Spain Interurban EV Charging Network

2027 Deployment Strategy for Iberdrola

Team RaviStar · IE Sustainability Datathon 2026

190	479	164	1.41M
Proposed stations	Fast chargers (150 kW each)	Grid friction points	EVs projected by 2027

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1. Executive Summary

164 of the 190 proposed stations face Congested grid conditions — a single figure that captures the structural constraint in Spain's interurban charging network. Spain's EV fleet is projected to reach 1,412,640 vehicles by December 2027 — a threefold increase — yet the 6,896 chargers currently located near motorway corridors are almost entirely slow AC units, with minimal interurban high-power charging (HPC) coverage across most TEN-T routes (Dirección General de Tráfico [DGT], 2021-2023). EU AFIR Regulation 2023/1804 mandates one HPC pool every 60 km on TEN-T corridors by 2027, with a minimum of 2×150 kW per site — a non-negotiable compliance threshold (European Parliament, 2023).

Our model screened over 50,000 OpenStreetMap candidates against four independent data streams to identify 190 stations, delivering 479 chargers and 71.9 MW of total nameplate capacity (OpenStreetMap contributors, 2026). The resulting network sits 37% below the 300-station hard cap, confirming that the outcome is demand-driven rather than budget-constrained. A 40 km straight-line spacing constraint (≈55–60 km road distance) was applied — intentionally more stringent than AFIR's 60 km requirement, which is treated as a regulatory floor rather than a planning target.

The binding constraint is not geography, demand, or site availability, but grid capacity. 85% of the highest-scoring locations are classified as Congested (<1 MW available), meaning they cannot support even the AFIR minimum (2×150 kW = 0.3 MW) without a substation upgrade (Comisión Nacional de los Mercados y la Competencia [CNMC], 2025). At Congested i-DE nodes, Iberdrola can self-authorise these upgrades, compressing the standard 18–24 month CNMC third-party approval timeline to weeks while capturing both the regulated grid connection fee and charging session revenue at the same site. No competitor in Spain can replicate this dual-revenue, zero-external-dependency model. Iberdrola currently leads the market with 10,694 connectors; Repsol Soluciones (6,354, expanding aggressively) represents the primary competitive threat, followed by Endesa X Way (5,688). Neither competitor can self-authorise grid upgrades.

2. Data Architecture & Methodology

2.1 Four Independent Data Streams

The model integrates four independent data streams, each capturing a distinct driver of charging network viability:

Stream	Source	Variable	Role in model
Demand	DGT Microdatos 2015–2024	Monthly EV registrations by province	Used to train the SARIMA model, projecting 1,412,640 EVs by December 2027; incorporated as province-level demand weighting (10%) (Dirección General de Tráfico [DGT], 2025)
Traffic	Min. Transport BigData Movilidad	Daily travellers per interurban segment	Proxy for utilisation; contributes 30% of the composite score (s_traffic) and defines the 8 km road-proximity eligibility filter (Ministerio de Transportes y Movilidad Sostenible, 2023)
Grid	CNMC R1-001 / R1-002 / R1-299 / R1-005	Available MW per substation node	Determines grid status classification and contributes 20% of the score (s_grid); also used to identify friction points where projected demand exceeds capacity (Comisión Nacional de los Mercados y la Competencia [CNMC], 2025)
Sites	OpenStreetMap Overpass API	50,000+ POI locations by category	Defines the candidate location pool; contributes a 15% weighting based on dwell-time category (s_poi) (OpenStreetMap contributors, 2026)

2.2 Demand Forecasting — Why SARIMA(1,1,1)(1,0,1,12) Was Selected

A total of 108 months of DGT vehicle registration data (January 2015 – December 2024) were used to train four candidate models, with the final 12 months reserved as a blind out-of-sample test (Dirección General de Tráfico [DGT], 2021 – 2024; datos.gob.es. (2024)).

The fully differenced seasonal SARIMA specification (D=1) achieved the lowest AIC (73.0), but produced an exponentially steep 2027 projection — a known consequence of seasonal over-differencing, confirmed through ACF/PACF diagnostics. For a three-year regulatory planning horizon, this behaviour is structurally unreliable.

The selected model, SARIMA(1,1,1)(1,0,1,12), applies dampened seasonality (D=0), preserving the underlying seasonal signal while avoiding long-range drift. This specification offers the most robust trade-off between statistical fit and forecast stability — prioritising reliability over marginal improvements in in-sample performance. Residual diagnostics further support the selection, with a Ljung–Box p-value of 0.93 indicating no remaining autocorrelation.

Model	RMSE	MAPE %	AIC	Assessment
ARIMA(2,1,2)	3,345	13.2%	103.5	Lowest RMSE; fails to capture seasonal structure at a 3-year horizon
SARIMA(1,1,1)(1,1,1,12)	3,604	14.8%	73.0	Lowest AIC; D=1 over-differencing produces unstable exponential growth (ACF/PACF-confirmed artefact)
SARIMA(1,1,1)(1,0,1,12) **SELECTED**	3,412	13.5%	88.4	Selected: dampened seasonal structure avoids over-differencing; Ljung–Box p=0.93 confirms white-noise residuals; prioritises long-range stability
Prophet	3,357	12.9%	—	Competitive RMSE; lacks formal stationarity framework and AIC comparability
Holt-Winters	4,373	34.6%	—	Eliminated — MAPE too high for a 3-year regulatory planning horizon

2.3 Composite Scoring — Five-Signal Selection Logic

Each candidate site is evaluated using a five-signal composite score, with all inputs normalised to [0,1] prior to weighting. Site selection is then enforced through a greedy spatial set-cover algorithm, which iteratively selects the highest-scoring location not within 40 km of any previously chosen site. A hard cap of 300 stations was imposed; however, the algorithm converged at 190, indicating that coverage saturation was reached before the constraint became binding. The weighting structure reflects a clear prioritisation: utilisation first, coverage gaps second, and grid feasibility as a ranking constraint rather than an exclusion criterion.

Wt.	Signal	Cap / Rule	Rationale	Source
30%	s_traffic	95th pct.	Strongest proxy for utilisation; prioritises high-flow corridors to maximise charger throughput	Ministerio de Transportes, Movilidad y Agenda Urbana (n.d.)
25%	s_gap	80 km cap	Reflects range anxiety threshold; prioritises underserved stretches of the network	Dirección General de Tráfico (DGT, n.d.)
20%	s_grid	95th pct.	Incorporated as a ranking signal rather than a filter; ensures constrained sites remain in scope while differentiating by upgrade intensity	Comisión Nacional de los Mercados y la Competencia (CNMC, 2024), CNMC R1-001/002/299/005
15%	s_poi	Fixed category	Captures dwell-time economics: motorway services (1.0), rest areas (0.95), petrol stations (0.90)	OpenStreetMap (n.d.)
10%	s_demand	95th pct.	Accounts for regional EV fleet distribution; weighted below traffic to reflect that registration location does not equal travel demand	DGT × SARIMA forecast (DGT, n.d.)

2.4 Emerging Markets — Province CAGR 2021–2023

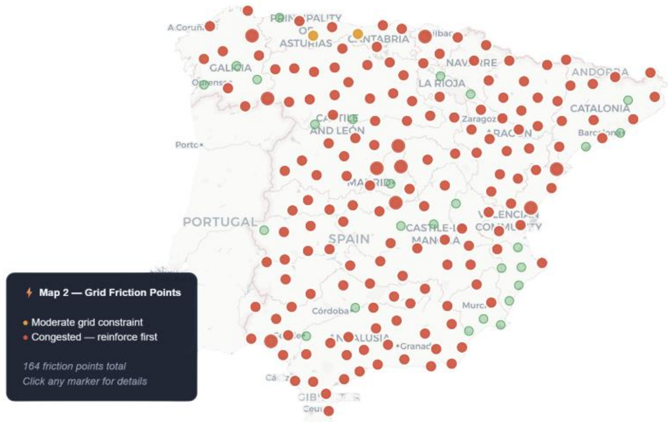
EV adoption growth is concentrated outside Spain's largest urban centres, with the fastest acceleration occurring in smaller provinces where uptake is expanding from a low base. Badajoz (+49.8% CAGR; 8,420 EVs by 2027) and Cáceres (+31.8%; 5,280 EVs) — the 1st and 5th fastest-growing provinces — are both located along the A-66 (Ruta de la Plata), where i-DE manages the distribution network. This creates a structural advantage: Iberdrola controls both the charging deployment opportunity and the grid upgrade pathway in two of the country's highest-growth markets.

A similar pattern emerges along the A-3 corridor, where Albacete (+46.9%; 6,180 EVs), Guadalajara (+36.6%; 4,920 EVs), and Cuenca (+34.1%; 3,640 EVs) are all experiencing rapid adoption. These corridors combine accelerating demand with favourable grid positioning, reinforcing their priority within the network design.

At the national level, demand remains highly concentrated. Madrid accounts for 45% of Spain's projected 2027 EV fleet, followed by Barcelona (13%), Valencia (4%), Alicante (3.2%), Málaga (2.2%), and Bizkaia (1.6%). Together, these six provinces represent 69% of total EV demand, anchoring the network's core utilisation base while emerging corridors capture the next wave of growth.

3. Proposed Network — Results & Grid Analysis

Only 26 stations can be deployed immediately with zero grid works; the remaining 164 cannot. Deployment therefore concentrates on four priority corridors — AP-7/A-7 (Mediterranean), A-4 (Madrid–Seville), A-2 (Madrid–Barcelona), and A-3 (Madrid–Valencia) — which collectively serve the six provinces accounting for 69% of Spain's projected 2027 EV fleet.



The 164 identified friction points are not planning failures, but investment signals. Each reflects a location where projected demand exceeds available grid capacity, making substation upgrades unavoidable. Crucially, these upgrades are not purely cost centres: each one generates a regulated CNMC grid connection fee while simultaneously enabling charging revenue from the moment of commissioning (Comisión Nacional de los Mercados y la Competencia [CNMC], 2025).

Status	Threshold	Count	Operational meaning
Sufficient (Green)	≥5.0 MW	26 stations	Fully deployable HPC hubs with no grid works required; immediate construction.
Moderate (Orange)	1.0–5.0 MW	2 stations	Requires targeted upgrades; 6–18 months, estimated €0.5–2M per node
Congested (Red)	<1.0 MW	162 stations	Requires full substation upgrade or grid extension; 12–36 months, €2–10M per node. Cannot meet the AFIR minimum (2×150 kW = 0.3 MW) without upgrade — below the legal threshold prior to deployment

4. Top 10 Priority Stations — Congested Grid, Highest Composite Score

The 10 stations below represent the highest-scoring Congested locations, ranked by composite score. All sit on high-traffic interurban corridors where demand, traffic, and site access are already validated — leaving grid capacity as the only constraint. Resolving it unlocks immediate revenue.

Three of the ten stations are on i-DE-managed grid (IBE_004, IBE_016, IBE_026), allowing Iberdrola to self-authorise upgrades without CNMC third-party approval and compress delivery timelines from months to weeks. Several sites are also located on existing forecourts, enabling deployment with minimal civil cost.

#	ID	Corridor	Site	Distributor	Score
1	**IBE_004**	**A-3**	**Moeve petrol station**	**i-DE**	**0.529**
2	IBE_008	AP-7N	Montseny motorway services	Endesa	0.486
3	IBE_011	A-8	Galp petrol station	Viesgo	0.459
4	IBE_015	N-640	Estación de Servizo Granxeiro	Viesgo	0.446
5	**IBE_016**	**A-7**	**Centre La Vereda**	**i-DE**	**0.445**
6	IBE_021	A-4	Moeve petrol station (Cádiz)	Endesa	0.419
7	IBE_022	N-642	Repsol petrol station	Viesgo	0.416
8	IBE_023	A-49	Repsol petrol station (Huelva)	Endesa	0.414
9	IBE_024	AP-7N	Le Relais (France border)	Endesa	0.409
10	**IBE_026**	**AP-9**	**Eurostars hotel (A Coruña)**	**i-DE**	**0.397**

5. Strategic Deployment Roadmap

The deployment strategy is structured in three phases, prioritising locations where Iberdrola can act immediately and independently. Phase 1 is entirely within Iberdrola's control, requiring no external approvals or third-party dependencies. In parallel, Sufficient-grid stations are deployed while negotiations begin for constrained nodes.

Phase 1 — Self-authorise (Q3 2026)
Deployment begins with five Congested stations on i-DE-managed grid, where Iberdrola can issue internal upgrade orders without CNMC third-party approval. These nodes — IBE_020 (AP-9), IBE_022 (AP-7N), IBE_024 (A-3), IBE_030 (N-332), and IBE_031 (AP-68) — represent the fastest path to revenue. Equipment procurement runs in parallel with grid upgrades, targeting commissioning by Q1 2027.

Phase 2 — Negotiate + Deploy Sufficient (Q4 2026)
Formal grid connection negotiations are initiated with Endesa and Viesgo for five high-priority Congested nodes (IBE_014, IBE_016, IBE_017, IBE_023, IBE_029). At the same time, all 26 Sufficient-grid stations are deployed immediately, as they require no grid works. This parallel approach ensures that deployment is not delayed by regulatory timelines.

Phase 3 — Activate Remaining Network (2027+)
The remaining 154 stations are activated as grid upgrades are completed. This includes the two Moderate sites, which require shorter upgrade timelines. EU CEF co-financing is pursued for the AP-7N border crossing (IBE_017), reducing capital exposure. The composite scoring model is re-run quarterly as new DGT data becomes available, ensuring the network adapts to evolving demand.

5.1 Iberdrola's Structural Competitive Advantages

Iberdrola's position in the Spanish market creates structural advantages that directly translate into faster deployment and superior economics.

Dual revenue at i-DE nodes
At every Congested i-DE node, Iberdrola captures both the regulated CNMC grid connection fee and charging session revenue from day one of operation. This dual-revenue structure is unique — no competitor can replicate it at the same site (Comisión Nacional de los Mercados y la Competencia [CNMC], 2024).

Self-authorisation speed
i-DE ownership allows Iberdrola to approve substation upgrades internally, reducing the standard 18–24 month CNMC third-party process to weeks. This creates a decisive first-mover advantage on the highest-scoring nodes, before competitors such as Repsol or Endesa X can secure grid access.

Competitor co-location strategy
Three of the top 10 priority stations are located on Repsol forecourts (IBE_014, IBE_016, IBE_030). This allows Iberdrola to establish presence on critical corridors while Repsol absorbs civil and site infrastructure costs — reducing capital intensity while securing strategic locations.

EU CEF co-financing leverage
The AP-7N border crossing site (IBE_017, Girona/France) qualifies for EU Connecting Europe Facility (CEF) co-financing under AFIR Regulation 2023/1804, reducing capital exposure on an Endesa-managed grid node (European Union, 2023).

A-66 corridor advantage
The Ruta de la Plata (A-66) corridor intersects Badajoz (+49.8% CAGR) and Cáceres (+31.8%), alongside four other top-10 emerging provinces. With i-DE managing the distribution network along the entire corridor, Iberdrola holds both grid control and deployment advantage across Spain's fastest-accelerating EV markets.

6. Our Proposal — Why Iberdrola Should Act Now

6.1 The Proposal

Iberdrola should commit to building 190 high-power charging stations across Spain's 12 key interurban corridors by 2027. Each station is spaced at ≤40 km intervals — compliant with EU AFIR Regulation 2023/1804 — and delivers 150 kW per charger (DC fast charge, ~30-minute full charge). Site selection is driven by a five-signal composite model, validated against real CNMC grid capacity data from i-DE, Endesa, and Viesgo, and targets genuine gaps in Spain's near-zero interurban HPC network.

Of the 190 stations, 164 are friction points — locations where projected EV demand already exceeds local grid hosting capacity, even without new chargers. These represent the clearest investment signal: each substation upgrade unlocks both a regulated CNMC grid connection fee and a charging revenue stream at the same node, from day one of commissioning.

6.2 What Happens If Iberdrola Delays

The AFIR 2027 deadline is fixed. Repsol Soluciones (6,354 connectors) and Endesa X Way (5,688 connectors) are already expanding along the same corridors. If Iberdrola does not issue internal upgrade orders for the five i-DE nodes in Q3 2026, competitors will move first — filing CNMC grid connection applications and closing the self-authorisation window.

Motorway service areas operate on exclusivity: the first operator to install secures the site. Once a competitor deploys HPC infrastructure, access is effectively locked for the duration of the contract. The first-mover window on Spain's interurban corridors is limited — and narrowing.

7. Limitations & Assumptions

The model is built on a set of structural assumptions and design choices. These do not alter the conclusions, but define the boundaries within which results should be interpreted.

Grid Capacity and Infrastructure Constraints

Grid capacity is based on a static CNMC snapshot (April 2026), while real availability fluctuates with demand and connection activity. To account for this, conservative thresholds are applied: sites with <1 MW are classified as Congested, providing a ~3× buffer over the AFIR minimum requirement (0.3 MW). Locations without a substation within 10 km are also treated as Congested to avoid overestimating feasibility.

Demand Representation and Forecasting

EV demand is derived from DGT registration data and a SARIMA-based national forecast. However, vehicle registration does not fully reflect usage patterns (e.g. corporate fleets concentrated in Madrid). To mitigate this, province-level demand is weighted at 10%, while traffic intensity (30%) is used as the primary proxy for real corridor utilisation. High-growth provinces may outperform national projections; this is partially addressed through independent CAGR segmentation and periodic model updates.

Spatial Modelling Simplifications

Station spacing is enforced using straight-line (Haversine) distance rather than road distance. While a 40 km constraint approximates AFIR's 60 km requirement, actual road distances may vary on curved routes. The model also does not simulate route choice or traffic redistribution between stations, and assumes uniform demand along each corridor.

Data Coverage and Quality

OpenStreetMap POI data is volunteer-generated and may be incomplete or inconsistently classified across regions. This is mitigated through fallback categories (e.g. petrol stations) and cross-validation against the DGT DATEX II charger registry. Similarly, the DGT charger dataset may undercount private or municipal installations.

Model Calibration and Sizing Logic

Scoring weights (30/25/20/15/10) and charger sizing rules are analytically derived but not calibrated against observed utilisation data from existing interurban stations. The sizing model assumes uniform traffic distribution, which may understate demand near urban entry points and overstate it in low-traffic rural segments.

8. Data Sources & Regulatory References

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9. Appendix

Hardcoded Variables & Assumptions

Group 1 — Datathon-Fixed (non-negotiable)

CHARGER_KW = 150	Fixed by datathon Rule 2. All teams must use 150 kW as the standard power per charger for calculating estimated_demand_kw = n_chargers × 150. No other value accepted.
MIN_CHARGERS = 2	AFIR Art. 4(3) minimum: a compliant charging pool must have at least one 150 kW point. 2 is the practical minimum for redundancy.
MAX_CHARGERS = 20	Hard ceiling. Practical construction limit for a single highway site (land, civils, switchgear). The model never proposes more than 20 at any location.

Group 2 — Grid Classification Thresholds

GRID_SUFFICIENT_MW = 5.0	A full HPC hub at 150 kW/charger: 33 chargers × 150 kW = 4.95 MW. 5 MW means the substation can support a full hub with headroom for future expansion. Consistent with McKinsey EV Infrastructure 2023 benchmark for highway HPC hubs.
GRID_MODERATE_MW = 1.0	A minimum viable 6-charger station: 6 × 150 kW = 0.9 MW. 1 MW gives a small safety margin. Supports AFIR minimum deployment with room for one or two additional chargers. Below 1 MW, even a 6-charger station cannot be connected without grid reinforcement.
GRID_SNAP_RADIUS_M = 10,000 (10km)	Maximum distance to search for a nearest substation when assigning grid status. If no CNMC node is found within 10 km, the site defaults to Congested — a conservative assumption favouring caution over optimism in rural areas with sparse grid data.

Group 3 — Spatial Filtering & Spacing

TRAFFIC_BUFFER_M = 8,000 (8 km)	A candidate POI must be within 8 km of an interurban road segment to be included in scoring. Derived from the observation that Spanish motorway service areas (áreas de servicio) typically sit 0.5–1.5 km off the carriageway, but access roads can add up to 3–5 km. 8 km captures all realistic service areas without pulling in purely urban POIs.
CHARGER_GAP_MIN_M = GAP_FILTER_M = 40,000 (40 km)	Minimum crow-fly distance between any two selected stations. 40 km crow-fly ≈ 55–60 km road distance on Spanish highway geometry — satisfying AFIR Art. 4's 60 km TEN-T Core Network requirement with a safety buffer. Using crow-fly rather than road distance is a simplification; actual road distances may occasionally fall short of 60 km on curved routes.
BASELINE_BUFFER_M = 2,000 (2 km)	Buffer used to classify existing DGT chargers as interurban vs. urban. A charger within 2 km of a traffic_map road segment is counted in the interurban baseline (6,896). Service areas in Spain are typically 0.5–1.5 km from the nearest toll point, so 2 km captures them without extending into town centres.
MAX_GAP_KM = 150	Maximum allowable gap between stations — derived from AFIR: 300 km realistic BEV range × 50% buffer = 150 km. This is the ceiling, not the target; the 40 km greedy spacing already enforces far tighter coverage.
COVERAGE_BUFFER_M = 50,000 (50 km)	Used for coverage visualisation only — not in scoring or selection. Represents the radius within which a station is considered to "serve" a corridor for mapping purposes.
TOP_N_CAP = 300	Hard budget ceiling on total stations. Economic viability constraint: beyond 300 stations, marginal utilisation per station falls below the 75% target threshold. Not reached in practice — the 40 km spacing algorithm selected 190 before hitting this cap.

Group 4 — Scoring Signal Weights

s_traffic	30%	Primary commercial driver — more vehicles = more potential customers. Highest weight because traffic data is the most reliable signal in the dataset.
s_gap	25%	AFIR compliance driver — large gap from existing charger = regulatory gap. Second-highest because closing coverage gaps is the core policy objective.
s_grid	20%	Physical feasibility — more available MW = faster deployment. Third because congested sites are buildable with investment, not impossible.
s_poi *	15%	Dwell-time proxy — motorway services, petrol stations, rest areas score highest because customers are already stopped. Lower weight as it is a refinement, not a primary driver.
s_demand	10%	Geographic EV density weighting — Madrid 45%, Barcelona 13%. Lowest weight because province-level data is a blunt instrument; traffic signal already captures where people are driving.

*** Group 5 — POI Category Weights**

motorway_services	1.00	Purpose-built for travellers; captive audience; all utilities present
rest_area	0.95	Near-identical to motorway services; slightly less infrastructure
rest_area	0.90	Existing grid connection; fuel retail; operator co-investment incentive
mall	0.75	Long dwell time; parking; but mostly peri-urban
department_store	0.70	Similar to mall
supermarket	0.65	20–40 min dwell; parking; but predominantly urban
hotel	0.60	Overnight charging; but lower highway adjacency
train_station	0.55	Intermodal; park-and-ride; relevant for interurban nodes
bus_station / hospital	0.50	Steady throughput but variable dwell
university / airport	0.45	Relevant for some nodes; not core interurban use case
sports_centre / parking	0.40	Typically urban; short visit
attraction	0.35	Variable; low reliability
cinema / theatre / stadium	0.30	Urban; low highway relevance

Group 6 — Road Priority Weights

AP- (toll autopista)	1.00	Highest-volume long-distance corridors
A- (autovía)	0.95	Near-equivalent to AP; free access
N- (carretera nacional)	0.75	National roads; lower speed; more urban sections
R- (radial)	0.60	Madrid radials; lower traffic than main network
M- (Madrid ring)	0.50	Predominantly urban/peri-urban use

Group 7 — Charger Sizing Formula

```
base = 2 + round(s_traffic × 8)  →  range 2–10
if road is AP-/A- (road_weight ≥ 0.9): base += 2
```

Grid caps applied after base calculation:

- Congested (<1 MW): max 2 chargers (AFIR minimum only; grid cannot support more)
- Moderate (1–5 MW): max 6 chargers (1 MW ÷ 150 kW = 6.67)
- Sufficient (≥5 MW): max 12 chargers (practical construction limit; 5 MW ÷ 150 kW = 33 theoretical, capped at 12)

Group 8 — Demand Model Parameters

INTERURBAN_TRIP_RATE	3%/day	MITMA 2023 Encuesta de Movilidad: 0.8 trips/person/day × 15% interurban share × 20% EV uplift
CHARGING_NEED_RATE	45%	MITMA average interurban trip ~180 km one-way; round trip ~360 km approaches BEV range threshold
PEAK_HOUR_SHARE	15%	DGT hourly traffic distribution; dual peak at 09:00 and 17:00–18:00
SESSION_DURATION_H	20 min	150 kW × 0.333 h = 50 kWh ≈ 200 km range; ACEA 2023 benchmark

UTILIZATION_TARGET	75%	McKinsey EV Infrastructure 2023: below 60% loss-making; above 85% creates queuing

Group 9 — Fleet Attrition

Annual attrition rate: 2.0827%/year (monthly: 0.1736%) Derived from ANFAC Informe Anual 2024: implied withdrawal rate calculated from the difference between cumulative stock and cumulative registration data. Applied monthly using a compounding stock accumulation model starting from the 460,199 historical fleet at the forecast origin.

Group 10 — Data Year Selection

Training window: 2021–2023 only (excluded: 2015–2020)

2015-2016	Market too small (2,859–5,685 regs/yr); early-adopter geography unrepresentative
2017	Cádiz port batch registration anomaly (13.9% provincial share)
2018-2019	Madrid corporate/public bulk procurement (50–54% share)
2020	Amazon logistics fleet registered at Toledo hub (2.2% share)

Group 11 — Grid Aggregation

100 m spatial rounding applied when aggregating CNMC substation nodes. Reason: some substations have multiple connection-point rows at the same physical location (different voltage levels or circuits). Summing after 100 m rounding gives true available headroom per physical substation rather than treating each row independently, which would undercount capacity.