution costs but increase subsequent exposure if the conditions required to sustain operations have not been sufficiently demonstrated. Conversely, additional assurance activities may be justified when the expected reduction in losses exceeds their incremental cost. Economic evaluation must therefore consider the cost of rehabilitation, the cost of sustaining restored capacity, and the exposure arising during transition and stabilization.

CoNR, Cash Flows, and Net Present Value

Net Present Value (NPV) evaluates an investment through its incremental cash flows, considering their timing and a discount rate consistent with the relevant risks and financial perspective. In rehabilitation programs, these cash flows depend on the capital required, operating costs, expected availability, production benefits, and the period over which the asset can sustain them.

Transition risks may alter these variables through additional interventions, delayed stabilization, or reduced availability. Benefits may shift into later periods while certain expenditures are accelerated or increased. Even if an asset eventually achieves its intended performance, the delay can adversely affect NPV because of the time value of deferred benefits.

CoNR can be incorporated by comparing observed economic performance with a counterfactual scenario reflecting adequate readiness, using consistent assumptions regarding causality, evaluation periods, and valuation. The difference attributable to preventable readiness gaps links acceptance decisions with financial consequences and enables alternative risk treatments to be compared according to their economic exposure.

This perspective is relevant to investors, lenders, and insurers because reliability influences the predictability of returns and exposure to additional capital requirements. Incorporating CoNR during planning enables readiness measures, testing, and assurance activities to be assessed before the return to service by comparing their costs with the economic risks they seek to reduce. Operational Readiness should therefore be evaluated not only as an execution cost, but also through its contribution to protecting the financial value of an investment.

CoNR and Venezuela's Energy Recovery

The recovery of Venezuela's energy industry will require allocating resources among assets with different technical conditions, deterioration levels, risks, and economic potential. An evaluation based exclusively on recoverable nominal capacity or initial costs may be insufficient, particularly where accumulated maintenance needs and interdependencies among installations are significant. Integrating transition risks, Operational Readiness, and CoNR enables decision-makers to evaluate the cost of restoring an installation, the capabilities required to operate it, the risks associated with stabilization, and their potential effects on cash

flows and expected benefits. This approach supports capital allocation based on the ability to create sustainable value rather than the physical restoration of equipment alone.

For electricity infrastructure, reliability has an additional dimension because of its contribution to other industrial processes. Greater generation availability can facilitate the utilization of existing oil, gas, and productive infrastructure, whereas unavailability may perpetuate constraints on projects dependent on a stable power supply. CoNR thus connects engineering, risk management, and finance to examine how readiness decisions can reduce preventable losses and protect investment benefits.

An Integrated Model for Asset Recovery and Outcome Assurance

The TZ7 case supports a recovery approach that connects technical integrity, transition risks, Operational Readiness, and economic performance. The starting point is an assessment of the asset's condition and intervention history, the establishment of a consistent technical configuration, and the definition of rehabilitation scope against operational requirements. During execution, component restoration must be accompanied by conformity verification and integrated testing that generate evidence for subsequent decisions.

As the asset advances toward startup, recommissioning results should inform updated transition risk assessments and evaluations of the human, technical, and organizational capabilities required to sustain operations. Each identified risk should be linked to appropriate controls, acceptance criteria, assigned responsibilities, and response mechanisms.

Operational acceptance represents the point at which these disciplines converge. It should be supported by evidence of integrity and functionality, demonstrated readiness conditions, residual risks, and clearly defined responsibilities. Subsequent stabilization provides an opportunity to verify performance through availability, reliability, efficiency, maintenance, and critical system indicators, identifying conditions requiring corrective action before the recovery is considered established.

Outcome Assurance completes the process by relating achieved operational performance to the economic benefits that justified the intervention. Cost, reliability, and availability information can then be used to assess recovery effectiveness, update risks, and improve future investment decisions. In this way, operational

experience feeds back into the criteria applied to subsequent rehabilitation programs.

The continuity between these stages can be represented as an assurance chain:



Each stage performs a distinct function, but its effectiveness depends on integration with the others. Physical integrity without organizational capability limits operational sustainability; readiness without sufficient technical verification increases exposure during startup; and restored functionality without stabilization can undermine expected benefits. Assurance must therefore maintain a connection among engineering, risk, operations, and finance from rehabilitation planning through sustained operational performance.

Implications for Venezuela's Energy Industry Recovery

Restoring Venezuela's energy infrastructure requires rehabilitation models capable of managing assets with extensive operational histories, successive interventions, and multiple technical dependencies. The recovery of productive capacity must be accompanied by the development of competencies, procedures, supporting systems, and governance mechanisms that enable operations to be sustained under uncertainty.

Termozulia's importance extends beyond the nominal capacity of its generating units. Regional generation availability affects the electricity supply required by industrial activities and provides an enabling condition for the recovery of other energy sectors. Rehabilitation effectiveness must therefore be assessed through both individual asset performance and the contribution of restored capacity to the wider productive system.

Integrating Operational Readiness, transition risks, and CoNR strengthens decision-making through three complementary mechanisms. First, it improves the quality of evidence used to accept rehabilitated assets, ensuring that execution milestones do

not replace the demonstration of operational capability.

Second, it develops the capacity to respond to emerging conditions during startup and stabilization. Finally, it incorporates the economic exposure associated with preventable readiness gaps into investment and acceptance decisions, connecting technical restoration with the protection of expected benefits. These capabilities are especially important when resources must be allocated among assets with different levels of criticality, deterioration, and recovery potential.

Sustainable recovery should consequently be understood as a progressive reconstruction of industrial capabilities. Its success depends on restoring facilities, integrating them into reliable operational systems, and ensuring their contribution to the intended productive and economic outcomes.

Conclusions

The experience of Termozulia Unit 07 offers a basis for examining the challenges of rehabilitating critical energy infrastructure and converting technical restoration into sustainable performance. Successive interventions, the major rehabilitation undertaken in 2026, and the early unavailability following synchronization demonstrate the importance of distinguishing execution milestones from the demonstration of operational capability. Physical integrity is necessary, but its effectiveness depends on the interaction of equipment, auxiliary systems, procedures, competencies, and organizational mechanisms.

Transition risks become particularly relevant when a restored asset operates under dynamic conditions and interdependencies emerge that require response, adaptation, and control. Operational Readiness provides a framework for developing and demonstrating these capabilities, while Transition Risk Management addresses the uncertainty associated with changing operating conditions.

CoNR adds an economic dimension by connecting preventable readiness gaps with additional costs, availability, unrealized benefits, and financial exposure. Its application positions readiness as a mechanism for protecting investment value and strengthens decisions concerning asset recovery, acceptance, and stabilization.

In the context of Venezuela's energy industry recovery, this integration is strategically significant: restoring installed capacity is essential, but success ultimately depends on sustaining reliable operations and converting investment into productive outcomes.

Successful industrial rehabilitation is not merely about returning an asset to service. It is about demonstrating its capacity to operate reliably, manage transition risks, and sustain the benefits that justified the investment.

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