Charging Infrastructure - Challenges and Solutions

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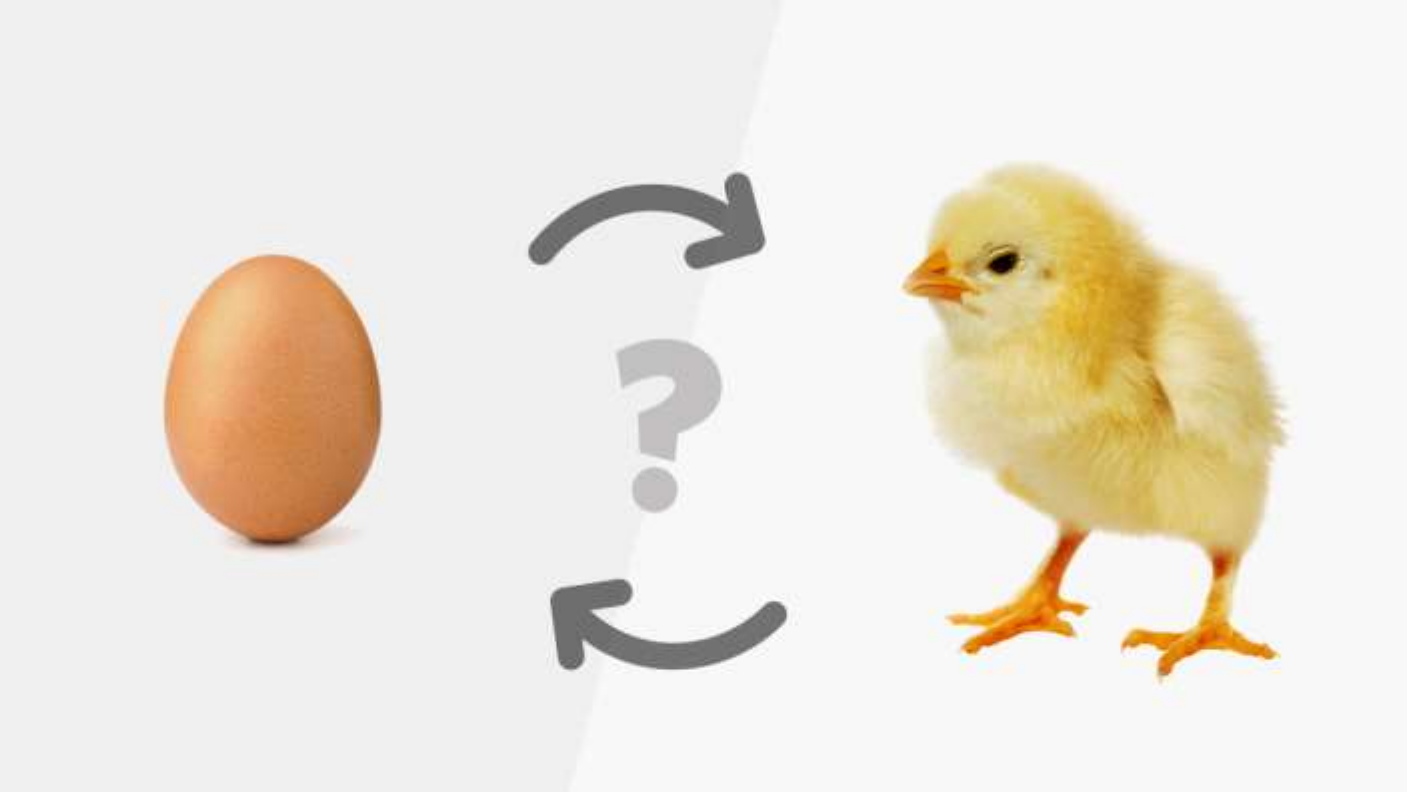
I Will Not Buy an EV Because:

- High Price compared to ICE
- Limited Driving Range
- Charging Time
- Limited Charging Infrastructure
- Battery Replacement Cost
- Battery Production/Disposal Pollution
- Battery Safety
- Low Resale Value
- Low Reliability
- Not Enough Knowledge About EVs
- Any other reason?

Biggest Limitation to Charging Infrastructure

- → High Cost
- → Land Availability
- → Many Vehicle Types to Serve
- → Electricity Availability
- → Electricity Reliability
- → Electricity Affordability
- → Low Utilization Rate
- → Uncertainty in Vehicle Arrival Rate
- → Grid Upgradation
- → Low Density of Charging Network
- → Maintenance Challenges

Electric Vehicles vs. Charging Infrastructure



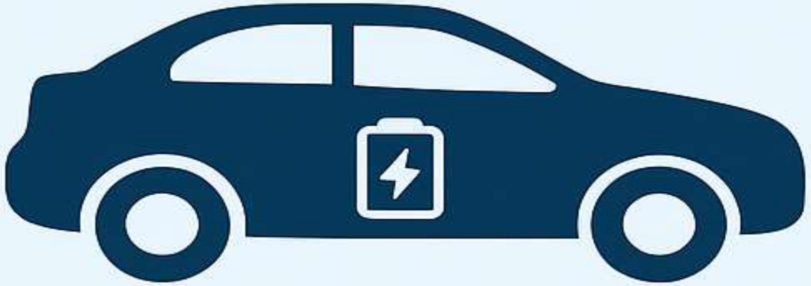
Two-Wheelers (E-Bikes & Scooters)

- Small batteries (1–3 kW charging, 3–10 hrs)
- Mostly charged at home/work with AC plugs (120–240 V)
- Public slow chargers (3–7 kW) common in Asia
- Battery swapping networks emerging — e.g., Gogoro (12 000+ stations in Asia)

Three-Wheelers (E-Rickshaws, Cargo Tukks)

- Larger batteries (5–20 kWh); range ≈ 100–150 km
- Depot charging (AC/DC) or battery swapping for uptime
- India leads global e-3W market (–425 000 units in 2022)
- Battery-as-a-Service and Sun Mobility swap stations support fast turnaround

Four-Wheelers (Cars & Vans)



- Home/work charging: 7–11 kW AC — overnight charge (50–150 km range)
- Public chargers: 11–22 kW AC, fast DC 50–350 kW — 80% charge in 15–30 min
- 2024: 58 million+ EV cars globally; Europe + 35/% croponeare)
- Home = daily use, public = long urps or urban users

Buses & Heavy Commercial EVs

- Batteries: hundreds of kWh
- Depot overnight charging: 50–150 kW (pantograph or plug-in
- On-route fast charging: up to 600kW
- 2024: 70 000 e-buses sold (+30% YoY), mainly China
- Trucks: testing >1 MW chargers for 30–60 min top-up

Charging Methods (1/3): Plug-In & Battery Swapping

- **Plug-In Charging (Conductive)**
- Standard and most common EV charging method.
- **AC Charging (Levels 1 & 2):**
  - Level 1 (120 V) → ~1–2 kW → ideal for overnight home charging.
  - Level 2 (208–240 V) → 7–22 kW, suitable for home/work use.
- **DC Fast Charging:**
  - Bypasses on-board charger; supplies 50–350 kW DC.
  - SAE J1772 standard: DC Level 1 (≤80 kW), Level 2 (≤400 kW).
  - Example: 150 kW charger adds ≈300 km range in 30 min.
- **Use Cases:** Homes, workplaces, public charging stations, and highways.

Charging Methods (2/3): Plug-In & Battery Swapping

- **Battery Swapping**
- Replace depleted battery with a fully charged one in minutes.
- Advantages: Fast refueling, supports Battery-as-a-Service (BaaS) models.
- **Examples:**
  - *NIO (China):* 2 000+ swap stations, 30 million swaps, ~3 min each.
  - *Gogoro (Taiwan):* 400 000+ scooter swaps daily at 12 000+ stations.
- Challenges: Non-standard batteries, high setup cost, safety/compatibility issues.
- Best for: High-use fleets (taxis, deliveries).

Charging Methods (3/3): Wireless (Inductive) Charging

Concept

- Transfers power wirelessly via electromagnetic induction — no cables needed.
- Static charging: parked vehicle over charging pad.
- Dynamic charging: charging while moving (road-embedded coils).

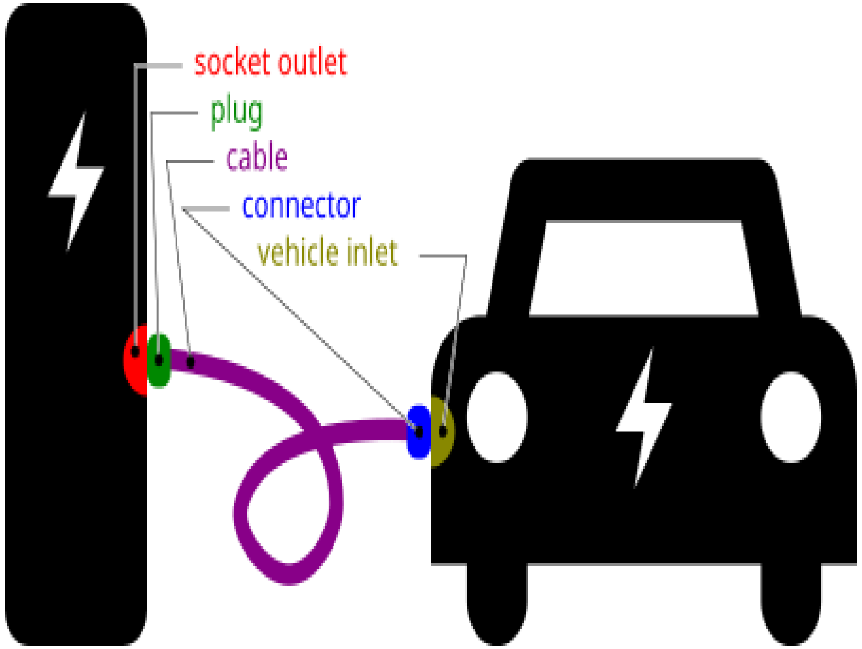
Key Facts

- Power levels: typically, 3–20 kW today.
- Standard: SAE J2954; early pilots in Oregon (buses), UK (taxis).
- Advantages: Ultimate convenience, reduced wear on connectors.
- Challenges: High cost, alignment sensitivity, lower efficiency.
- Future potential: Dynamic wireless highways could revolutionize long-distance EV travel — still in testing phase.

Charging Speeds and Levels (1/2): AC & DC Fast Charging

Slow / Normal AC Charging (Level 1 & 2)

- Level 1 (120 V, ~1–2 kW): Adds ~5–10 km range/hour → ideal for overnight charging.
- Level 2 (208–240 V, 30–80 A): Up to 7–19 kW.
  - Example: 32 A at 240 V → 19.2 kW → 60 kWh car in ~3–4 hrs.
- **Three-phase Level 2 (Europe/Asia):** Up to **22 kW**.
- Best suited for home, office, and slow public chargers.
- Lower grid impact and cost-effective.



Fast DC Charging (Level 3)

- Designed for highway & urban hubs.
- Power: 50–350 kW (typical).
- 80% charge in 20–40 minutes.
- Ultra-fast chargers (≥150 kW) now ≈10% of public fast chargers (IEA 2024).
- Enables long-distance travel and rapid fleet turnaround.

Charging Speeds and Levels (2/2): Ultra-Fast & Megawatt Charging

Ultra-Fast & Megawatt Charging (Heavy-Duty EVs)

- Power range: 750 kW – 1.2 MW+.
- First megawatt truck chargers installed in 2024.
- Add hundreds of km range in 10–20 min for 300–400 kWh batteries.
- Applications: electric trucks, buses, long-haul logistics.
- Require:
  - Dedicated power substations.
  - Active cooling systems.
  - Smart grid integration / on-site storage.
- Key enabler for heavy transport electrification — "a decisive factor for electric trucks in long-distance transport."

Passenger Vehicle Context

- Few cars support >350 kW yet.
- Networks installing 350 kW+ chargers to be future-ready.

EV Charging Ports and Connector Types (1/3): Global Standards Overview

Type 1 (SAE J1772 / Yazaki)

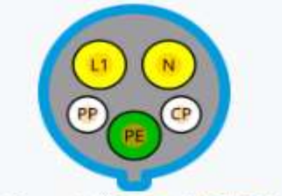
- **Region:** North America, Japan.
- **Power:** Up to ~7.7 kW (240 V, 32 A).
- **Usage:** Older EVs (e.g. Nissan Leaf, Mitsubishi).
- **Notes:** AC only; DC via separate CHAdeMO port.

Type 2 (Mennekes / IEC 62196-2)

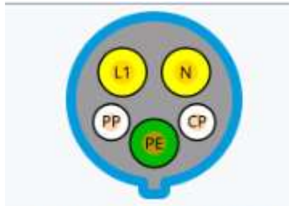
- **Region:** Europe, parts of Asia.
- **Power:** Up to 43 kW (3-phase AC).
- **Usage:** Standard in Europe (used by Tesla EU).
- **Features:** 7-pin design, locking mechanism, strong interoperability.

Combined Charging System (CCS)

- **Types:** CCS Type 1 (US) / CCS Type 2 (EU).
- **Design:** Adds two DC pins below AC section.
- **Power:** Up to ~350 kW.
- **Adoption:** De-facto global standard for most new EVs (Audi, VW, Ford, BMW, GM).



Type 1 (SAE J1772)



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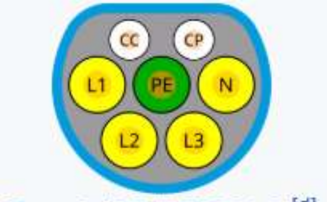
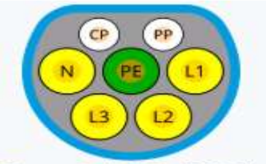
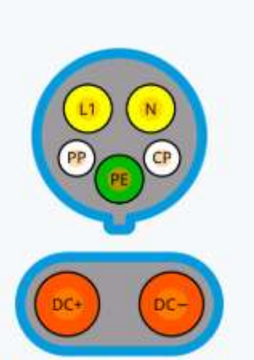


Type 2 (GB/T 20234.2)[d]

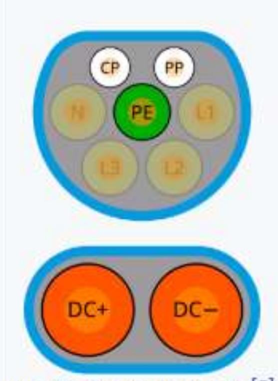
Type 2[b][c]



Type 2 (SAE J3068)



EE (CCS Combo 1)



FF (CCS Combo 2)[c]

EV Charging Ports and Connector Types (2/3): Regional Variants & Trends

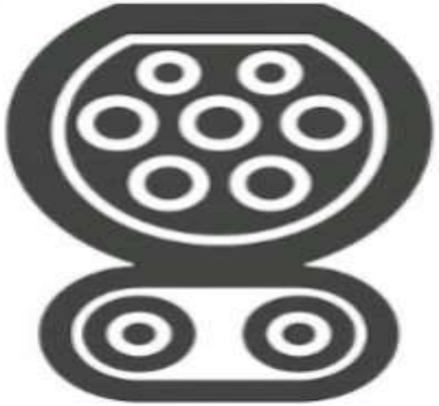
CHAdeMO (Japan-origin)

- **Power:** 100–200 kW (newer up to 400 kW).
- **Adoption:** ~25 600 stations (as of 2019).
- **Usage:** Nissan, Mitsubishi, mainly Japan/Asia.
- **Trend:** Being phased out in favor of CCS in most regions.

CHAdeMO connector (left), with the competing Combined Charging System (CCS) Combo 2 connector (middle), and the AC Type 2 connector (right)

GB/T (China)

- **Covers:** Both AC and DC.
- **Mandated:** China's national standard under GB/T 20234.x.
- **Network:** Largest in world (millions of connectors).
- **Future:** "ChaoJi" connector aims to unify GB/T + CHAdeMO at ultra-fast speeds.



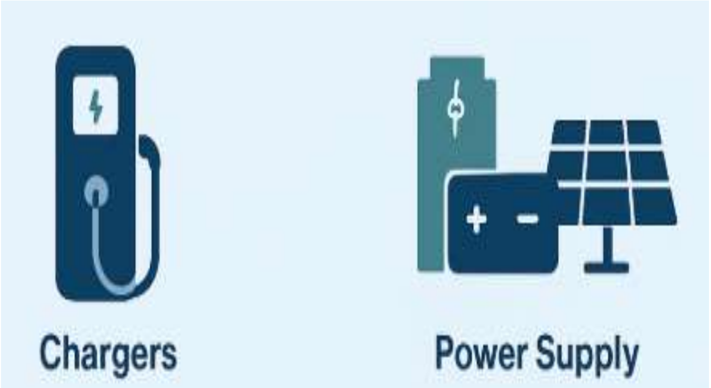
Tesla Supercharger (NACS)

- **Design:** Compact AC/DC combined plug.
- **Network (2021):** ~3 476 sites / 31 498 chargers globally.
- **Now:** Opened to other EVs via interoperability deals (since 2023).
- **Europe:** Uses Type 2 / CCS adapters.

IEC Type 1/SAE J1772 inlet (left); NACS (center); IEC Type 2 connector outlet (right)

Charging Infrastructure Setup (3/3): Hardware, Software & Deployment

- **Components:** Chargers include power converters, cooling, safety, and OCPP communication.
- **Power Supply:** From home outlets to high-voltage substations; often paired with solar or battery storage.
- **Software:** Networked control for billing, access, load balancing, and maintenance.
- **Deployment:**
  - **Home/Work:** AC Level 2 chargers.
  - **Public/Highways:** Fast & ultra-fast DC stations.
  - **Depots:** High-power (50–300 kW) fleet charging.
- **Smart Features:** Smart charging and V2G enable grid interaction and efficiency.



Who Pays for Charging — and What Does It Cost?

A charging station's price tag is made up of several separate line items — understanding them is the first step to designing a subsidy or PPP that targets the right one.

Hardware

The charger unit itself, ranges from a few hundred dollars for a home AC unit to $100,000+ for an ultra-fast DC station.

Land & Site Works

Real estate, civil works, parking-bay conversion and signage, often the least visible but a major fixed cost.

Grid Connection

The cost to bring sufficient power to the site, frequently the single largest and slowest-moving line item.

Operations & Maintenance

Servicing, uptime monitoring, insurance and software licensing over the station's working life.

* **Market scale:** private research firms estimate the global charging infrastructure market at roughly $30–50 billion in 2025, growing 20%+ annually through the early 2030s — estimates vary by methodology, but the growth direction is consistent across all of them.

* *MarkNtel, InsightAce, GMI Insights, MMR*

Electric Vehicle Infrastructure Case Study

- Absolutely Needed for EV penetration
- Different Strategies
  - Cars, SUVs, Vans, Small Trucks
  - Buses (Intercity and Intracity)
  - Large Trucks
  - Three Wheelers
  - Two Wheelers

Where do we need Charging Infrastructure?

- Home
- Office
- Mall
- Hotel
- Fuel Station
- CNG Station
- Highway
- Motorway

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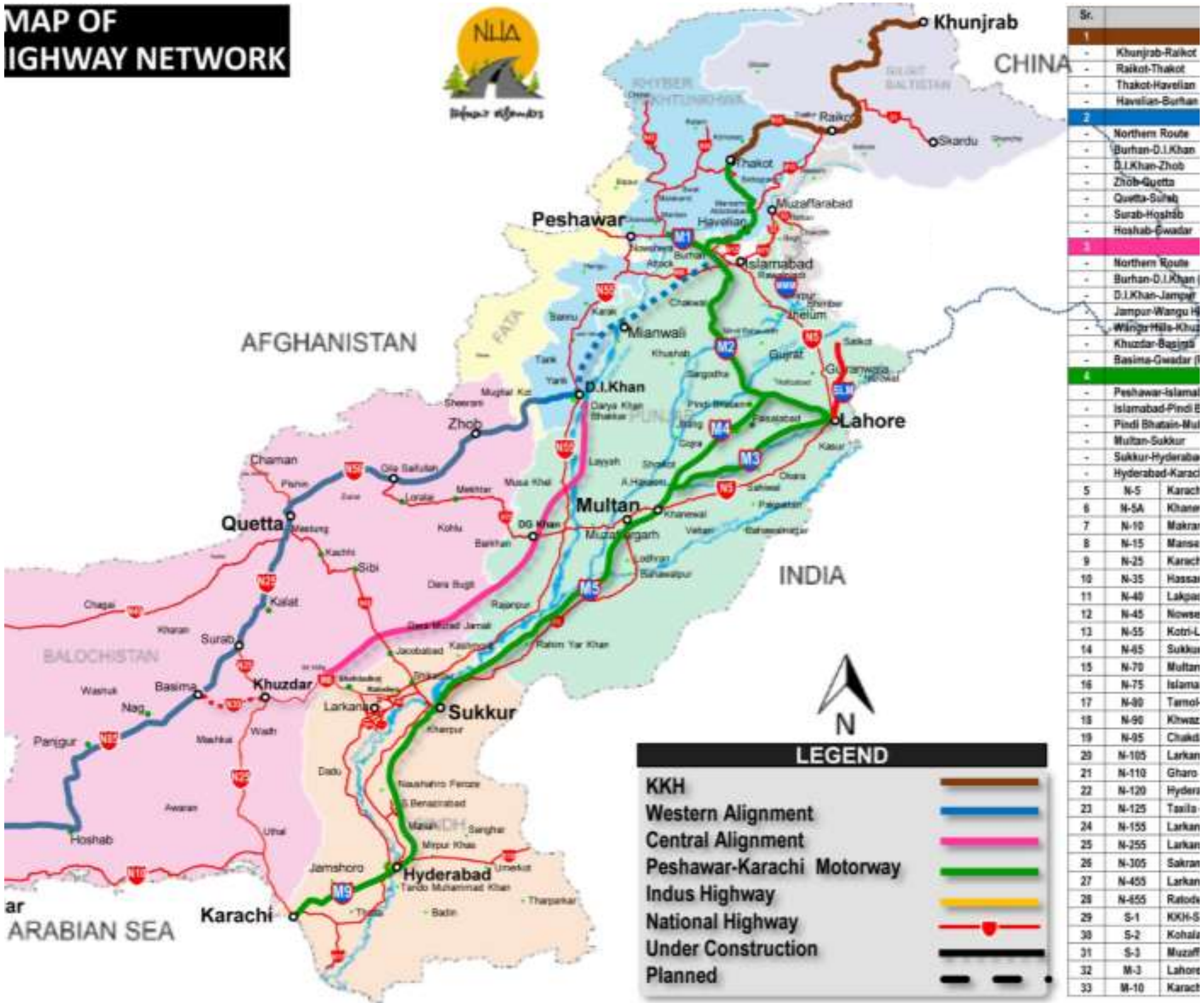
Charging Station Requirements

- → Provision of Adequate Electricity
- → Reliable Supply of Electricity
- → Enough Parking Space
- → Security and Safety
- → Prayer and Play Area
- → Food Shops and Restaurants
- → Tyre Shop and other allied facilities
- → Cellular Network Coverage

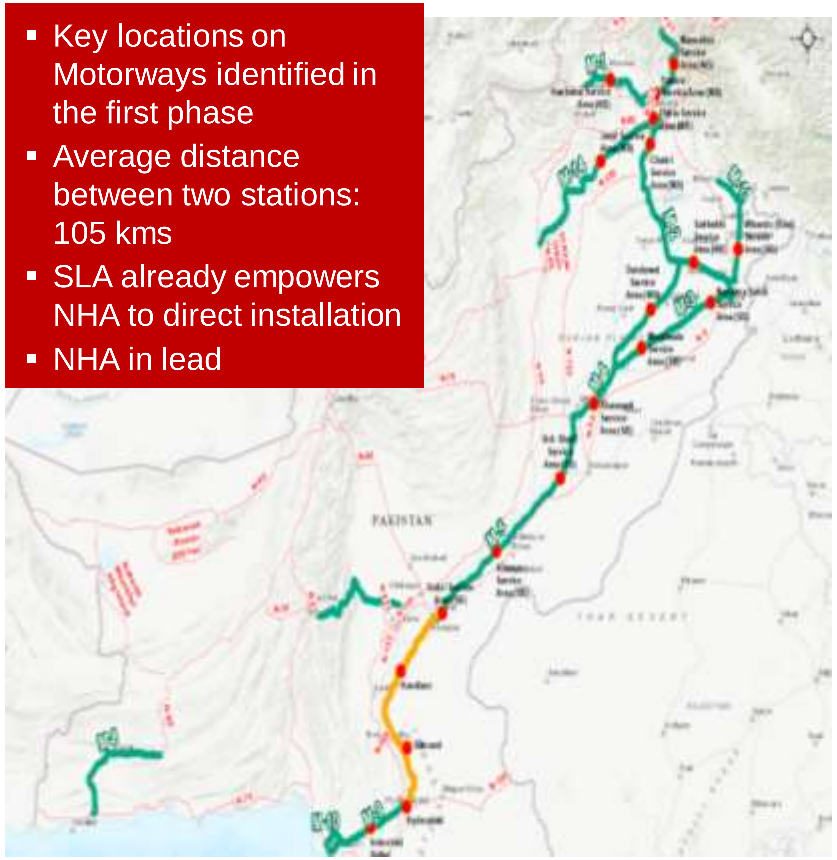
Road Network of Pakistan



Forty charging stations to be established in first phase

Motorway, National Highway	Number
M 1 Peshawar - Islamabad	04
M 2 Islamabad - Lahore	06
M 3 Lahore - Abdul Hakeem	04
M 4 Pindi Bhattian - Multan	04
M 5 Sukkur - Hyderabad	06
M 11 Lahore - Sialkot	02
M 14 Islamabad - DI Khan	02
E 35 Hassanabdal - Havelian	02
CPEC Havelian - Thakot	02
N5 Hyderabad - Sukkur	06
M 9 Karachi - Hyderabad	02
Total	40

- Key locations on Motorways identified in the first phase
- Average distance between two stations: 105 kms
- SLA already empowers NHA to direct installation
- NHA in lead



BYD BLADE BATTERY 2.0

Fast Charging Meets 1,000+ km Range

BYD's second-generation Blade Battery combines LMFP chemistry, ultra-fast charging, improved cold-weather performance, and lower cost to tackle key EV adoption barriers.

CHARGE SPEED	EXTENDED CHARGE	POWER DELIVERY
5 min	**9 min**	**1,500 kW**
10% → 70%	10% → 97%	at 1,000V flash charging

CHEMISTRY	ENERGY DENSITY	COST REDUCTION
LMFP	**190–210**	**15%**
Lithium manganese iron phosphate	Wh/kg at cell level	lower production cost

Source: CNEVPost March 5, 2026; CarNewsChina March 5, 2026; MLQ.ai March 6, 2026.

A CATL battery swap station on display at the Beijing Auto Show in April 2026. Credit: CnEVPost

A light-duty truck undergoes battery replacement at a CATL battery swap station. Image credit: CATL


CATL
heavy-duty truck battery swap
solution - QIJI Energy

1,080-panel, 642 kW solar array

3.5 MWh battery pack

360 kW available for charging ports

RAC developed UK's first lightweight charger to deliver a 'journey-saving' boost to EVs

GRIDSERVE Electric Forecourts. Credit: GRIDSERVE

What Actually Makes a Charging Station Profitable

Utilization	A station's return depends far more on how often it's used than on how fast it charges, an idle ultra-fast charger loses money faster than a busy slow one.
Specification Vs Demand	Placement of charger and high demand (shopping centers, highways, fleet routes) matters more than chasing the highest kW rating available.
Revenue Stacking	The best sites layer charging fees with advertising, partnerships, food courts, and demand-response payments.
Uptime Protects Trust	A broken charger doesn't just lose one sale, it damages driver confidence in the entire network, and in EVs generally.
Phase the Capex	Modular BESS - operators must start small and scale with real demand instead of overbuilding upfront.

Renewable-Integrated & Grid-Resilient Charging

For SAARC countries with constrained or unreliable grids, this trend matters more than any other on this list.

Solar Integration at Charging Hubs

Charging stations built with an on-site solar roof generate part or all of their own power, cutting grid draw and operating cost.

BESS Integrated Charging Station

An on-site battery bank charges slowly from the grid/solar, then discharges quickly to vehicles — delivering fast-charging speeds without needing a fast-charging grid connection.

Microgrids for Remote Sites

Combined solar, battery and small backup generation can power a charging station in areas the main grid doesn't reliably reach.

Resilience as a Side Benefit

The same battery buffer that enables fast charging can also keep a station (and nearby facilities) running during grid outages.

According to NERL, BESS can cut the need for grid upgrades by 50–80% at a given site.

Key Questions in Developing CI Plans

- Geography of the Country
  - Population Spread
  - Terrain
- Vehicle Usage Frequencies
- Vehicle Types and Priorities
- Traffic Movements
- Charger Type and Deployment Spread
- City Spread – Horizontal vs. Vertical
- Economic Activities
- Grid Layout and Expansion Plans
- Electricity Rate
- Funding Availability
  - Public and Private