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Heavy Metal:
A Transformer Replacement Program

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1. Introduction

Puerto Rico's electric grid has long operated under conditions that would be considered untenable on the U.S. mainland. Much of the island's high-voltage transformer fleet predates the 1990s, with individual units that have exceeded their designed service life by decades. Deferred maintenance, chronic underinvestment, and exposure to one of the most aggressive salt-spray and seismic environments in the U.S. territory system have left the fleet in a state of accelerating decline.

The destruction wrought by Hurricanes Maria (2017) and Fiona (2022) exposed these vulnerabilities in catastrophic fashion. Maria alone caused an estimated $20 billion in damage to Puerto Rico's infrastructure and triggered the longest blackout in U.S. history, leaving 3.4 million residents without power for months. Substations across the island sustained severe damage to transformers, bus work, and protection-and-control systems. Fiona, arriving five years later with the grid only partially restored, compounded the damage and underscored that incremental repair was no longer a viable strategy.

In June 2021, LUMA Energy assumed operation and management of Puerto Rico's transmission and distribution system under a 15-year public-private partnership with the Puerto Rico Electric Power Authority (PREPA). Among LUMA's most urgent mandates was the wholesale replacement of the island's deteriorated transformer fleet, not as a maintenance program but as a system-level reconstruction effort funded through a combination of FEMA Public Assistance programs and non-federal capital.

This white paper documents the design, execution, and field-tested lessons of LUMA's transformer replacement program. This paper is organized around the core technical and logistical challenges that practitioners in any constrained environment will recognize: how to prioritize a fleet-wide replacement when every unit is critical, how to move 250-ton assets across an island road network never designed for such loads, how to sequence civil works so that transformers are not stranded in storage, and how to sustain program velocity under dual federal and non-federal funding structures. The data, case studies, and recommendations presented here are drawn from active program execution through early 2026.

2. Executive Summary

LUMA Energy's transformer replacement program encompasses 91 power transformers spanning 66 substations across Puerto Rico's transmission and distribution network. The $273 million portfolio requires seamless coordination among global manufacturers, international shipping logistics, heavy-haul transport over challenging terrain, civil works site preparation, and regulatory compliance with both FEMA Public Assistance requirements and the Puerto Rico Highway and Transportation Authority (PRHTA).

As of February 2026, LUMA has completed heavy-haul deliveries to multiple sites including Bayamon, Mora, Guanica, Maunabo, Caguas, and Monacillos, with active campaigns at Costa Sur and Sabana Llana. Ten units are energized and in service. Transformers have been sourced from four manufacturers across multiple geographies, with logistics coordinated through three specialized heavy-transport firms.

The program's execution has validated several critical findings that form the backbone of this paper:

- **Work sequencing, not transformer procurement, governs the critical path.** A transformer arriving before its site is constructable triggers costly storage, secondary moves, and cascading schedule disruptions.
- **Bridge studies is the dominant schedule risk in constrained-corridor logistics.** Route studies have required evaluation of up to 53 bridges per substation, with unknown ownership and structural records consuming months of investigation.
- **Oil processing and assembly capacity represents an island-wide bottleneck** that must be sequenced alongside delivery and civil works calendars to sustain program throughput.
- **Dual federal/non-federal funding structures introduce timing dependencies** that can stall pre-construction activities even when transformers are physically available.

3. Program Scope and Asset Prioritization

The full program encompasses 91 transformers assigned across 66 unique substations island-wide. The portfolio splits into 63 distribution-class units (14–44.8 MVA) and 34 transmission-class units (112–544 MVA), spanning voltage classes from 38 kV distribution feeders up to 230/115 kV autotransformers.

Several substations receive multiple transformers: Monacillos TC, Sabana Llana TC, and Costa Sur SP each have 5 units assigned, while Bayamon TC and Viaducto TC each have 4. This concentration creates both opportunity through shared civil works and consolidated outage windows, and risk through resource contention and compounded schedule dependencies.

3.1 Prioritization Methodology

Sequencing 91 replacements across a degraded grid where every unit could be argued as critical required a structured prioritization framework. LUMA's Asset Management, System Planning, Engineering, and Construction groups collaborated to develop a single ranked deployment list based on multiple weighted criteria.

System reliability impact formed the primary ranking factor. Units were evaluated against N-1 contingency analysis to identify substations where a single transformer failure would result in unserved load with no viable switching alternative. Transformers serving radial load pockets or operating as the sole supply point for critical facilities received high reliability scores.

Condition assessment data provided another input. Dissolved gas analysis (DGA) trending, oil quality results, electrical testing, and known deficiency records were compiled. Transformers exhibiting accelerating gas generation rates, elevated moisture content, or documented deficiencies were flagged.

Load growth projections and planning studies identified substations approaching or exceeding nameplate thermal limits, particularly those where summer peak loading regularly exceeded 80% of rated capacity. These sites were cross-referenced with system planning's load forecast to confirm the trajectory.

Finally, constructability and logistics feasibility were factored to avoid sequencing replacements at sites where route access, civil works complexity, or permitting timelines would create extended program bottlenecks. The initial Stabilization Phase prioritized sites where the reliability case was strongest and the delivery pathway was most achievable, including Monacillos Banks 1 and 3 and Caguas TC Bank 2. These units were selected and presented to FEMA to restore stability, reliability, and resiliency based on LUMA and industry standards.

3.2 Procurement Strategy and Supply Chain Management

Power transformers in the 115 kV to 230 kV class are among the longest-lead-time items in the electric utility supply chain. Current market conditions require approximately two to three years from initial specification and request for quotation to final delivery. LUMA's program employs a deliberate multi-vendor strategy, sourcing from four manufacturers across different geographies to mitigate single-supplier risk. Each manufacturer brings distinct lead times, factory acceptance testing protocols, and shipping logistics requirements. All four vendors have committed specific quantity, MVA capacity, and voltage class into their production lines through 2028.

3.3 GOES Steel Price Volatility and Contractual Mitigation

Grain-Oriented Electrical Steel (GOES) remains the single largest material cost driver for power transformers, and its price volatility over the program lifecycle illustrates why early procurement commitments are essential. The roughly 44% swing over four years directly impacts unit costs.

LUMA's contractual approach addressed this volatility through several mechanisms. Procurement commitments were placed early in the program to lock steel allocations at lower price points where possible. The multi-vendor strategy also provides a degree of natural hedging, as manufacturers in different regions may source steel from different mills with partially independent pricing dynamics.

3.4 Risk Mitigation Summary

Risk Factor	Observed Impact	Mitigation Applied
Extended manufacturer lead times	18–36 month lead times; Group 2 deliveries pushed beyond original schedule	Multi-vendor sourcing (4 manufacturers); staggered purchase orders across production lines
GOES price volatility	44% swing ($4,200–$6,057/MT) over program lifecycle	Early commitment contracts with escalation/de-escalation clauses tied to published indices
Supply chain concentration risk	Single-vendor dependency would create single point of failure across 91-unit portfolio	Geographically diversified vendor base across multiple manufacturing regions
Delivery-to-site readiness gap	Transformers arriving before civil works completion, requiring costly storage	180-day advance site assessments; weekly readiness reviews; non-federal funding for early civil works

4. Transformer Engineering and Specifications

A program of this scale requires balancing fleet standardization against the site-specific electrical requirements of 66 distinct substations. LUMA's engineering team developed standardized base specifications for each voltage class while defining a controlled deviation process for sites with unique system characteristics.

4.1 Specification Criteria

Each transformer specification is driven by several interdependent parameters. Voltage class and winding configuration define the fundamental design: the portfolio spans 38 kV distribution units through 230/115 kV, with winding arrangements (delta-wye, wye-wye, autotransformer) determined by system grounding requirements and load characteristics at each substation.

Impedance matching is critical for units being paralleled with existing transformers or integrated into networked bus configurations. Mismatched impedance between parallel units causes unequal load sharing, potentially overloading one unit while the other operates below capacity.

Basic Insulation Level (BIL) is specified based on the system voltage class and the substation's exposure to lightning and switching surges. Puerto Rico's tropical climate and the island's extensive overhead transmission network produce a severe lightning environment, and BIL ratings are set accordingly with appropriate margins above minimum standards.

Puerto Rico's ambient temperature profile, with sustained temperatures above 30°C for much of the year, requires that cooling system ratings are validated against tropical derating factors rather than standard nameplate assumptions.

Load tap changers (LTCs) are specified for units where voltage regulation requirements dictate on-load adjustment capability. The specification defines tap range, step size, and LTC type based on the anticipated regulation duty cycle at each substation.

4.2 Factory Acceptance Testing

LUMA's Engineering Services group attends and reviews factory acceptance testing (FAT) at each manufacturer's facility to validate that each unit meets its specification before shipment. The FAT protocol goes beyond verifying nameplate ratings and includes a comprehensive suite of tests designed to establish the transformer's baseline condition and confirm design adequacy.

Standard FAT elements include ratio and polarity verification, winding resistance measurements at all tap positions, impedance and load-loss testing, no-load loss and excitation current measurements, applied voltage and induced voltage dielectric tests, and

impulse testing at the specified BIL. For units with LTCs, the FAT includes tap changer operation verification across the full range with timing measurements.

Beyond these standard tests, LUMA requires Sweep Frequency Response Analysis (SFRA) at the factory to establish a mechanical integrity baseline. SFRA traces are recorded and archived as the reference signature for all subsequent field measurements. Any deviation detected during site acceptance testing can then be evaluated against the factory baseline to determine whether transport damage has occurred. Frequency Response Analysis (FRA) and Dielectric Frequency Response (DFR) measurements supplement the baseline dataset.

4.3 Commissioning and Acceptance-to-Energization Sequence

Upon arrival at the substation, the commissioning team performs site acceptance testing before the unit is placed on its foundation. This includes a repeat SFRA measurement compared against the factory baseline to detect any mechanical displacement during transport, core insulation resistance and core ground verification, and a visual inspection of all accessible components. If SFRA traces show deviation beyond defined thresholds, the unit is held for further investigation before proceeding.

After the transformer is landed on its pad, oil processing begins. The unit is vacuum-filled with transformer oil, which is then circulated through processing equipment to remove moisture, dissolved gases, and particulate contamination to specified cleanliness levels. Oil processing capacity on the island is a finite resource; the program currently operates with a limited number of processing rigs, making this activity a potential bottleneck when multiple units arrive in close succession. To manage this constraint, oil processing and assembly activities are staggered across the delivery schedule so that specialized crews and equipment remain continuously occupied without requiring surge mobilization.

With oil processing complete, construction crews assemble field wiring including bus connections, cable terminations, conduit runs, and integration with the substation's protection-and-control systems. Apparatus testing crews then perform a comprehensive electrical test suite on the fully assembled transformer, verifying insulation power factor, winding resistance under oil, turns ratio at all tap positions, and protective relay calibration.

The energization sequence itself follows a rigorous protocol: a pre-energization inspection and walkdown, switching procedure development specific to the substation's bus configuration, System Control Center coordination, initial energization at reduced load, a 24-hour soaking period with continuous thermal and electrical monitoring, and finally load transfer and normalization. A leadership challenge session provides final review and approval before each energization event. Pre- and post-energization dissolved gas analysis sampling confirms transformer health under load and establishes the in-service DGA baseline for ongoing condition monitoring.

5. Logistics and Heavy Transport

Transporting power transformers weighing 80 to over 250 metric tons across Puerto Rico's road network represents the program's most operationally complex challenge. Each delivery requires a custom route study, structural analysis of every bridge along the path, PRHTA permitting, traffic management planning, and close coordination with municipalities, utilities, and security escorts. The program engages three specialized heavy-transport firms, each with different equipment profiles and regional experience, and coordinates route studies through a dual-firm architecture of independent preparation and review.

5.1 Route Study Framework

LUMA established a disciplined two-firm model for route studies: one architectural and engineering (A&E) firm develops the route study and bridge analysis, while a separate A&E firm provides independent quality assurance review. This dual-control approach was formalized after early program lessons demonstrated that bridge load ratings, geometric clearance assessments, and pavement evaluations require rigorous peer review before submission to PRHTA.

Each route study follows a two-phase approach. Phase I, the preliminary route study, includes route options identification and feature inventory mapping of roads, intersections, bridges, culverts, utilities, and structures, culminating in a preliminary route recommendation. Phase II, the final route study, includes the final route analysis, civil geometric and bridge load rating reports, PRHTA permit submissions, and final coordination with all logistics stakeholders including the transport vendor, municipalities, and security escorts.

5.2 Bridge Analysis: The Dominant Schedule Variable

The bridge evaluation workload has emerged as the single most significant schedule variable in the logistics chain. Across the 15 active route studies, the number of bridges requiring structural analysis per substation has varied dramatically, from as few as 8 for Bayamon to as many as 53 for Maunabo, which represents the most complex route in the program. Review cycles between the preparing and reviewing A&E firms typically require two to four rounds of comments and corrections. The Bayamon route study completed its review cycle in approximately one month; the Maunabo study required nearly three months from initial delivery to final review certification.

Substation	Bridges Requiring Structural Analysis
Maunabo	53
Costa Sur	45 (preparation) / 28 (review)
Sabana Llana	35

Caguas	22
Monacillos	18
Guanica	14
Bayamon	8 (preparation) / 10 (review)

Table: Bridge analysis counts by substation. Where preparation and review counts differ, both are shown.

5.3 Case Study: Costa Sur — Unknown Structures and Extended Investigation

The Costa Sur delivery illustrates the full complexity of the logistics challenge. LUMA acquired a 230–115 kV, 336 MVA autotransformer requiring transport from port to the Costa Sur Substation in Ponce. The route evaluation covers roadway segments along PR-127 (km 10.0 to 17.9) and PR-337 (km 0.0 to 1.90), both under PRHTA jurisdiction.

The reviewing firm evaluated two alternative port-to-substation routes: one from Puerto Las Americas Terminal and one from Peerless Dock. Both routes converge on the Costa Sur facility but present distinct challenges. Along PR-337, a structure crossing a drainage channel required structural integrity review. On PR-127, a subsurface structure including utility pipes and a culvert beneath the roadway needed evaluation for load-bearing capacity. Two additional structures near a decommissioned industrial facility required special investigation, including a site visit coordinated with the property owner to locate structural records.

The route study was presented at a PRHTA meeting in September 2025, but the review generated comments requiring additional investigation of specific structures. Final approval was not received until December 2025, extending the route study timeline significantly beyond initial projections. The Costa Sur preparation phase, initially targeted at 20 working days after notice to proceed, ultimately required over three months due to unknown bridge ownership complications and industrial site access coordination.

5.4 Case Study: Sabana Llana — Urban Corridor Constraints

The Sabana Llana delivery presented a different set of challenges rooted in urban corridor constraints. The route required bridge jumper installations—temporary structures allowing the transport to bypass load-restricted bridges—including one on Roosevelt Avenue that originally required a seven-day installation and removal window. The team worked with the transport contractor and municipal authorities to compress this to three days. Civil works for crossover points required approval from both PRHTA and the toll road authority.

Jersey barrier specifications at the San Patricio roundabout were modified at PRHTA's recommendation to use polyethylene barriers instead of concrete, reducing installation time

and eliminating the need for heavy-lift equipment at the roundabout. The transformer staging area required negotiation with commercial property owners, as the original staging option was lost due to insurance disagreements between the transport firm's logistics subcontractor and the property owner. The unit was ultimately staged at an alternative parking facility, arriving in November 2025.

5.5 Port Operations and Unloading

Port selection and unloading methodology have emerged as critical variables that must be resolved early in the route study process. The Maunabo transformer was originally planned for the port at Yabucoa, but the assigned transport firm determined that crane unloading was not feasible at that facility. The revised plan called for ramp unloading directly from a barge, with a crushed-rock base constructed for the ramp approach. These changes, while ultimately workable, consumed planning time and required re-coordination with port authorities and the barge operator.

6. Works Sequencing: The Critical Path

If this program has produced one overriding lesson, it is this: the critical path for a transformer replacement is not the transformer's manufacturing lead time or shipping schedule. It is the readiness of the site to receive it. The program charter identifies "transformers delivered but not immediately constructable" as the program's highest-priority risk, and field experience has validated that assessment repeatedly.

When a transformer arrives at a substation before civil works are complete, it triggers a cascade of problems. The unit must be stored under manufacturer-specified environmental conditions, often requiring ongoing power for space heaters and nitrogen blankets. A secondary move from temporary storage to the pad must be scheduled and funded, requiring re-mobilization of specialized heavy-transport equipment. The specialized workforce and equipment planned for installation must be redeployed to other tasks and later recalled, introducing schedule fragmentation. The overall program absorbs an avoidable delay that compounds across downstream activities.

6.1 The Civil Works Prerequisite Sequence

Each construction site requires a defined sequence of civil works before a transformer can be placed: site preparation and grading, foundation construction, transformer pad completion, oil containment system installation, and auxiliary equipment staging. Only after these prerequisites are verified can the transformer be physically placed, assembled, filled with oil, and connected to bus, cable, conduit, and protection-and-control systems.

To mitigate the delivery-readiness gap, the program charter mandates that engineering conduct detailed site assessments and desktop reviews 180 days prior to delivery acceptance. Project managers provide delivery-to-installation schedules and conduct weekly site preparation status reviews with engineering. Where FEMA obligation has not yet been received, the program uses non-federal capital funding to begin essential site preparations, ensuring that when a transformer arrives, it can proceed directly to installation rather than diverting to storage.

6.2 Oil Processing and Assembly

Beyond civil works readiness, oil processing and field assembly capacity represent an island-wide throughput constraint. The number of oil processing rigs, specialized crews, and test equipment available at any given time limits how many transformers can move through the acceptance-to-energization pipeline simultaneously. The program deliberately staggers post-delivery activities so that oil processing, assembly, testing, and commissioning crews remain continuously occupied at a sustainable tempo rather than surging and demobilizing around clustered deliveries. This approach trades theoretical schedule compression for practical reliability of execution.

7. Program Management and Stakeholder Coordination

Managing 15 simultaneous route studies and deliveries, each with distinct vendors, logistics firms, A&E teams, and regulatory timelines, requires program management infrastructure that can absorb disruption without losing visibility. LUMA's Capital Programs Substation Projects group coordinates the program through a structured governance framework with weekly status calls, shared tracking tools, and formalized escalation protocols.

7.1 Schedule Performance and Cost Variability

Route study preparation timelines have typically been specified at 20 working days from notice to proceed, but actual durations have frequently exceeded this target. As documented in the Costa Sur and Sabana Llana case studies, unforeseen complications with bridge ownership records, unknown subsurface structures, and multi-agency coordination can extend preparation timelines to three months or more. These durations must be factored into future route study schedules as the baseline expectation, not as exceptions.

Route study costs have varied significantly based on bridge count and route complexity, with estimated preparation costs ranging from $50,000 to $350,000 depending on the number of bridge analyses, bridge jumper requirements, site visits, and supplementary structural assessments required.

7.2 PRHTA Permitting

The Puerto Rico Highway and Transportation Authority is the primary regulatory authority for heavy-load transport permits. All route studies must comply with PRHTA's Standard Operating Procedure for Heavy Loads Transportation Approvals. The permitting process requires submission of civil geometric and bridge load rating reports, followed by PRHTA review and conditional approval. Observed cycle times have varied considerably: the Caguas permit moved from report submission to movement permit in approximately one month, while the Costa Sur permit required nearly three months including a formal presentation at a PRHTA review meeting and multiple rounds of supplementary structural investigation.

7.3 Multi-Agency Coordination

Each delivery requires coordination across multiple agencies and private entities, and the specific constellation of stakeholders differs for every route. The Sabana Llana campaign involved the toll road authority, a civil works contractor for demolition and crossover construction, a bridge jumper design subcontractor, the municipality of San Juan, PRHTA, and security escort services. The Costa Sur campaign involved PRHTA, the municipality of Ponce, a decommissioned industrial facility for bridge access and structural records, and the assigned logistics vendor. No two delivery campaigns have had identical stakeholder

maps, which limits the degree to which a single permitting playbook can be applied across the program.

7.4 Dual Funding Structure and Obligation Timing

The program's financial structure relies on two funding sources that operate on different timelines and approval processes. Non-federal capital funding covers initial site preparations, immediate system stabilization projects, temporary measures, and non-FEMA-eligible components. FEMA Public Assistance funding supports system stabilization projects, critical infrastructure upgrades, and resilience improvements.

This dual structure creates a practical challenge: when FEMA obligation for a specific project is delayed, pre-construction activities can stall even when the transformer itself is available and the site is technically ready for preparation work. The program addresses this by using non-federal capital to advance essential civil works ahead of FEMA obligation where schedule risk warrants it, accepting the funding complexity in exchange for maintaining program momentum. All expenditures maintain documentation standards sufficient for potential FEMA reimbursement, including work-breakdown-structure-coded timesheets, statutory declarations, and segregation of on-island versus off-island service costs.

7.5 Safety and Contractor Compliance

All contractor personnel working on the program must complete orientation training. Field work requires appropriate personal protective equipment, adherence to safety procedures, and proactive hazard recognition. The program's safety framework emphasizes team communication, environmental hazard awareness including weather changes, wet surfaces, and restricted spaces, and strict adherence to established procedures. Subcontractors require prior written approval and must provide full documentation including registration, certificates of good standing, insurance, and authorization to do business in Puerto Rico.

8. Lessons Learned and Recommendations

The following findings are drawn from the program's first wave of route studies and deliveries. They are presented as actionable guidance for practitioners managing large-scale transformer replacement programs, particularly in environments with constrained transportation corridors, aging infrastructure records, and multi-jurisdictional regulatory requirements.

8.1 Plan for Civil Works as the True Critical Path

The most consequential scheduling error in any transformer replacement program is treating the manufacturing lead time as the critical path. In practice, the readiness of the receiving site governs whether a delivered transformer translates into an energized asset or an expensive storage problem. Programs should institute mandatory site readiness reviews at 180 days, 90 days, and 30 days before scheduled delivery acceptance, with hold/redirect authority if civil works milestones are not tracking. Where funding constraints delay civil works, the program should have pre-authorized alternative funding mechanisms to avoid stranding delivered units.

8.2 Budget Bridge Analysis Time Realistically

Route study timelines based on 20-day preparation assumptions have proven consistently optimistic. Bridge counts of 30 to 50 per route are common in Puerto Rico's environment, and each bridge requiring analysis introduces the possibility of unknown ownership, missing structural records, or failed load ratings that require re-routing. Programs should baseline route study preparation at 60 to 90 days, not 20, and treat the 20-day target as achievable only for low-bridge-count routes with well-documented infrastructure.

8.3 Secure Structural Records and Bridge Ownership Early

Multiple route studies were delayed by the inability to locate bridge ownership records or structural documentation for aging infrastructure. In several cases, bridges were found to be under the jurisdiction of entities other than the assumed owner, requiring fresh outreach and separate approval processes. Programs should invest in a comprehensive bridge inventory and ownership verification exercise before issuing route study task orders, rather than discovering these gaps during the preparation phase.

8.4 Treat Port Operations as a Design Problem, Not a Logistics Detail

Port selection and unloading methodology should be resolved and validated during Phase I of the route study, not left to the transport vendor to determine during execution planning. The Maunabo experience, where the original port plan was abandoned because crane unloading was infeasible and a barge ramp approach had to be designed, illustrates the schedule risk of deferring port logistics decisions. Each port option should be formally evaluated for crane capacity, ramp feasibility, draft clearance, and staging area availability before the route study advances to Phase II.

8.5 Stagger Oil Processing and Assembly Deliberately

Oil processing rigs and specialized assembly crews are finite resources on an island. Allowing multiple transformer deliveries to cluster without staggering the downstream processing and assembly activities creates a resource contention bottleneck that is expensive to resolve through surge mobilization. The program should maintain a standing assembly pipeline tempo and schedule deliveries to feed that pipeline at a sustainable rate, rather than optimizing for the earliest possible delivery date in isolation.

8.6 Account for Urban-Corridor Complexity in Cost and Schedule Estimates

Urban delivery routes introduce a distinct class of challenges that rural routes do not: bridge jumper installations with compressed municipal windows, roundabout modifications, staging area negotiations with commercial property owners, and toll authority coordination. These elements are not incidental; in the Sabana Llana campaign they drove both the schedule and the cost profile of the delivery. Programs should classify routes by urban/rural corridor type early and apply differentiated schedule and cost contingencies accordingly.

8.7 Build Institutional Knowledge Across the A&E Team

The dual-firm preparation and review model provides essential quality assurance, but it also means that lessons learned on one route study do not automatically transfer to the next firm's preparation effort. Programs should establish a shared knowledge repository of bridge analysis findings, PRHTA comment patterns, and successful mitigation approaches that both preparing and reviewing firms can reference. Formalizing this knowledge transfer reduces the likelihood of repeating the same investigative cycles across successive route studies.

9. Conclusion

LUMA's transformer replacement program is delivering results while generating critical institutional knowledge about heavy-transport logistics, civil works sequencing, and multi-phase program execution in an island environment with constrained infrastructure. With a portfolio spanning 91 transformers across 66 substations, the program has moved from pilot deliveries through an aggressive Scale Phase.

The central finding of this paper is that the critical path in a transformer replacement program is not where most practitioners instinctively look. Manufacturing lead times and shipping logistics are significant, but they are knowable and largely controllable through multi-vendor procurement strategies and early commitment. The true critical path runs through civil works site readiness, the logistical move, bridge load-rating investigation, and the finite on-island capacity for oil processing and commissioning.

As the program scales to receive more transformers through 2028, the team will apply these lessons to compress timelines, anticipate structural-investigation complications, and build realistic schedule contingency into every route study task order. The program's success ultimately depends on maintaining the disciplined coordination framework that has been built across LUMA's engineering, capital programs, materials management, and A&E partner teams—and on the willingness to treat field-tested lessons as binding constraints rather than anecdotal observations.