ELECTRIC MOBILITY CORRIDOR READINESS STUDY

Operational Range, Charging Infrastructure & Grid Capacity Assessment for Passanger, Light Duty and Heavy Duty Vehicles
A109 Corridor: Nairobi - Mombasa - Nairobi

Study Period: 21-23 May 2026

CLIMATE CENTER
by Kühne Foundation

Visolis

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Content

List of figures

List of tables

About this publication

This report is a flagship technical study by the Kuehne Climate Center, produced in collaboration with Kenya Power and the Electric Mobility Association of Kenya. It documents the first long-haul electric-vehicle convoy along Kenya's A109 corridor and analyses corridor charging infrastructure, vehicle range performance and substation grid readiness to support the country's transition to electric mobility.

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DISCLAIMER

Abbreviations

A109	Nairobi–Mombasa highway corridor assessed in the study
AADT	Annual Average Daily Traffic
AC	Alternating Current
BESS	Battery Energy Storage System
CCS2	Combined Charging System Type 2
DC	Direct Current
DF	Diversity Factor
EMAK	Electric Mobility Association of Kenya
EPRA	Energy and Petroleum Regulatory Authority
EV	Electric Vehicle
GB/T	Chinese national EV charging connector standard
GHI	Global Horizontal Irradiance
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
HCV	Heavy Commercial Vehicle
KeNHA	Kenya National Highways Authority
KPLC	Kenya Power and Lighting Company PLC / Kenya Power
LCV	Light Commercial Vehicle
N-1	Network security criterion based on maintaining supply after loss of one network element
PF	Power Factor
PV	Photovoltaic
SOC	State of Charge
USD	United States Dollar

Units used in the report

A	Ampere
h	Hour
km	Kilometre
kV	Kilovolt
kVA	Kilovolt-ampere
kW	Kilowatt
kWh	Kilowatt-hour
m	Metre
m^2	Square metre
MVA	Megavolt-ampere
MWh	Megawatt-hour
%	Percentage

Foreword

Kuehne Climate Centre

Some studies begin in a conference room. This one began on a highway.

In May 2026, a convoy of six electric vehicles left Nairobi and drove south toward the coast through the Athi Plains, past Tsavo, down through the escarpment to Mombasa and then turned around and drove back. It was not a demonstration. It was not a publicity exercise. It was a deliberate act of evidence generation: an attempt to find out, under real operating conditions on one of East Africa's most important trade corridors, what electric freight and commercial transport can actually do, and what it cannot yet do.

The A109 Mombasa–Nairobi corridor moves goods that feed cities, power industries, and connect landlocked nations to the sea. It is a corridor where the gap between ambition and operational reality matters enormously — where a six-hour charging stop is not an inconvenience but a commercial failure, and where the difference between a 20 kW charger and a 240 kW charger is the difference between a viable freight operation and one that is not.

This study is the result of that convoy. It is field evidence, not modelling. The numbers in these pages the state-of-charge readings, the charging durations, the substation headroom margins were collected on the road, at charging stops, and through the instruments attached to the grid infrastructure that serves them. Where we have been confident, we have said so. Where the evidence is incomplete or requires validation, we have said that too.
We did not drive this corridor alone.

Kenya Power opened charging access at their Nyali facility in Mombasa and at Voi, provided critical substation loading data, and engaged with genuine seriousness on the grid infrastructure questions this study raises. Their participation transformed a vehicle test into a corridor systems study.

Kabisa brought vehicles, charging equipment, and deep operational knowledge of what electric mobility actually looks like when it leaves Nairobi. Their field presence throughout the convoy was indispensable.

GIZ — through their long-standing commitment to sustainable transport in Kenya provided both institutional support and the broader analytical context within which this work sits. Their investment in the e-mobility policy environment in Kenya made this kind of study possible.

EMAK — the Electric Mobility Association of Kenya connected us to the ecosystem of operators, deployers, and advocates who are building Kenya's electric mobility sector from the ground up. Their knowledge

of what is actually happening in the market, as distinct from what policy documents describe, sharpened our analysis throughout.

Visolis are the consulting team who made this study what it is. They designed the data collection methodology, deployed to the field for the duration of the convoy, and captured the evidence stop by stop, vehicle by vehicle, charger by charger that fills these pages. They then did the harder work: making sense of what the data was saying, identifying where the corridor works and where it does not, and shaping raw field observations into analysis that governments, utilities, and investors can act on. Without Visolis, there would have been a convoy but no story worth telling. This report is, in the most direct sense, their work.

One to One provided something the convoy could not have operated without: the drivers who sat behind the wheels for nearly a thousand kilometers of highway, and the load that gave the heavy-duty leg of the study its commercial weight. Their operational contribution is embedded in every data point collected from the road.

Advanced Mobility ensured that those drivers were ready. Through a dedicated training program on the operation of electric trucks covering charging protocols, range management, regenerative braking behavior, and the significant differences between electric and diesel powertrains under load Advanced Mobility gave the convoy's drivers the knowledge to operate safely and to generate data that is operationally meaningful rather than artificially cautious. Good field evidence depends on informed operators, and that preparation was Advanced Mobility's contribution.

Trademark Africa situates this work in its proper regional context. The A109 is not only Kenya's corridor — it is the Northern Corridor's artery, serving Uganda, Rwanda, Burundi, South Sudan, and the Democratic Republic of Congo. Trademark's corridor systems perspective reminded us that the infrastructure decisions documented here have consequences far beyond the stretch of road we drove.

CalStart through the Drive to Zero program and campaign that aims to speed the transition to zero emission commercial vehicles, helped us ask questions of our evidence that a purely local perspective might have missed. The A109 corridor is precisely the kind of emerging-market freight route that the Drive to Zero program and campaign aims to reach if its ambitions are to be more than a story about wealthy cities and short-haul delivery vans.

The Northern Corridor Transit and Transport Coordination Authority provided the corridor-level institutional framework within which any serious infrastructure investment must ultimately operate. Their engagement signals that the findings of this study are intended for policy use, not merely for publication.

Kuehne Climate Centre, which convened and coordinated this effort, does so in the belief that the most important contribution applied research can make to the energy transition is not to describe what is theoretically possible, but to measure what is actually happening and report it honestly including the gaps, the failures, and the questions that remain open. That means asking the questions a fleet manager would ask, not only the ones a researcher finds convenient: whether the charging stop fits a commercial schedule, whether the driver has been trained to get the most from the vehicle, whether the grid behind the charger can carry the load. Evidence without commercial realism is planning without consequence.

This study has open questions. The Sultan Hamud charging event requires further data validation. The substation loading figures require KPLC confirmation for publication. The commercial viability of heavy-duty electric freight on this corridor genuinely promising in its direction, genuinely incomplete in its evidence base requires more convoy runs, more vehicles, more instruments, and more freight operators willing to test their trucks on a road that asks a great deal of them.

We intend to continue. We hope this document, honest about what it knows and what it does not, is a foundation worth building on.

Kuehne Climate Centre Nairobi, June 2026

Executive Summary

The A109 corridor demonstrated practical viability for the tested electric passenger vehicles, light commercial vehicles and heavy commercial vehicle, if charging is planned around the available nodes at Nyali, Emali, Mtito Andei, Voi and Sultan Hamud. However, the study shows that operational readiness is not uniform across vehicle categories. Passenger vehicles were generally able to complete the route with planned charging stops, while light commercial vehicles required more conservative charging buffers, particularly on the return leg from Mombasa to Nairobi. Heavy-duty operation presented the most significant infrastructure challenge, especially where low-power charging was the only available option.

The most critical charging infrastructure constraint was observed on the return leg at Sultan Hamud, where the X7E heavy-duty truck required a substantial partial top-up before proceeding towards Nairobi. Although the vehicle was not fully charged, the stop still lasted approximately six hours, demonstrating that the available GB/T charging capacity at the site was not commercially viable for heavy-duty freight operations. This finding highlights that the main issue for electric trucks in the corridor is not only total battery capacity, but also the ability to restore sufficient operational energy within an acceptable dwell time. For this reason, Sultan Hamud requires a higher-power GB/T DC charging solution if it is to support heavy commercial vehicles reliably.

Voi emerged as the strongest strategic charging location along the corridor. It serves traffic moving in both directions, carries significant corridor demand, and can function as an overnight charging hub for vehicles travelling between Nairobi and Mombasa. However, the site also recorded several long charging events exceeding four hours, indicating that its current charging capacity is inadequate for scaled commercial operations. Voi should therefore be treated as a priority anchor hub requiring higher-power DC charging capacity, especially to reduce congestion, improve vehicle turnaround times and support both passenger and commercial electric vehicles.

Mtito Andei and Emali remain important intermediate nodes for redundancy, operational flexibility and corridor risk management. Mtito Andei is particularly important on the return journey from Mombasa because vehicles climb from the coast towards the

highlands, increasing energy consumption and reducing operating range. These intermediate sites therefore provide useful safety margins for vehicles with smaller batteries, higher payloads or lower remaining state of charge. Based on the limited evidence from this study, the minimum recommended infrastructure standard for corridor scale-up is at least 60 kW DC charging at every strategic node, while Sultan Hamud should be upgraded to 100 kW GB/T DC or higher to support heavy-duty vehicles.

The substation loading assessment shows that grid readiness varies significantly across the corridor. Among the substations used to charge the convoy, Mtito Andei 33/11 kV is the main binding grid constraint. The substation has a single 2.5 MVA transformer and, based on the 2025 KPLC baseline loading of 1.80 MVA, is already loaded to approximately 72% of nameplate capacity. This leaves only about 200 kVA of headroom against the 80% planning ceiling, making it unsuitable for substantial Phase 2 charging expansion without reinforcement. A second major constraint emerges when corridor traffic demand is considered: Athi River 66/11 kV carries the heaviest freight volumes on the corridor, with approximately 8,260 trucks per day at Syokimau, but is already loaded to about 97% of its N-1 firm capacity. With a 22.41 MVA load against a 23 MVA firm rating, Athi River has no firm headroom for additional EV charging load unless reinforcement, a curtailable connection, or a solar-and-storage-backed solution is implemented.

By contrast, Kiboko, Voi, Mariakani and Nyali retain sufficient grid headroom to support both Phase 1 and Phase 2 charging deployment without immediate substation expansion. The analysis covers seven substations along the A109 corridor, namely Athi River, Kiboko, Mariakani, Mtito Andei, Nyali, Sultan Hamud and Voi. Site prioritization was informed by KeNHA average annual daily traffic counts matched to the relevant corridor sections, allowing charging locations to be assessed not only by grid capacity, but also by observed traffic demand and expected freight relevance.

Seven corridor charging sites were assessed in total i.e. Sultan Hamud and Emali, both supplied through Kiboko, Mtito Andei, Voi, Nyali and the traffic-driven additions of Mariakani and Athi River. Six of these sites can be deployed in Phase 1, providing approximately 16 charge points corridor-wide, with each site hosting between one and four charge points depending on demand and grid capacity. In Phase 2, the corridor can scale to approximately 32 charge points. Athi River has the strongest demand case but remains contingent on grid reinforcement, while Mtito Andei can support Phase 1 but requires a transformer upgrade before Phase 2. Kiboko remains available for further Phase 3 infill because of its strong available headroom and strategic location serving both Sultan Hamud and Emali.

Two substations require reinforcement to support the full corridor charging program. For Phase 2 deployment at the parade-served sites, Mtito Andei should be upgraded from a single 2.5 MVA transformer to a 2×5 MVA configuration, providing 5 MVA of N-1 firm capacity. This would create adequate headroom for EV charging, expected five-year non-EV load growth and redundancy under transformer outage conditions. Separately, Athi River 66/11 kV, despite being the highest-traffic node on the corridor, has no firm headroom for new EV charging load and therefore requires demand-led reinforcement before a major charging hub can be developed. All other assessed substations, including Kiboko, Voi, Mariakani and Nyali, have sufficient headroom to support both Phase 1 and Phase 2 charging deployment.

1. Introduction and Rationale

1.1 Background: Kenya's E-Mobility Journey

Kenya has emerged as one of Sub-Saharan Africa's most active electric-mobility markets, supported by an electricity system that is predominantly renewable (largely geothermal, hydro and wind). The recently launched Kenya E-mobility policy has created an environment that has increasingly recognized transport electrification as an opportunity for cutting fuel-import costs, reducing carbon emissions and meeting Kenya national climate commitments. Over recent years the e-mobility ecosystem has extended from two- and three-wheelers into electric matatus, buses, passenger cars and heavy commercial vehicles, accompanied by a growing network of public and depot charging points. Currently there are no electric trucks in Kenya. For the study, an electric truck from Rwanda was used.

Institutional momentum has followed the growth of EVs with the launching of the National Electric Mobility Taskforce, the development of e-mobility standards through the Kenya Bureau of Standards, and the introduction of a dedicated e-mobility electricity tariff by the Energy and Petroleum Regulatory Authority (EPRA). These initiatives signal deliberate actions by the government to support the shift to Electric Vehicles in the country.

Despite this progress, the transition has so far concentrated on urban fleets operating within Nairobi, where charging dwell time and grid access are short. Long-distance corridor travel particularly for freight and inter-city passenger services along the main corridors such as the A109 Mombasa–Nairobi highway has not been evaluated. It is on these corridors that vehicle range, charger power, charging duration and the capacity of the underlying distribution grid interact most acutely, and where the readiness of Kenya's charging and grid infrastructure has not previously been measured under real operating conditions.

1.2 Parade Context

To test corridor readiness in practice, a convoy of 6 electric vehicles (the EV Parade) drove the full length of the A109 corridor from Nairobi to Mombasa and back over the study period (21–23 May 2026), charging at the available en-route stops. The convoy tested the charging capacity along the corridor for the passenger cars and light commercial vehicles (LCV), and Heavy Commercial Vehicles (HCV). This was to assess the corridor across every vehicle category likely to use it.

The parade matters because it converts assumptions into evidence. The staged parade across the corridor exposes the constraints that desk studies tend to miss e.g. chargers that are present but under-powered for the vehicles that need them, vehicle charging events that stretch to commercially unviable durations, range penalties driven by the corridor's steep return-leg climb, and the loading state of the specific Kenya Power substations that feed each charging stop. The findings are intended to inform KPLC, EMAK and policy stakeholders on where to prioritize charging deployment and grid reinforcement as the corridor is formalized as an EV-ready route.

1.3 Objectives of This Study

The study's main objectives were:

1. **Assess corridor navigation and range.** Determine whether the current EV fleet can complete the A8/A109 round trip under real conditions and quantify the topography-driven range penalty on the return (climbing) leg by vehicle class.

2. **Characterize charging performance and bottlenecks**. Measure charger power, charging duration and energy delivered at each stop, and identify where charging is operationally unviable — particularly for the heavy-duty truck.

3. **Evaluate grid readiness.** Integrate Kenya Power substation loading data with the parade-derived charging demand to establish which substations can host charging without expansion and which require reinforcement.

4. **Incorporate corridor demand.** Use KeNHA traffic-flows to prioritize the best charging locations by aligning observed vehicle volumes (especially freight) with available grid capacity.

5. **Recommend a phased program.** Translate the evidence into a number, size and configuration of charging stations, and an associated substation-reinforcement sequence, for Phase 1 (2026–2027) and Phase 2 (2028–2030).

1.4 Scope and Limitations

The study covers the A109 corridor between Nairobi and Mombasa, and the charging and grid infrastructure directly associated with it. It is a single, staged convoy run rather than a continuous monitoring campaign. The results represent a snapshot under the specific conditions of the parade window. Several limitations should be borne in mind when interpreting the findings:

- **Single-run, controlled conditions.** Payload, driving speed, ambient temperature and auxiliary loads were not held constant or independently controlled, so measured range and consumption figures are indicative rather than type-test values; a repeat run under control conditions is recommended to produce bankable planning data.

- **Independent logging at two nodes only.** Verified current logging was available at Voi and Nyali; at the other stops the analysis relies on charger-reported and vehicle-reported data, which were cross-checked where possible but not independently logged.

- **Small, mixed sample.** The convoy comprised a limited number of vehicles spanning several classes and connector standards, so per-class results (especially for the single heavy-duty truck) should be treated as illustrative of the vehicle type rather than statistically representative.

2. Methodology

2.1 Methodological Approach

This study used a field-based corridor assessment approach. A convoy of electric vehicles travelled along the A109 Nairobi–Mombasa–Nairobi corridor during the period 21–23 May 2026, charging at available nodes along the route. The objective was to generate practical evidence on vehicle range, energy consumption, charging performance, connector readiness, dwell time and grid readiness under real operating conditions.

The methodology combined direct field measurements, charger-reported data, vehicle readings, grid loading information and corridor traffic-flow data. This enabled the study to assess not only whether the vehicles could complete the journey, but also whether the charging infrastructure and electricity distribution network can support scaled corridor operations.

The study combined direct on-site measurement during the parade with secondary data supplied by network and roads authorities.

- **Independent current logging at Voi and Nyali.** A Fluke 1730 data logger was installed at the Voi and Mombasa (Nyali) charging points to record charging current independently of the charger's own readout, providing a verified, time-stamped trace of each charging session (Figures 6 and 7).
- **Charger specification.** The make, connector standard (CCS2 / GB/T), and rated AC and DC power of each charger used along the corridor were recorded to establish the technical envelope at every stop.
- **Charger data during and after charging.** Charger-reported power, energy delivered and session duration were captured for each charging event, then cross-checked against the independent logger traces at Voi and Nyali.
- **Vehicle logs before and after charging.** State-of-charge (SOC) and, where available, battery energy was recorded for each vehicle immediately before and after every charging event, allowing energy delivered and effective range to be derived per segment and per vehicle.
- **KeNHA corridor traffic-flow data.** The Kenya National Highways Authority (KeNHA) provided average annual daily traffic (AADT) counts at count stations along the corridor, disaggregated by vehicle class. These were matched to each substation's road section to weight charging-site prioritization by observed demand, especially heavy-truck volumes.

- **Charger-acceptance assumptions.** Heavy-duty charger-sizing estimates assume the vehicle can accept higher DC power than was available during the parade; the actual maximum DC acceptance rate and charging curve above 80% SOC remain to be confirmed.
- Grid data is a 2025 baseline. Substation loadings are KPLC 2025 baseline figures and forecast 2026 loads; non-EV load growth is modelled separately, and actual future loading will depend on wider demand evolution along the corridor.
- Traffic data is annually average. KeNHA AADT counts taken in 2024, capture average daily flows and do not resolve seasonal, daily or hourly peaks that would influence instantaneous charging demand at a hub.

2.2 Data Sources

- Five main data streams were used.

Table 1: Summary table of Data Streams

Data source	Description	Purpose in the study
Vehicle data	State of charge, battery capacity and segment movement before and after charging	To estimate effective range and energy consumption by vehicle and route segment
Charger data	Charger rating, connector type, energy delivered, session duration and reported charging power	To assess charging performance and identify infrastructure bottlenecks
Independent current logging	Fluke 1730 logging at Voi and Nyali charging points	To independently verify charging behaviour at selected sites
Kenya Power substation data	2025 baseline loading and transformer capacity for substations serving the corridor	To assess grid headroom and reinforcement needs
KeNHA traffic-flow data	Average annual daily traffic counts by vehicle class along relevant corridor sections	To prioritise charging locations based on demand and freight relevance

2.3 Field Measurement and Charging Event Capture

At each charging stop, the study team recorded vehicle state of charge before and after charging, charger type, connector standard, charger rating, charging duration and energy delivered. Where available, charger-reported data was cross-checked against vehicle readings.

Independent current logging was undertaken at Voi and Nyali using a Fluke 1730 logger. This provided a time-stamped current profile for selected charging sessions and helped verify the behaviour of the charging points during active charging. The logger traces showed the sequence of charging sessions, current levels, interruptions and idle periods at the monitored sites.

However, independent logging was not available at every charging location. For charging events at other stops, the analysis relies on charger-reported and vehicle-reported data. These records are useful for operational assessment but should be validated before being used for final investment-grade modelling.

2.4 Grid Capacity Assessment

Kenya Power substation data was used to assess the ability of the electricity distribution network to support corridor charging. The study reviewed transformer capacity, 2025 baseline loading, percentage loading and available headroom at substations associated with key charging locations.

The grid assessment applied an 80% planning threshold to determine available operational headroom. For substations with multiple transformers, the analysis considered N-1 firm capacity where applicable. For single-transformer substations, the reported margin should be interpreted as operational loading headroom rather than true N-1 firm capacity, since the outage of the single transformer would result in loss of supply.

This distinction is important. A site may appear to have thermal headroom but still lack redundancy. Therefore, charging infrastructure at single-transformer sites should be treated more conservatively, especially for critical corridor nodes.

2.5 Corridor Traffic and Site Prioritization

KeNHA average annual daily traffic data was used to assess corridor demand at relevant road sections. Traffic counts were matched to substations and nearby charging locations to identify where charging infrastructure would have the strongest demand case.

Attention was given to heavy trucks, buses and matatus because these vehicle classes are more likely to require high-energy charging and have less flexibility around charging dwell time. The traffic analysis was used together with grid headroom and field charging evidence to prioritize sites for Phase 1 and Phase 2 deployment.

2.6 Key Assumptions

The following assumptions were used in the analysis and should be clearly retained in the final report:

Table 2: Key Assumption Summary Data

Area	Assumption
Charger utilization	Not all chargers are assumed to operate at full power simultaneously
Power factor	Modern DC fast chargers are assumed to operate at approximately 0.95 power factor
Diversity factor	Diversity factors vary by site size, with lower diversity applied to larger charging hubs
Grid planning threshold	Transformer loading is assessed against an 80% planning ceiling
Heavy-duty charger sizing	Constant-rate charging is used for indicative sizing, subject to validation of the vehicle charging curve
Traffic demand	KeNHA AADT data is used as an average demand indicator and does not represent hourly peak charging demand
Vehicle range	Effective range is derived from observed SOC change and should not be treated as type-test performance
Future load growth	Non-EV load growth is considered separately and should be validated through feeder-level planning studies

2.7 Limitations

The study provides practical evidence of corridor readiness but should be interpreted within the following limitations:

- **Single staged convoy:** The study was based on one organized convoy run during the period 21–23 May 2026. Results therefore represent the conditions observed during that period and should not be treated as statistically representative of all weather, traffic, payload and driving conditions.

- **Limited vehicle sample:** The convoy included a small number of vehicles across different categories. Passenger vehicles, light commercial vehicles and one heavy commercial vehicle were assessed. The heavy-duty findings are therefore especially important but should be validated through additional tests involving more trucks, different payloads and repeat runs.

- **Incomplete independent metering:** Independent current logging was undertaken at Voi and Nyali only. Charging events at other locations relied primarily on charger-reported and vehicle-reported data. These records are useful but should be verified before major investment decisions are made.

- **Payload, speed and driving conditions not fully controlled:** Payload, driving style, speed, ambient temperature, wind, tyre condition, auxiliary loads and traffic conditions were not fully standardized. These variables can materially affect energy consumption and effective range, particularly for loaded commercial vehicles and heavy-duty trucks.

- **Heavy-duty charging curve not fully validated:** The heavy-duty charging analysis assumes that the X7E truck can accept higher DC charging power than was available during the study. The vehicle's actual maximum charging acceptance rate, charging curve, tapering behaviour and performance above 80% SOC require further testing.

- **Grid data requires planning validation:** Substation loading figures provide a useful baseline for assessing corridor charging readiness. However, final investment decisions should be based on updated substation and feeder-level studies, including protection, voltage profile, power quality, transformer loading, feeder capacity, land availability and connection requirements.

- **Traffic data is average, not peak demand:** KeNHA traffic-flow data provides average annual daily traffic. It does not capture hourly peaks, seasonal freight movements, port-related surges, incident-driven congestion or actual charging demand profiles. Site-level business cases should therefore include more granular traffic and dwell-time analysis.

3. Corridor Infrastructure Overview

3.1 Corridor Profile

The A109 route covers approximately 484 km one way and 968 km round trip. The corridor is highly asymmetric: Nairobi to Mombasa is predominantly downhill, while the return leg climbs from sea level at the coast to approximately 1,669 meter in Nairobi. This elevation profile is the primary reason the return leg is the more infrastructure-sensitive direction.

For corridor planning, the return leg should therefore be treated as the critical design case. A charging network that is sufficient for the downhill Nairobi-to-Mombasa journey may still be inadequate for the uphill Mombasa-to-Nairobi journey, particularly for loaded light commercial vehicles and heavy-duty trucks.

3.2 Parade Charging Stops

During the study, charging was undertaken at the available nodes along the route. These stops represented the practical charging infrastructure accessible to the convoy during the study period.

Table 3: Outbound charging stops — Nairobi to Mombasa

Stop	Distance from previous (km)	Cumulative (km)	Elevation (m)	Est. charging demand (kWh)	Corridor role
Nairobi (Stima Plaza)	0	0	1,684	0	Origin and urban charging base
Emali	125	125	1,015	400	Intermediate redundancy node
Mtito Andei	108	233	731	400	Mid-corridor support node
Voi	96	329	580	700	Strategic anchor and overnight node
Mombasa (KPLC Nyali)	155	484	15	700	Coastal destination anchor

Table 4: Return charging stops — Mombasa to Nairobi

Stop	Distance from previous (km)	Cumulative (km)	Elevation (m)	Est. charging demand (kWh)	Corridor role
Mombasa (KPLC Nyali)	0	0	15	0	Coastal origin anchor
Voi	155	155	580	800	Strategic return-leg anchor
Mtito Andei	96	251	731	500	Mid-corridor support node
Sultan Hamud	122	373	1,226	700	Critical return-leg buffer
Nairobi (Stima Plaza)	111	484	1,684	0	Final destination and urban charging base

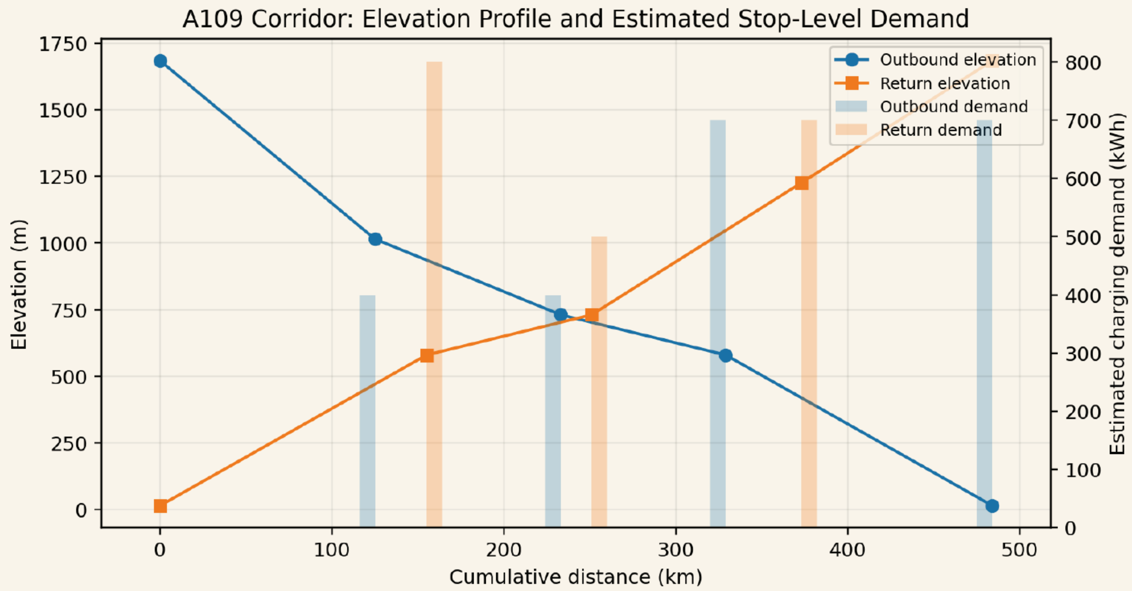


Figure 1: Elevation and estimated charging demand by route direction

3.3 Operational Meaning of the Corridor Topography

The return route has important infrastructure implications because vehicles travelling from the Coast toward Nairobi climb from sea level to the highlands and therefore consume more energy. This effect is significant for light commercial vehicles and heavy commercial vehicles, especially when they are loaded. For this reason, the return leg requires stronger charging redundancy to reduce range risk and improve operational reliability. Sultan Hamud is appropriately positioned as the final return charging point because it is closer to Nairobi than Emali and provides vehicles with a safer energy buffer for the remaining 111 km to Nairobi. Based on the operational risks observed along the route, Voi and Sultan Hamud should be prioritized for high-power DC charging infrastructure, as they represent the most critical charging locations for maintaining reliable corridor operations.

3.4 Strategic Role of Key Nodes

The study indicates that the corridor charging network should be planned around differentiated node roles rather than treating every stop equally.

Table 5: Role of Key Nodes

Node	Recommended role	Rationale
Nairobi/Stima Plaza	Urban origin/destination and fleet preparation node	Starting and finishing point for the tested route
Emali	Intermediate redundancy node	Provides support between Nairobi and Mtito Andei/Sultan Hamud
Sultan Hamud	Critical return-leg charging buffer	Important for vehicles climbing towards Nairobi
Mtito Andei	Mid-corridor support and risk-management node	Strategically placed, but grid-constrained

Voi	Main mid-corridor anchor hub	Serves both directions and supports overnight/longer dwell charging
Mombasa/ Nyali	Coastal anchor hub	Destination and origin point for return movement
Mariakani	Future freight/logistics charging node	Strong demand case near Mombasa logistics flows
Athi River	Future high-demand peri-urban charging hub	Highest traffic-demand case but grid-constrained

This classification is important because investment should not be spread evenly across the corridor. The first priority should be to create a reliable backbone at the nodes that provide the greatest operational value, traffic demand and grid feasibility.

3.5 Planning Implication

The corridor should be planned as a phased electric mobility infrastructure system, not as a collection of isolated charging points. The minimum viable network should ensure that vehicles can move safely in both directions, with sufficient redundancy for the more demanding Mombasa-to-Nairobi return leg.

The evidence from the parade suggests the following planning priorities:

1. **Voi should be treated as the main mid-corridor anchor hub.**
   It serves both directions and can support long-dwell, overnight and commercial charging.

2. **Sultan Hamud should be prioritized as a return-leg risk buffer.**
   It is strategically located before the final climb and approach into Nairobi.

3. **Mtito Andei should remain part of the corridor network but requires grid attention**.
   Its location is important, but its transformer capacity limits scale-up.

4. **Nyali/Mombasa should be strengthened as the coastal anchor.**
   It supports vehicles beginning the more demanding return journey.

5. **Mariakani and Athi River should be incorporated into future planning.**
   They are not merely optional additions; they are demand-driven nodes with strong logistics relevance.

4. Vehicle Battery and Connector Readiness

4.1 Vehicle Battery and Connector Profile

The convoy included passenger vehicles, light commercial vehicles and one heavy commercial vehicle. The vehicles had different battery capacities, connector standards and charging acceptance characteristics. This diversity is important because corridor charging infrastructure must be designed for the vehicles that will actually use the route, not only for a single standard or vehicle class.

Table 6: Vehicle battery specifications and connector types

Make / Model	Category	Battery (kWh)	Connector	Max AC	Max DC
MG ZS EV	Passenger	49	CCS2	11 kW	94 kW
JAC T8 EV	LCV	65	CCS2	10 kW	32.5 kW
Mahindra XUV400	LCV	40	CCS2	7.2 kW	50 kW
Ridara RD6 / Kabisa	LCV	63	GB/T	7 kW	20 kW
Hyundai Kona	Passenger	64	CCS2	7.2 kW	75 kW
X7E Truck	HCV	400	GB/T DC	-	≥40 kW

The tested fleet demonstrates that the corridor cannot be planned around battery capacity alone. A larger battery improves theoretical range, but if the vehicle can only access low-power charging or if compatible connectors are unavailable, the vehicle may still be operationally constrained.

4.2 Battery Capacity and Operational Implications

Battery size has different implications depending on vehicle class. Passenger EVs with battery capacities of about 49–64 kWh can complete the corridor with planned stops, provided that charging points are available at reasonable intervals. Their charging needs can be met by a combination of DC fast charging and slower destination charging, depending on dwell time. Light commercial vehicles require more conservative planning. Although their battery capacities are broadly similar to passenger EVs, their energy consumption may be higher due to payload, vehicle mass, route gradients and operating duty cycle. They therefore require larger state-of-charge buffers, particularly on the return leg from Mombasa to Nairobi.

Heavy-duty electric freight requires a different infrastructure standard altogether. The X7E truck's 400 kWh battery places it in a freight-grade charging category. Low-power DC charging can technically deliver energy to the vehicle, but it results in long dwell times that are not commercially acceptable for freight operations. For heavy-duty corridor use, charging power, charging curve and turnaround time become as important as total battery capacity.

4.3 Connector Readiness and Interoperability

Connector diversity is a material deployment issue for the A109 corridor. The tested vehicles used both CCS2 and GB/T charging standards. CCS2 can serve most of the tested passenger and light commercial vehicles, while GB/T support was required for the Ridara/Kabisa vehicle and the X7E truck.

This means that a corridor charging network designed only around CCS2 would exclude part of the current operating fleet. Equally, a network with isolated GB/T charging points of low power would not be sufficient for heavy-duty freight. Strategic charging hubs should therefore be designed with dual-standard DC charging capability, or with adapter solutions that are technically validated, safe, reliable and compliant with applicable standards.

Sites along high priority corridors should support:

Table 7: Site and Connector Type

Site type	Recommended connector capability
Major anchor hubs	CCS2 and GB/T DC charging
Heavy-duty priority sites	High-power GB/T or dual-standard DC charging
Intermediate support nodes	At least one dual-standard DC charger where feasible
Destination/overnight sites	DC charging supported by AC charging for long dwell-time users

4.4 Charger Rating versus Vehicle Acceptance

The report should distinguish clearly between charger rating and vehicle charging acceptance. A charger may be rated at 100 kW, 120 kW or 150 kW, but the vehicle will only draw power up to the limit allowed by its battery management system, state of charge, temperature and charging curve. This is particularly important for the X7E truck. The current analysis assumes that the truck can accept higher DC charging power than was available during the study. That assumption must be validated before final charger sizing is adopted. The next test should confirm:

Table 8: Charger Validation

Validation item	Why it matters
Maximum DC acceptance rate	Determines whether 100–150 kW charging is technically useful
Charging curve from low SOC to high SOC	Determines actual dwell time, not just theoretical charging time
Tapering behaviour above 80% SOC	Important for freight scheduling and top-up strategy
GB/T compatibility at higher power	Confirms interoperability with proposed charging equipment
Thermal performance under repeat fast charging	Important for reliability and battery protection

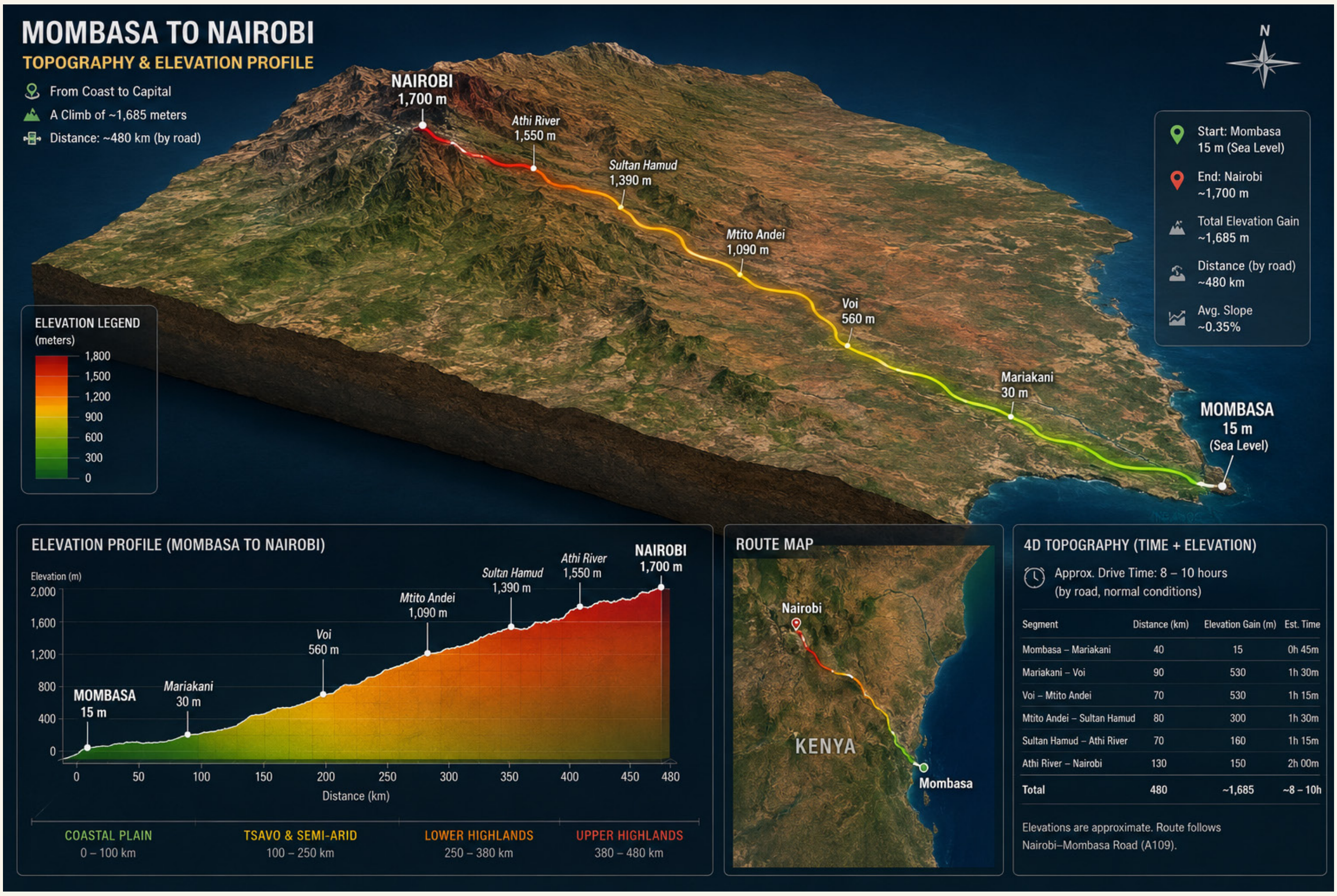
4.5 Role of AC and DC Charging

The corridor should not rely heavily on AC charging for en-route operations. AC charging is useful for overnight parking, depot charging, hotel or destination charging, and vehicles with long dwell times. However, it is not suitable as the main en-route charging solution for commercial corridor operations. DC fast charging should be the backbone of the A109 corridor charging network because it reduces dwell time and improves vehicle throughput. This is especially important for commercial vehicles, intercity fleets and heavy-duty freight. The AC charging should be installed as supplementary infrastructure, not the primary corridor solution.

Table 9: Charger Specification

Charging type	Appropriate role
AC charging	Overnight, destination, depot, backup and long dwell-time use
20–40 kW DC	Early-stage or emergency support; not sufficient for scaled freight
60 kW DC	Minimum practical corridor fast-charging level for intermediate nodes
100–150 kW DC	Light-duty priority nodes and anchor hubs
>240 Kw DC	Recommended for all Nodes across the corridor Road side stations
Future high-power DC	Required as truck battery sizes and fleet volumes increase

5. Effective Range and Topography Sensitivity



5.1 Purpose of the Range Analysis

The purpose of the range analysis is to determine how the tested electric vehicles performed under actual corridor conditions, rather than relying on manufacturer-rated range. For corridor infrastructure planning, observed effective range is more useful than stated vehicle range because it captures the combined effect of road gradient, payload, driving conditions, auxiliary loads, traffic, charger availability and driver behaviour.

In this study, effective range was estimated from observed state-of-charge movement across route segments. The values should therefore be interpreted as operational indicators under the specific conditions of the parade, not as certified type-test performance.

Effective range *refers to the estimated distance a vehicle could travel based on observed state-of-charge consumption during the study. It is derived from actual route operation and is therefore useful for corridor planning, but it should be validated through repeat tests under controlled conditions.*

5.2 Effective Range by Direction

The A109 corridor is directionally asymmetric. The outbound route from Nairobi to Mombasa is generally downhill, while the return route from Mombasa to Nairobi involves a substantial climb from the Coast to the Nairobi highlands. This makes the return journey the more demanding infrastructure design case.

Table 10: Effective range by direction

Vehicle	Category	Outbound range (km)	Return range (km)	Return change (%)
MG ZS EV	Passenger	263	301	+14.4
JAC T8	LCV	281	237	-15.7
Mahindra XUV400	LCV	321	246	-23.4
Ridara RD6 /Kabisa	LCV	336	280	-16.7
Hyundai Kona	Passenger	494	682	+38.1
X7E Truck	HCV	745	306	-58.9

The results show that light commercial vehicles generally experienced a material reduction in effective range on the return leg. The JAC, XUV400 and Kabisa recorded return-leg range reductions of approximately 16% to 23%. This is significant for corridor planning because these vehicles have less operational flexibility than passenger vehicles and may carry payloads that further reduce range.

The X7E truck recorded the most severe directional range effect, with effective range reducing from 745 km outbound to 306 km on the return leg. This confirms that heavy-duty electric freight should not be planned using passenger-vehicle or light-commercial assumptions. It requires a separate infrastructure standard based on higher energy consumption, larger batteries, payload sensitivity and longer charging events.

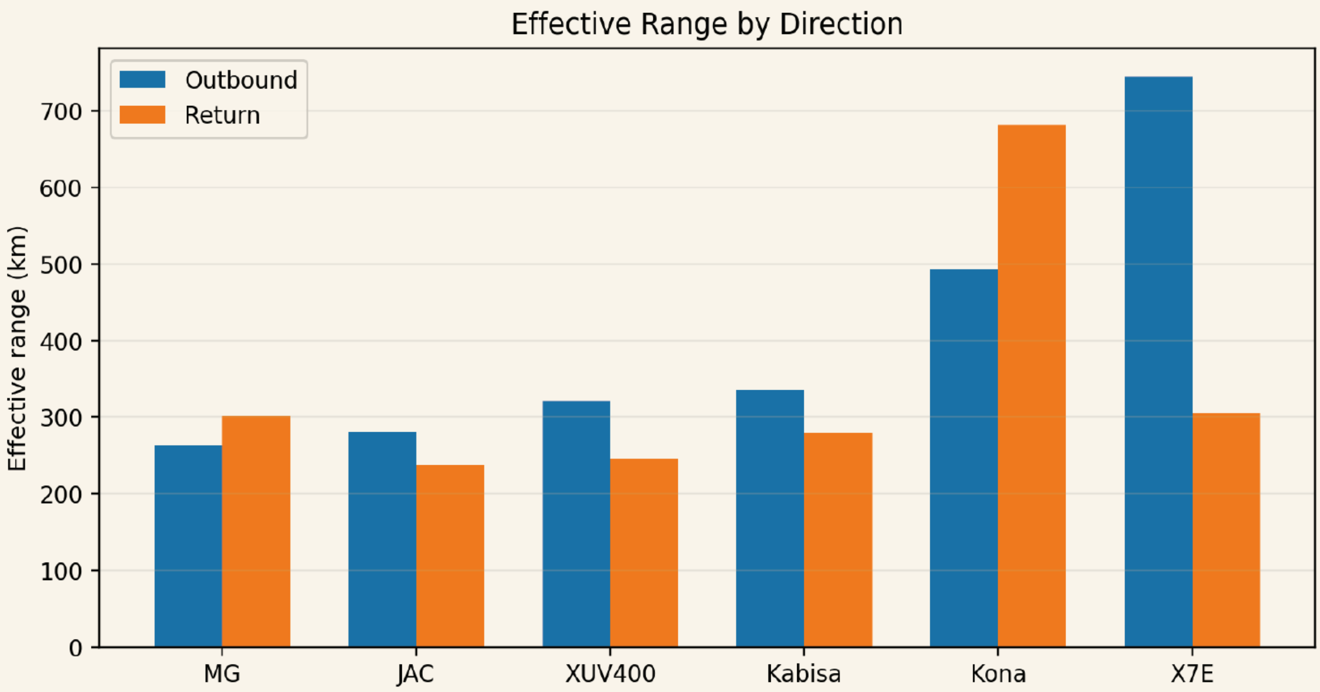


Figure 2: Effective range by vehicle and direction

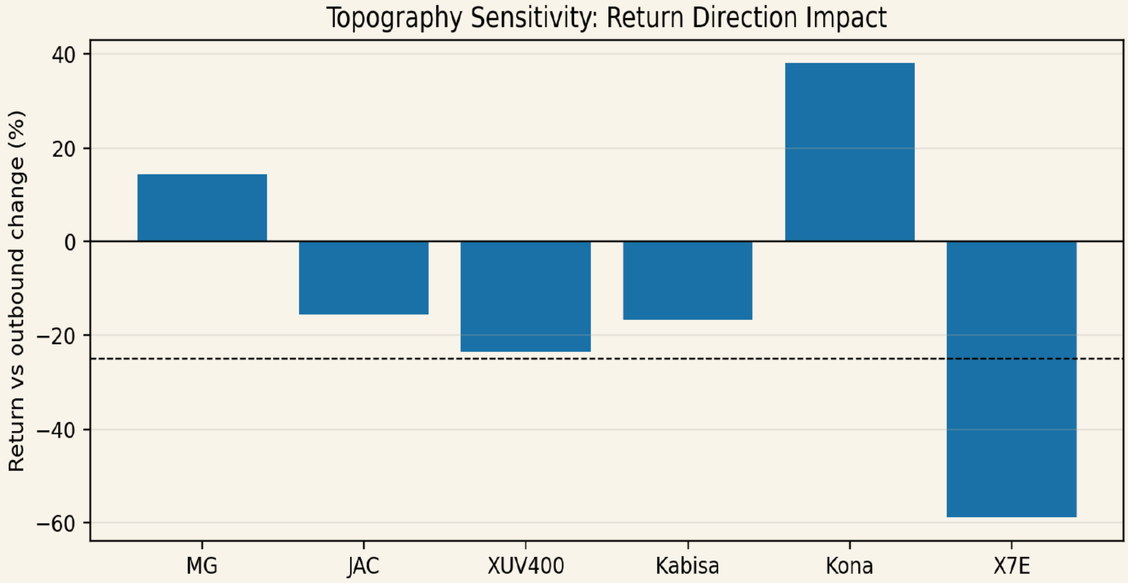


Figure 3: Return-leg range change relative to outbound

6. Segment Energy Consumption

6.1 Purpose of Segment Consumption Analysis

Segment energy consumption analysis is used to identify the most energy-intensive sections of the A109 corridor. This is important because charging infrastructure should not be placed only according to distance. It should also reflect terrain, vehicle class, payload, charging risk and the energy required to safely complete the next segment.

In this study, energy consumption is expressed as the percentage of battery capacity consumed per 100 km. Lower values indicate lower relative consumption. However, because vehicles have different battery sizes, percentage-based consumption should be interpreted carefully. A heavy-duty vehicle with a large battery may show lower percentage consumption than a smaller vehicle while still consuming substantially more energy in absolute kWh terms.

Where possible, future analysis should also report consumption in kWh/100 km, especially for commercial and heavy-duty vehicles, because this is the more useful metric for charger sizing, electricity demand forecasting and commercial modelling.

6.2 Outbound Energy Consumption: Nairobi to Mombasa

The outbound journey from Nairobi to Mombasa is generally downhill and therefore less demanding than the return journey. The observed outbound consumption shows that most vehicles were able to manage the route with planned charging stops. However, consumption still varied across segments and vehicle types.

Table 11: Outbound energy consumption by segment (% of battery / 100 km)

Vehicle	Nairobi–Emali	Emali–Mtito	Mtito–Voi	Voi–Mombasa	Eff. range (km)
MG	36.0	36.1	37.5	41.3	263
JAC	32.0	30.6	36.5	41.3	281
XUV400	24.8	23.1	37.5	38.1	321
Kabisa	18.4	27.8	38.5	34.8	336
Kona	17.6	13.9	17.7	28.4	494
X7E	14.4	11.5	14.2	13.5	745

The outbound results confirm that the Nairobi-to-Mombasa direction is not the limiting design case for corridor charging. The route is operationally manageable for the tested passenger and light commercial vehicles, provided charging is available at planned nodes. However, the Voi–Mombasa segment still shows elevated consumption for several vehicles and should not be treated as risk-free, especially for commercial vehicles operating with payload.

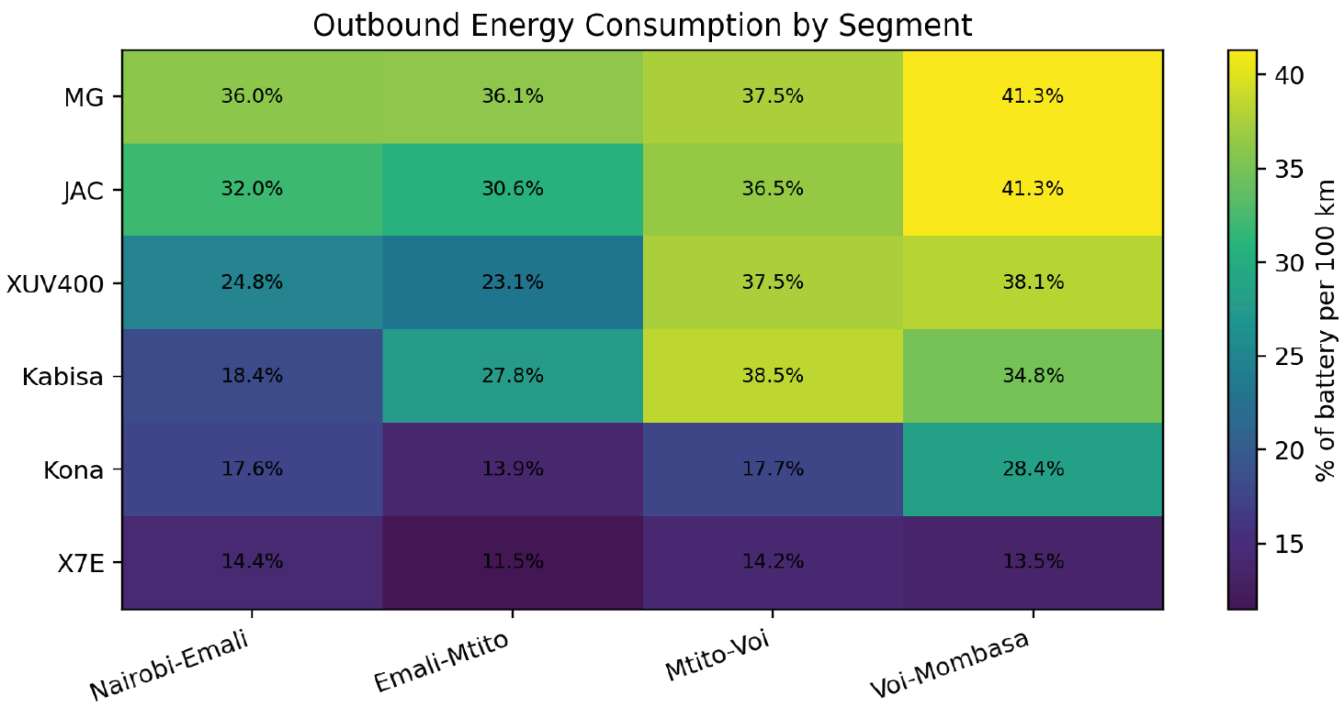


Figure 4: Outbound energy-consumption intensity by segment

6.3 Return Energy Consumption: Mombasa to Nairobi

The return journey from Mombasa to Nairobi is more demanding because vehicles climb from the Coast towards the Nairobi highlands. This is where the strongest infrastructure pressure appears, particularly for light commercial vehicles and the heavy-duty truck.

Table 12: Return energy consumption by segment (% of battery / 100 km)

Vehicle	Mombasa–Voi	Voi–Sultan/Nairobi	Sultan–Nairobi	Eff. range (km)
MG	30.2	32.6	35.1	301
JAC	49.7	33.0	49.5	237
XUV400	47.7	33.9	44.1	246
Kabisa	39.4	34.4	33.3	280
Kona	25.2	9.7	—	682
X7E	29.0	33.9	35.1	306

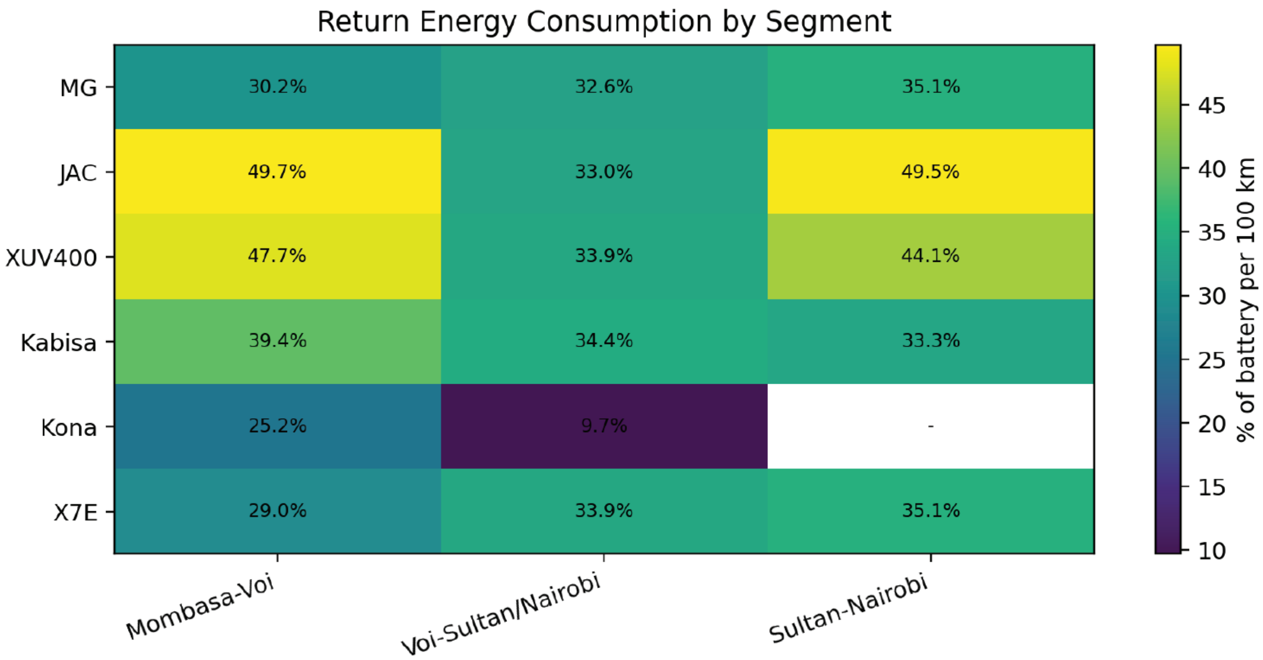


Figure 5: Return energy-consumption intensity by segment

The Mombasa–Voi segment is the most demanding return segment for light commercial vehicles. The JAC and XUV400 consumed approximately half of their battery capacity per 100 km on this section, indicating that the coastal-to-inland climb is a critical planning segment. Vehicles leaving Mombasa should therefore have a sufficiently high state of charge to reach Voi safely, with an operational reserve.

The Voi–Mtito/Sultan Hamud section is also energy intensive but more consistent, with several vehicles clustering around the low-to-mid 30% battery consumption range per 100 km. This suggests that the section is predictable but still requires reliable charging redundancy.

The final approach from Sultan Hamud to Nairobi remains important because vehicles are still climbing towards the Nairobi highlands. For smaller-battery vehicles and loaded commercial vehicles, this final leg should not be planned with minimal SOC margin.

6.4 Battery Percentage Consumption Interpretation

The current tables use percentage of battery capacity consumed per 100 km. This is useful for estimating whether each vehicle can complete a segment, but it is not enough for infrastructure sizing.

For example, a vehicle with a 40 kWh battery consuming 50% per 100 km uses about 20 kWh/100 km. A truck with a 400 kWh battery consuming 30% per 100 km uses about 120 kWh/100 km. The truck may therefore look better in percentage terms while placing a much larger energy demand on the charger and the grid.

This distinction matters because:

Table 13: Battery SOC Percentage Planning

Planning question	Better metric
Can the vehicle reach the next stop?	% battery consumed and SOC margin
How much charger energy is required?	kWh delivered
What charger power is needed?	kW and charging curve
What grid capacity is required?	kVA coincident demand
What is the commercial cost per trip?	kWh/km and tariff
What is the station utilization requirement?	kWh/day and sessions/day

The report should therefore retain the percentage-based tables but add kWh/100 km calculations in an annex or revised table where reliable data is available.

6.5 Findings from the Data Logging Exercise

The data logger at Voi (Figure 6) captured a single vehicle, the X7E heavy-duty truck, charging at a sustained current of approximately 57–58A through the afternoon, with several short interruptions (brief drops toward 28 A and momentary disconnections to zero) before the session stepped down to about 12 A and ended near 16:00. The repeated dips illustrate the reliability and continuity challenges of relying on a single en-route charger for a long heavy-duty session.

The data logger at Nyali (Figure 7) captures three charging sessions: the JAC, X7E and Kona in sequence.

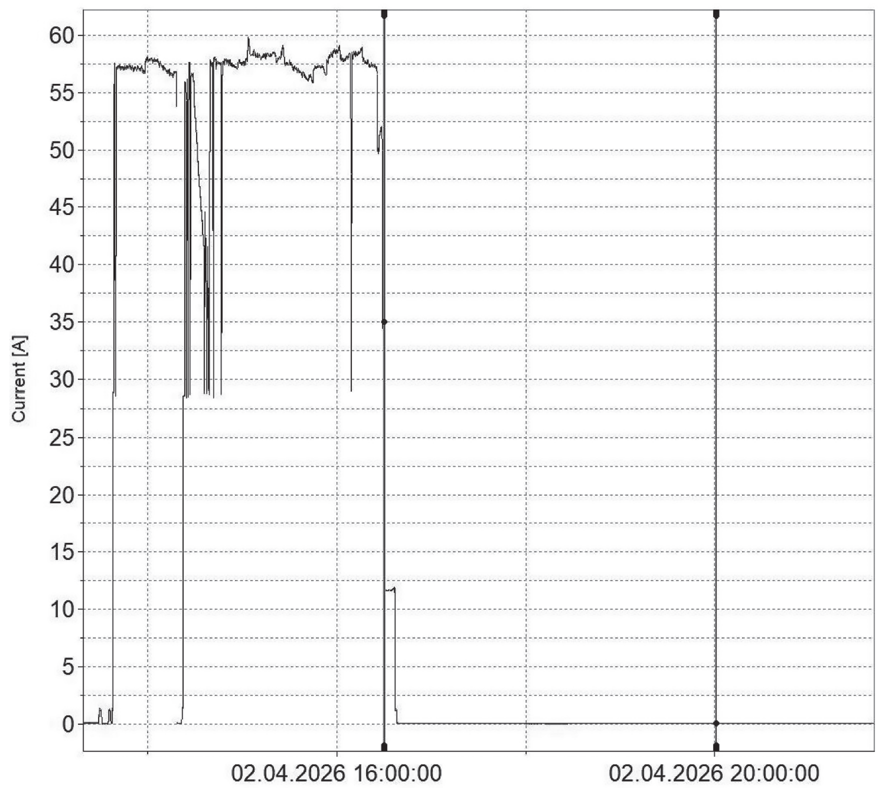


Figure 6: Voi charging-point current log (X7E heavy-duty truck). Sustained ≈57–58 A charging with intermittent interruptions, tapering to ≈12 A before completion.

During each active session the per-phase current sits at roughly 58–61 A, with the three phases tracking each other closely (balanced loading), separated by extended idle periods at zero current as one vehicle finished and the next connected.

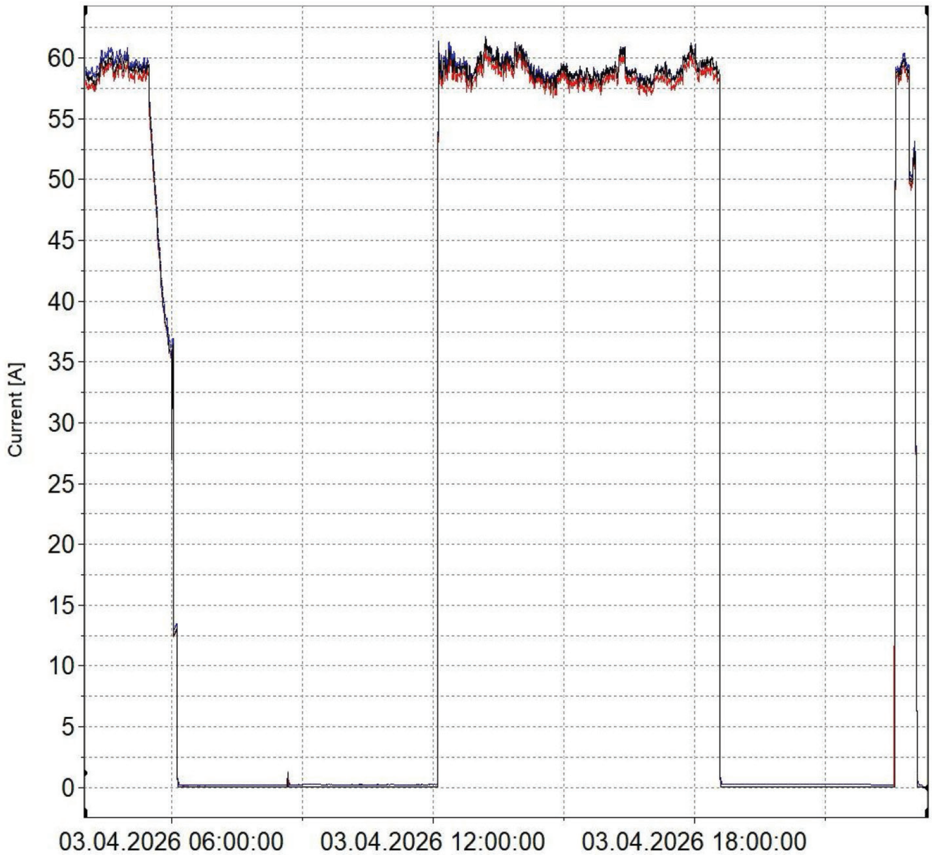


Figure 7: Nyali (Mombasa) charging-point current log. The sessions in time order are JAC (first), X7E (second) and Kona (last), each at ≈58–61 A per phase, separated by idle periods.

6.6 Planning Implications

The segment consumption results lead to four practical planning implications.

(i) **Use the return leg as the conservative planning case:** The Mombasa-to-Nairobi direction should be used as the primary design case because it combines elevation gain, higher energy consumption and greater range risk.

(ii) **Treat Mombasa–Voi as a critical energy segment:** Vehicles departing Mombasa should not leave with marginal charge. Voi must be strengthened as a reliable return-leg anchor because it is the first major inland charging point after the coastal climb.

(iii) **Strengthen Sultan Hamud as a return-leg buffer:** Sultan Hamud is strategically important for vehicles approaching Nairobi. It reduces the risk of vehicles attempting the final climb with insufficient SOC and should therefore have reliable DC fast charging.

(iv) **Do not size commercial charging using passenger EV assumptions:** LCVs and HCVs consume more energy under practical operating conditions and require larger SOC buffers, higher charger power and stronger redundancy. Heavy-duty freight should be analyzed using absolute energy demand in kWh, not only percentage battery consumption.

6.7 Recommended SOC Planning Buffers

For corridor operations, vehicles should not be planned to arrive at charging nodes with minimal SOC. Commercial vehicles should maintain a reserve that accounts for elevation, payload, charger downtime, traffic delays and diversion risk. The exact reserve should be determined through repeat testing and operator-specific duty-cycle analysis.

Table 14: Recommended SOC Planning Buffers

Vehicle category	Recommended planning approach
Passenger EVs	Maintain sufficient SOC reserve to reach the next charger plus contingency for charger unavailability
Light commercial vehicles	Use conservative return-leg assumptions and avoid departing Mombasa or Voi with marginal SOC
Heavy commercial vehicles	Plan charging around kWh required, payload, dwell time and charger power, not only percentage SOC
All commercial vehicles	Include contingency for weather, congestion, payload, charger downtime and diversion

7. Charging Time and Infrastructure Bottleneck Analysis

7.1 Purpose of Charging Time Analysis

Charging time is the most important operational readiness metric for corridor electric mobility. Vehicle range determines whether a vehicle can reach the next charging point, but charging time determines whether the journey is commercially viable.

For passenger vehicles, longer charging stops may be acceptable where users combine charging with meals, rest stops or overnight parking. For light commercial vehicles and heavy-duty freight, long dwell times directly affect vehicle productivity, delivery schedules, driver operations and fleet economics. A charging event that lasts several hours may prove that a vehicle can complete the corridor, but it does not prove that the corridor is ready for commercial operations.

7.2 Outbound Charging Performance

The outbound charging stops from Nairobi to Mombasa showed that passenger and light commercial vehicles could continue along the corridor with planned charging. However, several charging events were long, especially where AC charging or low-power DC charging was used.

Table 15: Outbound charging time by stop and vehicle

Stop	Vehicle	Battery (kWh)	SOC In (%)	SOC Out (%)	kWh	Charger	Power (kW)	Time (min)
Emali	MG	49	60	98	19.53	Tellus 20 kW DC	20	71
Emali	JAC	65	61	67	3.16	Tellus 20 kW DC	20	27
Emali	Kabisa	63	67	96	15.21	Kabisa 7 kW GB/T DC	7	59
Mtito Andei	JAC	65	37	61	15.6	Circontrol ~10 kW AC	10	94
Mtito Andei	XUV400	40	44	81	14.8	Tellus 7 kW AC	7	127
Mtito Andei	Kona	64	63	82	12.2	Tellus 7 kW AC	7	104
Voi	MG	49	23	89	32.3	Beny AC 11 kW Type-2	11	176
Voi	JAC	65	26	100	48.1	Circontrol ~10 kW AC	10	289
Voi	XUV400	40	45	100	22.0	Beny 7 kW AC	7	189
Voi	Kabisa	63	7	100	58.6	Kabisa 20 kW GB/T DC	20	176

The outbound results show that the current infrastructure can support a controlled convoy, but it is not yet configured for high-throughput commercial operations. The heavy reliance on AC and low-power DC charging creates long dwell times and increases the risk of congestion as vehicle volumes grow.

7.3 Return Charging Performance

The return leg from Mombasa to Nairobi is more demanding because it combines higher energy consumption with the need to climb towards Nairobi. This places greater pressure on charging time, charger power and site reliability.

Table 16: Return charging time by stop and vehicle

Stop	Vehicle	Battery (kWh)	SOC In (%)	SOC Out (%)	kWh	Charger	Power (kW)	Time (min)
Voi	MG	49	35	96	29.9	Beny AC 11 kW Type-2	11	163
Voi	JAC	65	23	90	43.6	Circontrol ~10 kW AC	10	262
Voi	XUV400	40	12	98	34.4	Beny 7 kW AC	7	295
Voi	Kabisa	63	32	91	37.2	Kabisa 20 kW GB/T DC	20	112
Voi	X7E	400	36	83	188.0	Grasen 40 kW GB/T DC	40	282
Mtito Andei	MG	49	65	100	17.2	Circontrol ~11 kW AC	11	94
Mtito Andei	XUV400	40	59	91	12.8	Tellus 7 kW AC	7	110
Sultan Hamud	MG	49	60	80	9.8	Tellus 20 kW DC	20	29
Sultan Hamud	JAC	65	18	82	41.6	Tellus 20 kW DC	20	125
Sultan Hamud	XUV400	40	56	91	14.0	7 kW AC	7	120
Sultan Hamud	Kabisa	63	16	100	52.9	Kabisa 20 kW GB/T DC	20	159
Sultan Hamud	X7E	400	9	69	240.0	40 kW GB/T DC	40	360

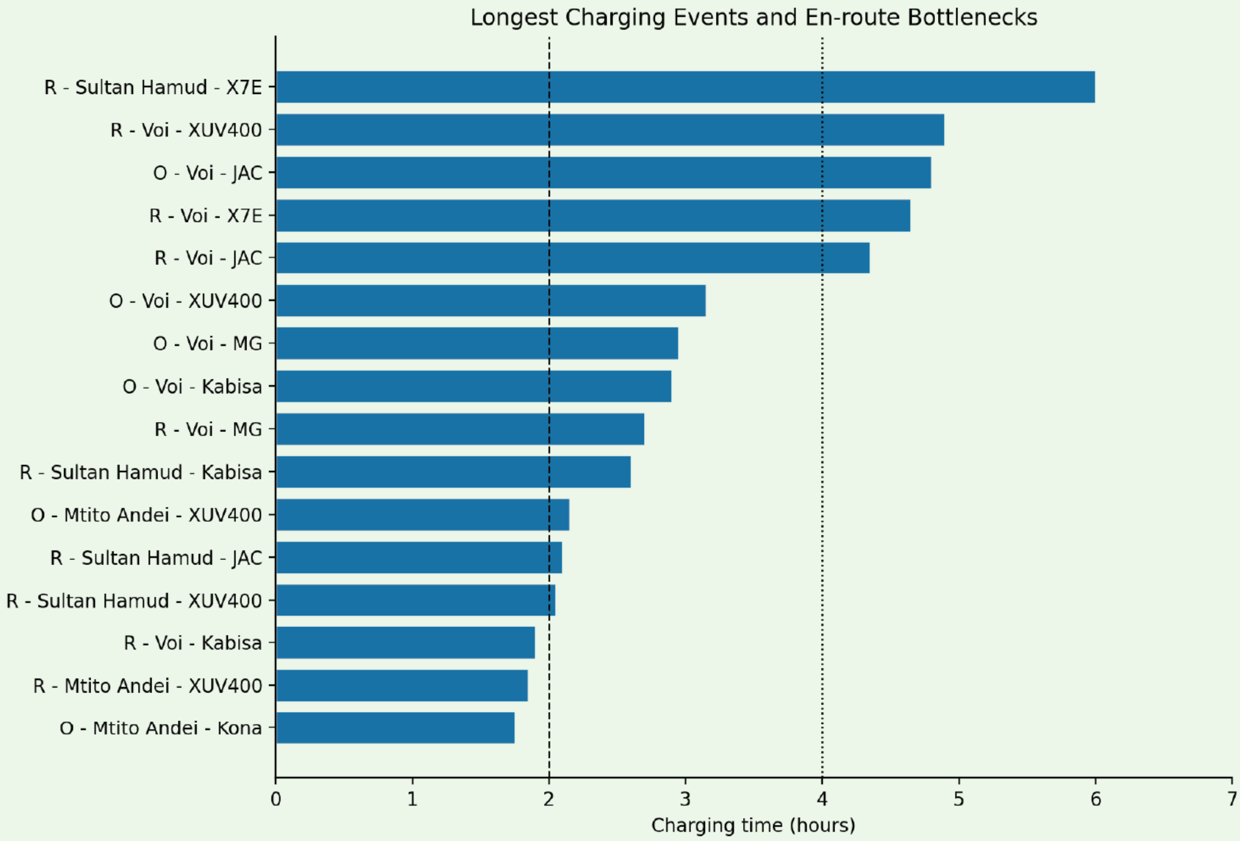


Figure 8: Longest charging events across the corridor

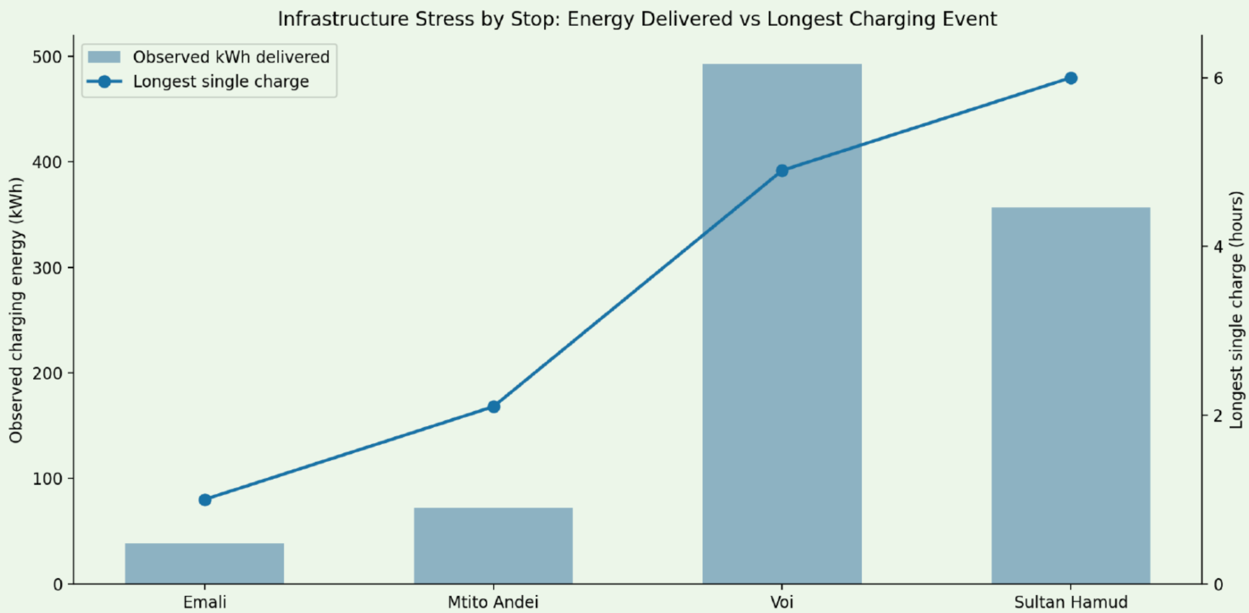


Figure 9: Stop-level infrastructure stress — observed kWh delivered vs longest single charging event

Sultan Hamud represents the single highest-risk charging node on the route because the X7E truck required a six-hour top-up when using a 40 kW charger. This charging duration is not compatible with freight operations, driver schedules, or the requirements of reliable commercial corridor service. Voi also recorded several long charging events exceeding four hours; however, these are less operationally disruptive where they can be managed as overnight charging sessions. Even so, Voi should still be upgraded to reduce charging congestion, improve turnaround times, and support a higher number of vehicles per day. Overall, the current AC-heavy charging configuration may be adequate for controlled parade or demonstration conditions, but it is insufficient for scaled commercial corridor operations. En-route public charging infrastructure should therefore prioritize DC fast charging to support reliable, high-throughput vehicle movement along the corridor.

8. Heavy-Duty Charging: X7E Truck Sizing Requirement

8.1 Purpose of Heavy-Duty Charging Analysis

Heavy-duty electric freight has different infrastructure requirements from passenger electric vehicles and light commercial vehicles. The X7E truck tested during the parade has a battery capacity of approximately **400 kWh**, placing it in a freight-grade charging category. For this vehicle class, the key planning question is not simply whether the truck can receive enough energy to complete the route. The more important question is whether it can receive that energy within a dwell time that supports commercial freight operations.

For heavy-duty transport, charging time affects vehicle utilization, driver scheduling, delivery reliability, fleet size requirements and total cost of ownership. A charging event lasting several hours may be acceptable for a demonstration or overnight parking, but it is not acceptable as a routine en-route freight operation unless it is deliberately built into the logistics schedule.

8.2 Observed X7E Charging Events

The X7E truck required substantial charging at Mombasa/Nyali, Voi and Sultan Hamud. These events demonstrate both the technical possibility of heavy-duty electric movement along the corridor and the inadequacy of current low-power charging for commercial freight scale-up.

Table 17: X7E truck charging events

Stop	Stop type	SOC In (%)	SOC Out (%)	kWh to charge	Current charger
Mombasa (Nyali)	Overnight	31	81	200	Grasen 40 kW GB/T DC
Voi (return)	Overnight	36	83	188	Grasen 40 kW GB/T DC
Sultan Hamud (return)	**En-route daytime**	**9**	**69**	**240**	**40 kW GB/T DC — CRITICAL**

The Sultan Hamud event is the most important heavy-duty finding in the report because it represents an en-route charging requirement on the more demanding return leg towards Nairobi. Unlike overnight charging at Mombasa or Voi, a six-hour en-route stop is commercially problematic for freight operations.

8.3 Charger Power and Indicative Dwell Time

The indicative time required to deliver the observed X7E charging energy reduces sharply as charger power increases.

Table 18: X7E charger sizing reference (hours to deliver event kWh, constant rate)

Charger Power (kW)	Mombasa 200 kWh (h)	Voi 188 kWh (h)	Sultan 240 kWh (h)
20	10.0	9.4	12.0
40	5.0	4.7	6.0
60	3.3	3.1	4.0
80	2.5	2.4	3.0
100	2.0	1.9	2.4
120	1.7	1.6	2.0
150	1.3	1.3	1.6

The charging times shown are indicative constant-rate estimates. Actual charging duration will depend on the X7E's charging curve, battery management system limits, SOC range, temperature and charger compatibility. The values should therefore be used for preliminary sizing only.

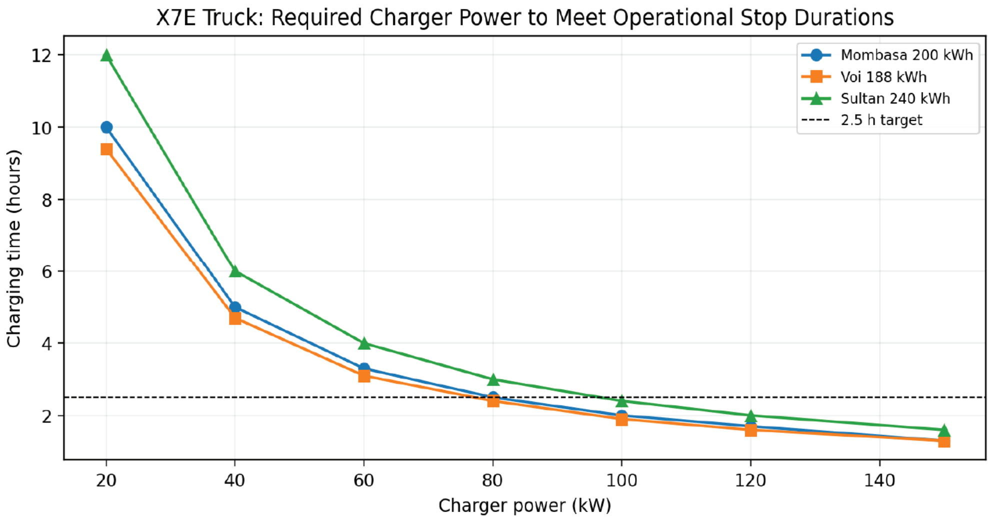


Figure 10: X7E charging time under different charger-power scenarios

- **Minimum upgrade:** install additional 60 kW GB/T DC at Sultan Hamud, Voi and Mombasa to make HCV charging technically manageable.
- **Recommended Sultan Hamud upgrade:** 100 kW GB/T DC or higher. This reduces the 240 kWh event to approximately 2.4 hours under the constant-rate assumption.
- **Future-ready option:** 240 kW GB/T DC at Sultan Hamud and Voi. This supports heavier payloads, higher daily throughput and future freight EVs with larger batteries.
- **Planning caveat:** these estimates assume the X7E can accept higher GB/T DC power. The next test should confirm the truck maximum DC acceptance rate and charging curve above 80% SOC.

9. Substation Loading and Grid Capacity Analysis

9.1 Purpose of the Grid Readiness Assessment

This section integrates Kenya Power substation loading data with the parade-derived EV charging demand to answer two questions:

(i) Which substations have sufficient existing headroom to host the recommended charging stations without expansion

(ii) Where the corridor will need substation reinforcement to support Phase 2 deployment.

The analysis applies to the utility planning convention that transformers should not be loaded above 80% of their N-1 firm capacity, so that an N-1 outage of a single transformer can still be absorbed by the remaining units. All substation loadings are KPLC 2025 baseline figures; non-EV load growth is treated separately in Section 9.

9.2 Grid Planning Methodology

The analysis assesses available transformer capacity against an 80% planning threshold. For substations with more than one transformer, the study considers available firm capacity under an N-1 planning approach where applicable. Under N-1, the system should be able to continue supplying demand following the outage of one major transformer.

For multi-transformer substations, available headroom is assessed against the 80% planning threshold applied to firm capacity, subject to confirmation of the applicable N-1 configuration. For single-transformer substations, the reported margin represents operational loading margin against the 80% planning threshold and should not be interpreted as N-1 firm capacity.

9.3 Substations Serving the Corridor

This assessment covers seven Kenya Power substations along the A109 corridor between Mombasa and Nairobi, and pairs each with the KeNHA traffic count station(s) located on the adjacent road section so that charging-site prioritization reflects observed vehicle flows. During the May 2026 parade, charging stops were served by Kiboko 132/33 kV (serving both the Sultan Hamud and Emali charging sites), Mtito Andei 33/11 kV, Voi 132/33 kV, and Nyali 33/11 kV (serving Mombasa). With corridor traffic-flow data, the analysis is extended to two further strategic sites that were not used during the parade but carry significant freight and passenger volumes: Athi River 66/11 kV (Machakos Turn-Off–Athi River–Syokimau sections) and Mariakani 33/11 kV (Mazeras–Mariakani section).

The Sultan Hamud 132/33 kV substation lies on the corridor at Sultan Hamud town but did not directly supply any charging site during the parade and is retained for context. Table 19 summarizes rated capacity, current load, percentage loading against nameplate (matching KPLC's reporting convention), and headroom against the 80% planning ceiling. Single-transformer substations have no N-1 redundancy meaning that outage of the transformer causes a full loss of supply. Their loading must therefore be managed conservatively. For multi-transformer substations the headroom is computed against N-1 firm capacity (largest unit out of service).

Table 19: A109 corridor substation baseline (KPLC 2025)

Substation	Voltage	Charging site(s) served	Config	Rated MVA	2025 load (MVA)	% of nameplate	Headroom 80% N-1 firm (MVA)
Mtito Andei	33/11 kV	Mtito Andei	1×2.5	2.5	1.80	**72%**	**0.20**
Sultan Hamud	132/33 kV	(not used for charging)	1×23	23	9.15	40%	9.25
Nyali	33/11 kV	Mombasa	2×23	46	15.28	33%	3.12
Kiboko	132/33 kV	Sultan Hamud + Emali	1×23	23	6.72	29%	11.68
Voi	132/33 kV	Voi	1×15+1×23	38	9.67	12%	8.73
Athi River	66/11 kV	Athi River / Syokimau	2×23	46	22.41	49%	**-4.01**
Mariakani	33/11 kV	Mariakani	1×7.5	7.5	2.62	35%	3.38

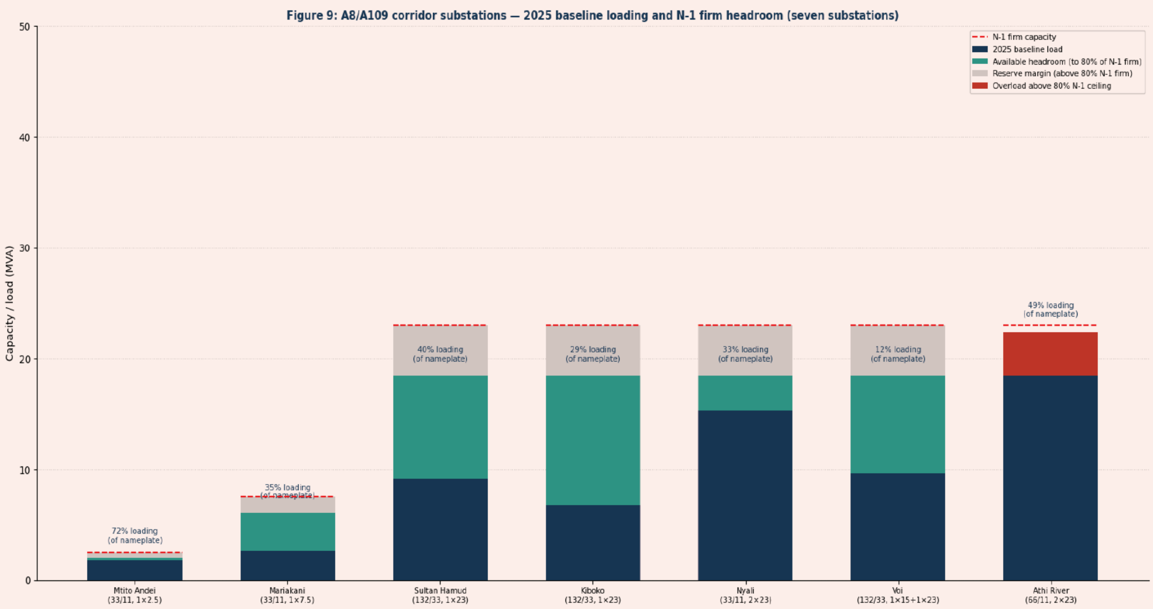


Figure 11: A109 corridor substations (all seven) 2025 baseline loading and N-1 firm headroom

Key observations on the baseline: Across the seven substations, five have generous headroom for new EV load. Kiboko (132/33 kV), the primary point of supply for both the Sultan Hamud and Emali charging sites, has 11.68 MVA of available headroom and is loaded at only 29% of its 23 MVA nameplate. Voi (132/33 kV, 1×15+1×23 MVA) has 8.73 MVA available on an N-1 firm basis and is loaded at only 12%, Mariakani 3.38 MVA, Nyali 3.12 MVA, and Sultan Hamud (132/33 kV) 9.25 MVA. Two substations are constrained. Mtito Andei and Athi River are the constrained nodes. Mtito Andei is loaded at 72% of its 2.5 MVA single-transformer nameplate, leaving only approximately 200 kVA of headroom against the 80% planning ceiling.

Athi River 66/11 kV is the most severe case. It carries the corridor's heaviest traffic (74,000 AADT and 8,260 trucks/day at the Syokimau count station) yet its 22.41 MVA load already sits at 97% of its 23 MVA N-1 firm capacity, i.e. about 4 MVA above the 80% N-1 planning ceiling. Athi River therefore has no firm headroom for new charging load and would require transformer reinforcement (or a non-firm/curtailable connection plus on-site solar-plus-storage) before a charging hub could be added there.

9.4 Corridor Traffic Flow and Site Prioritization

Charging station siting is driven not only by grid headroom but by where vehicles travel and dwell. KeNHA average annual daily traffic (AADT) counts for the A109 corridor were matched to each substation through the count station(s) on its adjacent road section. Heavy-truck and bus/matatu volumes are the most relevant indicators of en-route fast-charging demand, since these are the vehicle classes with the largest batteries and the least scheduling flexibility. Table 20 summarizes the flows and the resulting demand ranking.

Table 20: Corridor traffic flow by substation (KeNHA AADT counts) and charging-demand ranking

Substation	Count station(s) / road section	AADT (veh/day)	Heavy trucks/ day	Buses + matatu/ day	Charging-demand rank
Athi River	Syokimau, Millennium Stn (Machakos T/O–Athi River–Ole Sereni)	15,900–74,100	2,500–8,300	3,500–7,600	**1 (highest)**
Kiboko	Konza, Salama, Kiboko (Emali–Machakos T/O; Mtito–Emali)	3,800–9,800	1,560	1,520	2
Mariakani	Kokotoni (Mazeras–Mariakani)	10,800	1,880	840	3
Voi	Ndome, Mtito Andei (Mariakani–Mtito Andei)	3,900–7,500	880	690	4
Mtito Andei	Ndome (Mariakani–Mtito Andei)	7,500	835	650	5
Nyali (Mombasa)	Coastal terminus / Changamwe–Mazeras approach	19,900	3,150	1,490	Coastal anchor
Sultan Hamud	Served via Kiboko (Salama/ Konza counts)	9,500–9,800	1,900	1,910	Via Kiboko

The traffic data reorders priorities relative to the parade-only view. Athi River carries by far the highest volumes on the corridor, up to 74,000 vehicles/day and 8,260 trucks/day at Syokimau, making it the single most attractive charging location on demand grounds, but also the one substation with no firm grid headroom (Section 8.1). Kiboko (serving Sultan Hamud and Emali) and Mariakani follow on freight volume, and both retain ample headroom, so they are the highest-value sites where demand and grid capacity align. Mtito Andei remains strategically important as a mid-corridor buffer despite lower absolute flows, but its 1×2.5 MVA transformer is the binding grid constraint on the parade-served sites.

The best charging locations, weighing both traffic and grid capacity, are therefore: Kiboko/Sultan Hamud–Emali and Mariakani (high demand, ample headroom); Voi and Nyali (strong anchor hubs, comfortable headroom); Mtito Andei (needed for coverage, requires transformer upgrade); and Athi River (highest demand of all, but requires grid reinforcement or solar-plus-storage before a hub can be energized).

9.5 EV Charging Load: Methodology

Each charging site is sized using the recommended charger mix from Sections 6–7 and converted into a coincident grid load through three engineering parameters:

(i) Nameplate capacity = sum of the rated DC and AC power of all chargers;

(ii) Diversity factor (DF) applied to account for the probability that all chargers are not simultaneously at full power, ranging from 0.95 for small sites (≤2 charge points) to 0.70 for larger sites with 6+ charge points; and

(iii) Power factor (PF) = 0.95 for modern active-front-end DC fast chargers, used to convert kW into kVA at the grid interface.

9.6 Phase 1 and Phase 2 Charger Configurations

Two deployment phases are modelled: Phase 1 (near-term commissioning, 2026–2027) providing the minimum viable charger mix at each site, and Phase 2 (corridor scale-up, 2028–2030) providing the anchor-hub configuration recommended in Section 9.

Table 21: Recommended charger configurations per site, Phase 1 and Phase 2

Site	Charger mix	Nameplate (kW)	Charge points	Diversity factor	Coincident demand (kVA)	Phase
Sultan Hamud	1× 120 kW dual CCS2+GB/T DC + 1× 22 kW AC	142	2	0.95	142	1
Sultan Hamud	2× 150 kW dual-gun DC + 1× 60 kW DC + 2× 22 kW AC	404	5	0.80	340	2
Voi	1× 120 kW dual CCS2+GB/T + 1× 60 kW GB/T DC + 2× 22 kW AC	224	4	0.85	189	1
Voi	2× 150 kW dual-gun DC + 1× 60 kW DC + 2× 22 kW AC	404	5	0.80	340	2
Mombasa (Nyali)	1× 120 kW dual CCS2+GB/T DC + 1× 22 kW AC	142	2	0.95	142	1
Mombasa (Nyali)	1× 150 kW DC + 1× 60 kW DC + 2× 22 kW AC	254	4	0.85	214	2
Mtito Andei	1× 60 kW dual CCS2+GB/T DC + 1× 22 kW AC	82	2	0.95	82	1
Mtito Andei	1× 120 kW DC + 1× 60 kW DC + 1× 22 kW AC	202	3	0.90	191	2
Emali	1× 60 kW dual CCS2+GB/T DC + 1× 22 kW AC	82	2	0.95	82	1
Emali	1× 120 kW DC + 1× 60 kW DC + 1× 22 kW AC	202	3	0.90	191	2

9.7 Charging Demand versus Substation Headroom

Comparing the simultaneous demand from Table 21 against the substation headroom from Table 19 produces clear recommendations for each site and phase. Sultan Hamud and Emali share the Kiboko 132/33 kV substation, therefore their loads are summed against a common headroom.

Table 22: EV charging demand vs available substation headroom

Site	Supplying substation	Phase 1 demand (kVA)	Phase 2 demand (kVA)	Substation headroom (kVA)	Phase 1 fits?	Phase 2 fits?
Sultan Hamud	Kiboko 132/33	142	340	11,680	Yes (1.2%)	Yes (2.9%)
Emali	Kiboko 132/33	82	191	11,680 (shared)	Yes	Yes
Combined Sultan + Emali	Kiboko 132/33	224	531	11,680	Yes (1.9%)	Yes (4.5%)
Mtito Andei	Mtito Andei 33/11	82	191	200	Yes (41%)	Marginal (96%); no growth margin
Voi	Voi 132/33	189	340	8,730	Yes (2.2%)	Yes (3.9%)
Mombasa (Nyali)	Nyali 33/11	142	214	3,120	Yes (4.6%)	Yes (6.9%)
Mariakani	Mariakani 33/11	189	340	3,380	Yes (5.6%)	Yes (10.1%)
Athi River	Athi River 66/11	224	340	-4,010	No - over N-1 ceiling	No - reinforcement needed

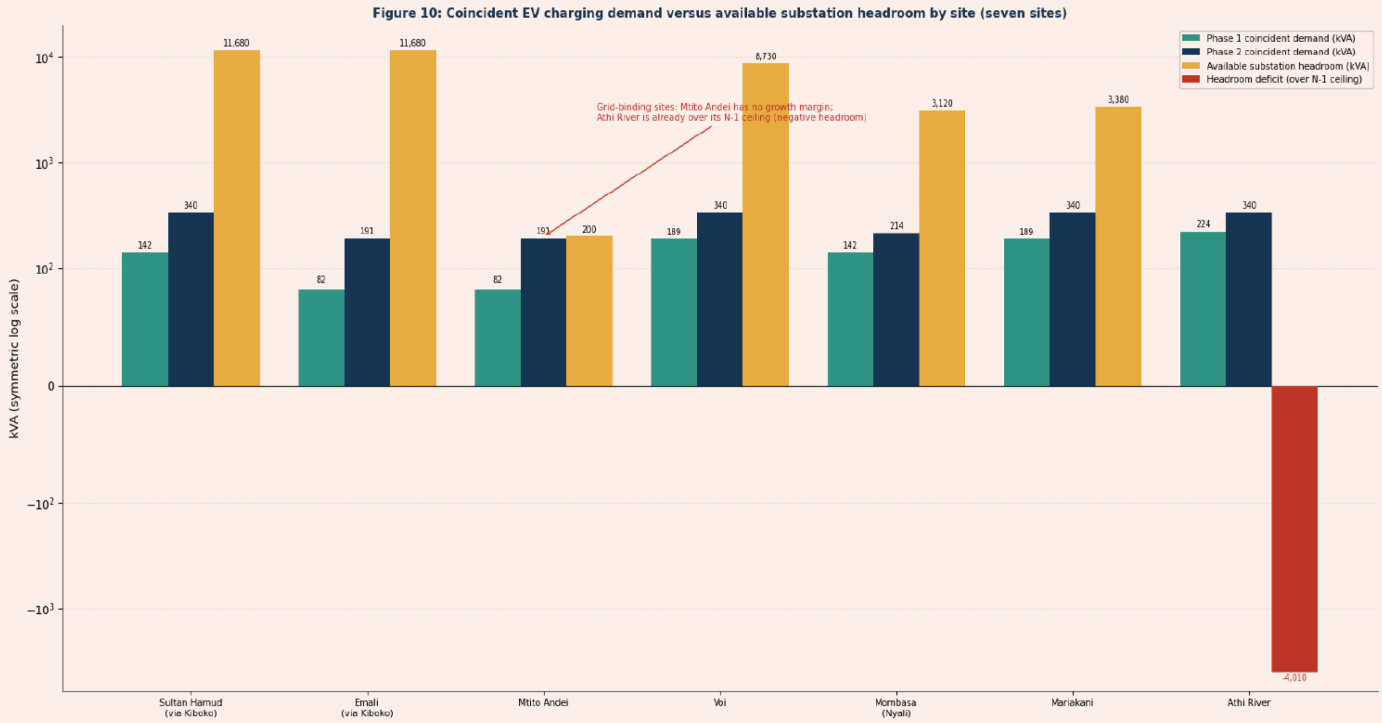


Figure 12: Coincident EV charging demand versus available substation headroom by site (seven sites)

- **Recommendations on Phase 1 (2026–2027) deployment.** Of the seven substations, six can host Phase 1 charging entirely within existing capacity. The parade-served sites (Sultan Hamud and Emali via Kiboko, Voi and Mombasa via Nyali) use less than 6% of their available headroom, and the newly added Mariakani site uses about 5.6% of its 3.38 MVA headroom. Mtito Andei uses 41% of its small (200 kVA) headroom which is within the planning ceiling and adequate for the lifetime of the Phase 1 charger mix. Athi River is the exception. Although it carries the corridor's heaviest traffic, its 66/11 kV substation is already loaded to 97% of N-1 firm capacity, therefore no Phase 1 charging load can be added there without prior grid reinforcement or a non-firm/solar-backed connection.

- **Recommendations on Phase 2 (2028–2030) deployment.** All sites except Mtito Andei and Athi River can be scaled up to the anchor-hub configuration without grid intervention; the Kiboko-fed sites, Voi, Mombasa and Mariakani each still use about 10% or less of their headroom. Mtito Andei and Athi River are the binding grid constraints at Phase 2. For Mtito Andei the 191 kVA Phase 2 demand sits within the 200 kVA planning ceiling (using 96% of headroom), leaving no safety margin. When realistic 2025–2030 non-EV load growth is added (about 22% over five years at 5%/yr, raising the baseline from 1.80 MVA to about 2.19 MVA), the substation moves above its 80% N-1 firm planning ceiling and expansion becomes mandatory before Phase 2 commissioning. Athi River cannot host either Phase 1 or Phase 2 charging on its existing firm capacity. At 22.41 MVA, the substation is already at 4 MVA above its 80% N-1 ceiling, therefore a charging hub there is contingent on transformer reinforcement (or a curtailable connection backed by on-site solar-plus-storage). Given that Athi River carries the corridor's highest traffic, this reinforcement should be prioritized as a strategic, demand-led investment rather than treated as optional infill.

10. Substation Expansion Requirements

10.1 Purpose of the Expansion Assessment

The substation expansion assessment identifies the grid reinforcements required to support the phased deployment of electric vehicle charging infrastructure along the A109 corridor. The objective is not only to determine whether current charging demand can be accommodated, but also whether the supplying substations can support future growth in EV charging, non-EV demand and corridor logistics activity while maintaining acceptable reliability.

The analysis shows that most assessed substations can support early-phase charging deployment subject to feeder-level validation. However, two locations require specific grid interventions:

1. Mtito Andei, because it is a strategically important mid-corridor node with limited transformer capacity; and
2. Athi River, because it has the strongest traffic-demand case but no firm headroom for a major charging hub under the current planning criterion.

10.2 Mtito Andei — Required Expansion

Mtito Andei 33/11 kV is the only corridor substation that cannot host the recommended Phase 2 charging station with adequate safety margin. The current configuration (single 2.5 MVA transformer, loaded to 72% in the 2025 KPLC baseline) provides no N-1 redundancy and approaches its planning ceiling on non-EV load alone once organic 5-year growth is factored in. Four options were assessed:

Table 23: Mtito Andei substation expansion options

Option	Configuration	Rated MVA	N-1 firm MVA	Planning ceiling (80% N-1)	Capex range (USD)	Suitability
Existing	1×2.5 MVA	2.5	2.5 (no N-1)	2.0	—	Phase 1 fits; Phase 2 + 5-yr non-EV growth EXCEEDS
A	1×5 MVA (replace)	5.0	5.0 (no N-1)	4.0	250k–400k	OK for both phases; no N-1 redundancy; single point of failure
B	2×2.5 MVA (add second)	5.0	2.5	2.0	350k–500k	OK for Phase 1; Phase 2 marginal; provides N-1 but no growth headroom
C (recommended)	2×5 MVA	10.0	5.0	4.0	600k–900k	OK for both phases; N-1 secure; 5-year growth headroom

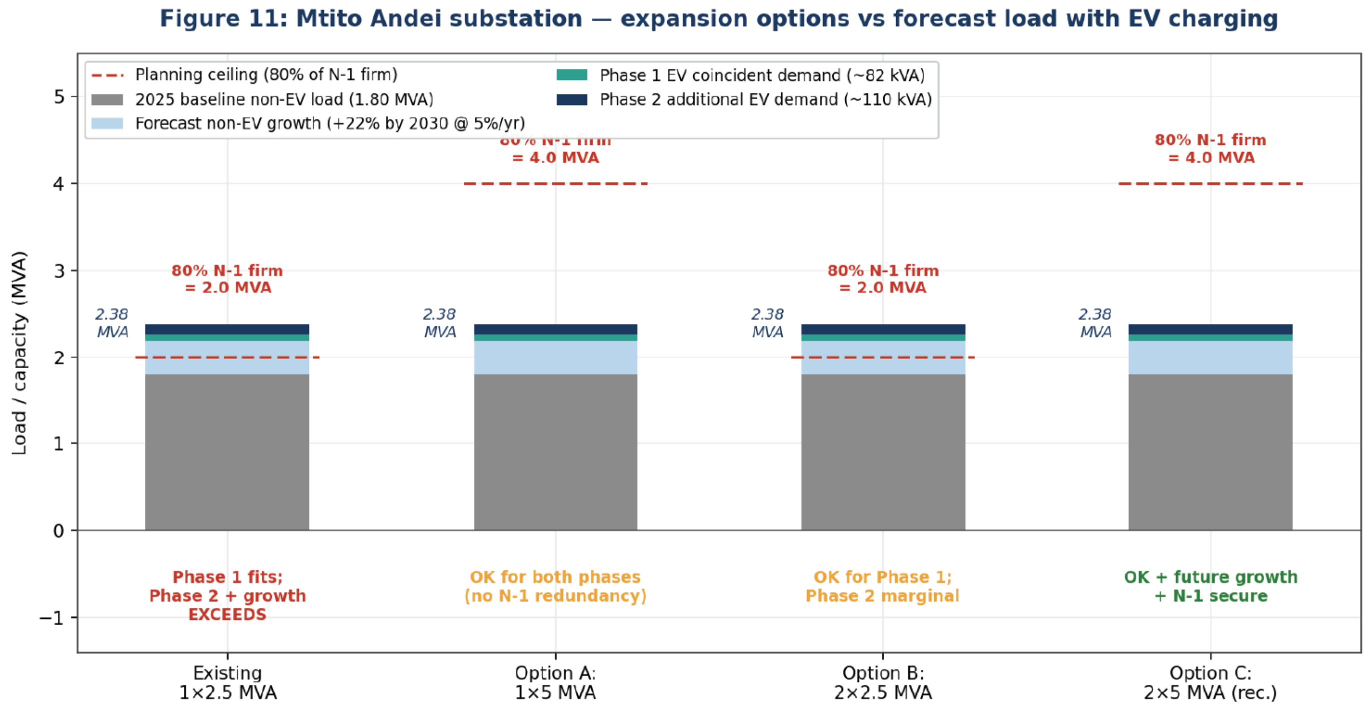


Figure 13: Mtito Andei substation — expansion options vs 2025 baseline load, 5-year non-EV growth and EV charging

Recommendation: upgrade Mtito Andei to 2×5 MVA (Option C), giving a firm capacity of 5 MVA and a planning ceiling of 4 MVA. The 2030 stacked total (2025 baseline 1.80 MVA + 5-year non-EV growth 0.39 MVA + Phase 1 EV 0.08 MVA + Phase 2 additional EV 0.11 MVA = 2.38 MVA) sits well inside the 4 MVA ceiling, providing approximately 1.6 MVA of clear safety headroom for any further unforeseen non-EV growth in Mtito Andei township through 2030, and full N-1 redundancy. Option A (1×5 MVA) is acceptable for shorter-term constraints but leaves no contingency margin and exposes the corridor to a single point of failure. Option B (2×2.5 MVA) improves redundancy but does not add capacity (the planning ceiling stays at 2.0 MVA) and re-introduces a Phase 2 constraint within a few years.

10.3 Alternative: Solar with Storage to Defer Expansion

Mtito Andei lies within the Tsavo solar belt (5.6–6.0 kWh/m^2/day annual mean GHI), and a solar PV with battery energy storage system (BESS) installed at the charging site could downsize the substation upgrade. A 200 kWp PV array generating approximately 300 MWh/year combined with a 200–400 kWh BESS would absorb approximately 60–70% of daytime DC fast-charging energy and reduce the coincident grid peak by 80–120 kW. The grid would still need to support overnight HCV charging via the existing substation. Indicative Capex for the solar and BESS option is in the range USD 250,000–400,000, comparable to Option A above; it does not deliver N-1 redundancy but does provide grid-outage continuity and offsets carbon. This option deserves a dedicated feasibility study before the Mtito Andei substation upgrade is finalized.

10.4 Athi River — Demand-Led Reinforcement

Athi River 66/11 kV is the highest traffic location on the entire corridor: the Syokimau and Millennium Station counts record between 15,900 and 74,100 vehicles/day, including up to 8,260 heavy trucks/day which is about four times the heavy-vehicle flow seen at any other corridor substation. On demand grounds it is the single most attractive site for a high-power charging hub. However, the substation is also the most heavily loaded on the corridor in absolute terms. Its 2025 baseline load of 22.41 MVA against a 2×23 MVA configuration leaves a healthy margin on nameplate (49% loading), but on an N-1 firm basis (one 23 MVA transformer out of service) the load is already 97% of firm capacity, i.e. about 4 MVA above the 80% N-1 planning ceiling. There is therefore no firm headroom for new EV charging load without intervention.

Three routes can unlock charging at Athi River.

(i) Transformer reinforcement — adding a third 23 MVA unit (3×23 MVA) would raise N-1 firm capacity to 46 MVA and restore comfortable headroom for both non-EV growth and a large charging hub; indicative Capex is in the order of USD 1.5–2.5 million and would require a KPLC load-flow study.

(ii) A non-firm or curtailable grid connection, where the charging hub accepts interruption during peak system stress, allowing it to use spare capacity under normal conditions without counting against firm planning limits.

(iii) On-site solar-plus-storage sized to cover the bulk of daytime fast-charging energy, reducing the peak grid draw to a level the existing connection can absorb. As Athi River combines the corridor's highest demand with its tightest grid position, the reinforcement should be treated as a strategic, demand-led priority rather than optional infill, and a dedicated feasibility study is recommended in parallel with the Mtito Andei upgrade.

10.5 Recommendations for Other Substations

The remaining corridor substations, Kiboko, Voi, Nyali and Mariakani, do not require expansion to support Phase 1 or Phase 2 charging. Several observations are worth recording for medium-term planning:

- **Nyali 33/11 kV** is operating at 33% of its 2×23 MVA nameplate (66% of N-1 firm) in the 2025 KPLC baseline, which is comfortable but not abundant on an N-1 basis. The Phase 2 charging load adds approximately 7% of headroom, taking total post-EV utilization to ~67% of N-1 firm. This remains within prudent operating limits, but KPLC should monitor non-EV load growth at Nyali; if total loading approaches 80% of N-1 firm before 2030, a third transformer (3×23 MVA) should be considered.

- **Voi 132/33 kV** now has substantial headroom (8.73 MVA on an N-1 firm basis, loaded at only 12%) following confirmation of its 1×15+1×23 MVA configuration. Phase 2 demand uses under 4% of available headroom however because Voi is the strategic anchor hub of the corridor and will host the highest charging throughput, the Voi 132/33 kV substation should be the first candidate for monitoring if a Phase 3 future build (e.g. 350 kW ultra-fast HCV or swap bay) is added.

- **Kiboko 132/33 kV** has 11.68 MVA of headroom and comfortably supports both the Sultan Hamud and Emali charging sites at Phase 2 (combined demand about 0.53 MVA = 4.5% of headroom). No reinforcement required within the planning horizon.

- **Mariakani 33/11 kV** is a newly added site justified by the corridor traffic data: the Mazeras–Mariakani section carries ~10,800 vehicles/day including ~1,880 heavy trucks/day. Its single 7.5 MVA transformer is loaded to only 35% (2.62 MVA), leaving 3.38 MVA of headroom against the 80% planning ceiling — ample for a Phase 1 and Phase 2 charging hub. As a single-transformer (1×7.5 MVA) site it has no N-1 redundancy, so KPLC should track non-EV growth and consider a second transformer if combined loading later approaches the planning ceiling.

11. Number, Size and Configuration of Charging Stations Required

11.1 Purpose of the Charging Network Configuration

The purpose of this section is to translate the corridor evidence into a phased charging infrastructure programme. The recommended network is designed to support safe movement of passenger EVs, light commercial vehicles and early heavy-duty electric freight along the A109 Nairobi–Mombasa–Nairobi corridor.

Consolidating Sections 2–9 and the corridor traffic-flow data, the recommended A109 charging program now spans seven substations. Six host charging sites in Phase 1 (2026–2027) i.e. Sultan Hamud and Emali (via Kiboko), Mtito Andei, Voi, Mombasa (Nyali) and Mariakani, scaled up in Phase 2 (2028–2030), with Athi River added in Phase 2 once its substation is reinforced and Kiboko retained for further Phase 3 infill. Total corridor charge points grow from 16 (Phase 1) to 32 (Phase 2).

11.2 Charger Power Standards

In this report, a 240 kW hub recommendation should be interpreted as minimum aggregate DC capacity at the site, unless otherwise stated. Individual charger ratings and charge-point numbers should be determined through site-level demand, vehicle mix, grid connection capacity and utilization modelling.

Table 24: Charging-station rollout — number, size and configuration by phase

Charger level	Recommended role	Planning interpretation
7–11 kW AC	Legacy, backup or long-dwell charging	Not suitable as main corridor infrastructure
22 kW AC	Destination, overnight, fleet parking and fallback charging	Useful supplementary infrastructure
20–40 kW DC	Early-stage top-up or emergency support	Insufficient for scaled commercial operations
60 kW DC	Minimum practical DC level for intermediate corridor nodes	Acceptable for Phase 1 support nodes
100–150 kW DC	Preferred for anchor hubs and heavy-duty priority nodes	Required for commercial readiness
240 kW aggregate site capacity	Practical early anchor-hub capacity	Suitable as Phase 1/2 site-level target
350 kW+ future-ready bay	Future heavy-duty freight, high-throughput corridors	Reserve space and grid pathway

11.3 Phase 1: Minimum Viable Corridor Backbone

Phase 1 should establish a reliable DC fast-charging backbone that allows the corridor to operate safely in both directions, with stronger redundancy on the return leg.

Table 25: Recommendations for Phase 1

Site	Phase 1 role	Recommended Phase 1 configuration	Grid condition
Voi	Main mid-corridor anchor	Minimum 120 kW dual-standard DC + 60 kW GB/T/DC support + AC fallback	Proceed subject to feeder validation and Voi N-1 confirmation
Sultan Hamud	Critical return-leg buffer	Minimum 120 kW dual-standard DC + AC fallback	Proceed via Kiboko/Sultan supply arrangement subject to feeder validation
Emali	Intermediate redundancy node	Minimum 60 kW dual-standard DC + 22 kW AC	Proceed subject to feeder validation
Nyali/Mombasa	Coastal anchor	Minimum 120 kW dual-standard DC + 22 kW AC	Proceed subject to feeder validation
Mariakani	Coastal logistics/freight node	Minimum 120–240 kW aggregate dual-standard DC	Proceed subject to site and feeder validation
Mtito Andei	Strategic but constrained support node	Limited 60 kW dual-standard DC + 22 kW AC	Keep limited until substation reinforcement
Athi River	High-demand future hub	Do not deploy major hub in Phase 1	Detailed reinforcement study required

Phase 1 should avoid installing isolated low-power chargers that will quickly become obsolete. Even where initial utilization is uncertain, chargers should be modular, remotely monitored, expandable and capable of supporting both current and future corridor demand.

11.4 Phase 2: Corridor Scale-Up

Phase 2 should scale the corridor from demonstration readiness to commercial readiness. This means increasing charger capacity, adding redundancy and strengthening grid-constrained nodes.

Table 26: Recommendations for Phase 2

Site	Phase 2 configuration	Condition for deployment
Voi	240–300 kW aggregate DC capacity, with dedicated HCV-capable GB/T/dual-standard bay	Confirm substation and feeder headroom
Sultan Hamud	240–300 kW aggregate DC capacity, including 100–150 kW HCV-capable charging	Confirm feeder capacity and GB/T compatibility
Nyali/Mombasa	240 kW aggregate DC capacity plus AC fallback	Confirm coastal hub site and grid arrangement
Mariakani	240 kW or higher aggregate DC capacity for freight/logistics demand	Confirm site, feeder and logistics catchment
Mtito Andei	Scale to 120–180 kW DC plus AC fallback	Only after substation upgrade, preferably 2×5 MVA
Emali	120–180 kW aggregate DC capacity	Confirm demand and feeder capacity
Athi River	240 kW or higher high-demand charging hub	Only after grid reinforcement or managed connection solution
Kiboko	Phase 3 infill option	Consider after corridor utilisation is proven

11.5 Connector and Power Standards

All strategic DC charging nodes should provide validated CCS2 and GB/T charging capability. This may be achieved through dual-standard chargers, dedicated chargers, or certified adapter solutions. Interoperability should be tested under actual charging conditions and should not be assumed solely from connector availability.

- **Dual-standard DC at every node**. All DC chargers in Phase 1 and beyond should be dual-standard CCS2 + GB/T, ideally dual-gun, to serve the mixed Kenyan EV fleet (CCS2 for MG, JAC, XUV400, Kona; GB/T for Kabisa/Ridara and the X7E truck) without forcing operators into single-standard sites.

- **AC Type-2 at every anchor town**. 22 kW AC Type-2 at Sultan Hamud, Voi and Mombasa supports overnight dwell at low cost, exploits off-peak tariffs, and provides a low-power fallback during DC outages.

- **HCV / freight provision at Sultan Hamud and Voi.** The X7E result confirms a dedicated 100–150 kW GB/T DC bay at Sultan Hamud is the highest-priority single intervention on the corridor. Future-proof Voi for an ultra-fast (350 kW) or battery-swap bay reserved for HCV.

11.6 Substation Action Summary

Table 27: Substation expansion priorities

Substation	Priority	Action	Timing	Indicative Capex (USD)
Mtito Andei 33/11 kV	Critical	Upgrade to 2×5 MVA (Option C)	Before Phase 2 (by 2028)	600k–900k
Nyali 33/11 kV	Monitor	Track non-EV growth; consider 3×23 MVA if total load > 80% N-1 firm	Review annually; act 2029–2030 if triggered	TBD
Athi River 66/11 kV	High (demand-led)	Reinforce (e.g. 3×23 MVA) or use curtailable connection + solar-plus-storage; highest-traffic site but no firm headroom	Feasibility study 2026–27; build before any hub energized	1.5m–2.5m (reinforcement)
Sultan Hamud 132/33 kV	None required	Corridor-adjacent at Sultan Hamud town; no charging load assigned	—	—
Voi 132/33 kV	None required	Existing 1×15+1×23 MVA capacity comfortable (8.73 MVA N-1 headroom); host Voi hub directly	Immediate	—
Kiboko 132/33 kV	None required	Connect Sultan Hamud + Emali charging (Phase 1 + Phase 2) to existing 33 kV feeder; spare capacity for future Kiboko station	Immediate	—
Mariakani 33/11 kV	None required	Spare 3.38 MVA headroom; host Mariakani hub directly on existing 1×7.5 MVA transformer	Immediate	—

12. Infrastructure Recommendations

12.1 Overall Recommendation

The May 2026 EV parade confirmed that the A109 Nairobi–Mombasa–Nairobi corridor is technically passable for the tested passenger, light commercial and heavy commercial electric vehicles. However, the current charging infrastructure is not yet sufficient for commercial-scale corridor operations, especially for freight, high-volume light commercial vehicles and reliable return-leg movement from Mombasa to Nairobi.

The corridor should therefore be developed as a phased electric mobility infrastructure backbone, supported by DC fast charging, dual-standard connector capability, grid reinforcement at constrained nodes, feeder-level validation, operating protocols and commercial investment modelling.

The central conclusion is straightforward:
The corridor is promising, but it must now move from demonstration-grade charging to commercially reliable corridor infrastructure.

12.2 Priority Infrastructure Interventions

Table 28: Infrastructure Interventions

Node / system	Priority	Recommended intervention	Implementation condition
Sultan Hamud	Critical	Install 100–150 kW GB/T or dual-standard DC charging, with CCS2 redundancy and AC fallback	Validate charger compatibility and confirm whether supply should come via Kiboko or Sultan Hamud substation
Voi	High	Develop as main mid-corridor anchor hub with at least 240 kW aggregate DC capacity, multi-standard charging and overnight capability	Confirm Voi N-1 basis and feeder capacity
Mombasa/Nyali	High	Strengthen as coastal anchor with 120–240 kW aggregate DC capacity and AC fallback	Monitor Nyali loading and confirm feeder/site expansion capacity
Mariakani	Medium-high	Develop as coastal freight/logistics charging node with 120–240 kW aggregate DC capacity	Confirm site, feeder and logistics catchment
Mtito Andei	Critical grid / medium-high charger	Maintain limited Phase 1 charging; scale to higher DC capacity only after transformer reinforcement	Upgrade to 2×5 MVA before Phase 2
Emali	Medium	Provide 60–120 kW dual-standard DC charging for redundancy and fallback	Confirm feeder capacity via Kiboko arrangement
Athi River	High demand-led	Develop as high-power peri-urban logistics hub only after grid solution	Undertake reinforcement/ managed connection study
Kiboko future node	Phase 3	Consider as infill charging site after utilization is proven	Confirm demand case and supply resilience
Corridor-wide systems	Critical	Introduce uptime monitoring, payment interoperability, signage, safety lighting, remote diagnostics and emergency recovery	Include in minimum service standards

12.3 Immediate Actions: 0–6 Months

The immediate priority is to correct data gaps, validate grid assumptions and prepare deployable Phase 1 sites.

Action	Purpose
Validate X7E Sultan Hamud charging data	Resolve charger rating, delivered kWh and average power inconsistency
Confirm Voi N-1 headroom calculation	Ensure grid conclusion is technically defensible
Undertake feeder-level checks at Voi, Nyali, Sultan Hamud/Emali, Mariakani and Mtito Andei	Confirm actual connection readiness
Define minimum corridor charging standards	Set power, connector, uptime, safety and payment requirements
Confirm site ownership and land availability	Avoid delays during deployment
Repeat heavy-duty charging test at higher DC power	Validate 100–150 kW GB/T or dual-standard charging requirement
Prepare Mtito Andei upgrade concept	Begin reinforcement planning before Phase 2

12.4 Short-Term Actions: 6–18 Months

Action	Purpose
Deploy Phase 1 DC fast chargers at priority nodes	Establish minimum viable corridor backbone
Install high-power heavy-duty-capable charging at Sultan Hamud and Voi	Address freight bottlenecks
Develop Voi as the first major corridor anchor hub	Reduce dwell time and improve route confidence
Strengthen Nyali/Mombasa and Mariakani coastal charging cluster	Support return-leg departures and freight flows
Start Mtito Andei 2×5 MVA design and approvals	Prepare for Phase 2 scale-up
Undertake Athi River feasibility study	Convert demand opportunity into a grid-ready investment case
Establish corridor operating protocol	Support pre-booking, SOC rules, recovery and real-time charger status

12.5 Medium-Term Actions: 18–36 Months

Action	Purpose
Complete Mtito Andei reinforcement	Enable Phase 2 charging scale-up
Scale Voi, Sultan Hamud, Nyali and Mariakani hubs	Support commercial traffic growth
Develop Athi River hub after grid solution	Capture highest-demand corridor opportunity
Add infill charging at Kiboko or other locations if utilisation supports it	Improve redundancy and reduce queueing
Implement data-driven load management	Optimise grid use and defer unnecessary upgrades
Introduce performance-based service standards for CPOs	Ensure charger reliability and customer confidence

12.6 Corridor-Wide Minimum Service Standards

Corridor readiness should not be measured only by the presence of chargers. It should be measured by whether those chargers are powerful, reliable, interoperable, safe, visible, properly connected to the grid and available when commercial vehicles need them.

The A109 Mombasa- Nairobi route should be designated as a priority EV corridor with minimum service levels for each strategic node.

Service area	Minimum requirement
Charger power	DC fast charging as backbone; AC only as supplementary
Connector support	CCS2 and GB/T at anchor hubs
Uptime	Defined uptime target and fault response time
Payment	Interoperable payment and roaming capability
Safety	Lighting, fire response, emergency isolation, signage
Operations	Reservation protocol for commercial fleets
Data	Live charger status and utilization reporting
Grid	Metering, load control and power-quality monitoring
Customer support	24/7 fault reporting and recovery escalation
Expansion	Space and electrical design for future scaling

12.7 Other Recommendations

A. Policy and corridor designation

(i) Formally designate the A109 as a priority electric mobility corridor.

(ii) Define minimum service levels by node, covering connector type, DC power, uptime, safety, payment interoperability and emergency support.

(iii) Align corridor charging standards with national EV charging standards as they evolve.

B. Infrastructure and technology standards

(i) Separate infrastructure standards for passenger EVs, LCVs and HCVs.

(ii) Deploy dual-standard CCS2 and GB/T DC charging at strategic nodes.

(iii) Treat AC charging as supplementary infrastructure for overnight, destination and backup use.

(iv) Plan high-power DC charging and future freight bays at Voi, Sultan Hamud, Mariakani and Athi River.

C. Grid planning and reinforcement

(i) Initiate Mtito Andei substation reinforcement planning immediately.

(ii) Undertake detailed grid and feeder studies before major charger deployment.

(iii) Treat Athi River as a demand-led reinforcement opportunity.

(iv) Investigate solar PV and BESS as complementary or interim solutions, not automatic replacements for grid reinforcement.

D. Operations and reliability

(i) Develop a corridor operations protocol for commercial fleets, including pre-booked charging slots, SOC thresholds, live charger status and emergency recovery.

(ii) Establish charger uptime monitoring and maintenance obligations.

(iii) Provide clear roadside signage, safety lighting and driver information at all strategic charging nodes.

E. Data validation and bankability

(i) Repeat the corridor test with controlled payload, speed, weather and auxiliary-load assumptions.

(ii) Install full metering at all charging sites during future tests.

(iii) Complete traffic-flow and charging-demand modelling to determine the actual number and capacity of chargers required.

(iv) Develop site-level business cases covering CAPEX, OPEX, utilization, tariff assumptions, revenue and payback.

Table 29: Summary of data insights and recommendations (extended with substation analysis)

Table / section	Data finding	Infrastructure / grid recommendation
Route overview	The corridor is not symmetrical. The return route climbs from sea level to Nairobi and is more energy-intensive.	Put stronger charging redundancy on the return leg, especially Voi, Mtito Andei and Sultan Hamud.
Vehicle specifications	The fleet has mixed battery sizes and connector standards; the X7E is a different infrastructure class from the light vehicles.	Plan separate standards for passenger/LCV and HCV charging.
Effective range	LCVs lose 15–23% range on return while X7E loses nearly 59%.	Set conservative SOC buffers for LCVs and require high-power DC for HCVs.
Outbound consumption	Downhill direction is manageable, although Voi–Mombasa still shows elevated consumption for some CCS2 vehicles.	Keep Voi as a major charging and staging node.
Return consumption	Mombasa–Voi is the most demanding LCV climb; Voi–Sultan is consistently energy-intensive.	Upgrade Voi and Sultan Hamud first.
Charging times	AC and low-power DC charging create long dwell times. The 12-hour X7E event at Sultan Hamud is the worst bottleneck.	Move daytime en-route charging toward 60–100 kW DC minimum.
X7E sizing	20 kW and 40 kW charging are insufficient for daytime HCV operations.	Install 100 kW GB/T DC at Sultan Hamud and confirm vehicle charging acceptance.
Substation baseline	Of seven corridor substations now assessed, five have ≥3 MVA available headroom. Mtito Andei is at 72% of nameplate with ~200 kVA headroom, and Athi River — the highest-traffic node — is at ~97% of N-1 firm with no headroom.	Phase 1 can be deployed across six sites without grid intervention; Athi River needs reinforcement first.
Charging demand vs headroom	Phase 2 demand at Mtito Andei (191 kVA) sits at 96% of its 200 kVA headroom; Athi River has no firm headroom at all (loaded ~4 MVA above its 80% N-1 ceiling).	Mtito Andei and Athi River are the grid constraints; both must be reinforced before high-power charging.
Substation expansion	Three options assessed for Mtito Andei: 1×5 MVA, 2×2.5 MVA and 2×5 MVA.	Recommend 2×5 MVA (Option C) — provides N-1 redundancy, accommodates Phase 2 EV plus 5-year non-EV growth.
Number of stations	Seven sites assessed; ~16 charge points in Phase 1 scaling to ~32 in Phase 2 (Athi River added in Phase 2 post-reinforcement; Kiboko for further infill).	Sequence: Phase 1 builds within existing substations; Phase 2 commissioned only after Mtito Andei substation upgrade.

References

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[5] GB/T 20234, ***Connection set for conductive charging of electric vehicles. [Standardization Administration of China.]***

[6] Kenya National Highways Authority (KeNHA), ***Average Annual Daily Traffic (AADT) counts, Mombasa–Nairobi (A109) corridor, [2024].***

[7] ***EV Parade A109 corridor field measurements: data-logger traces (Voi, Nyali), charger specifications, and vehicle state-of-charge logs, May 2026*** [primary data].


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