How the density of kerbside charging sites impacts utilisation

Concise technical note for ECA

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1. Executive summary

This study investigated how nearby charging infrastructure influences utilisation of public EV charging stations across the Eastern Suburbs Councils charging network.

The analysis examined both AC and DC charging infrastructure using network-based service area catchments (rather than simple circular buffers) at 1 km, 2 km and 5 km scales. Nearby charger density was quantified using charging spaces (CS), charger counts, power capacity and utilisation-weighted metrics.

A clear distinction emerged between AC and DC charging behaviour. AC charging exhibited relatively weak relationships with surrounding charger density and appeared to operate primarily as a local neighbourhood charging service. The strongest AC relationships occurred at approximately 1 km, suggesting that most demand is captured locally and that broader network effects are limited.

In contrast, DC charging exhibited strong network-scale interactions. Utilisation increased with local charger density up to an optimum before declining at higher densities. The most robust and consistent results occurred at the 2 km scale, with maximum utilisation observed at approximately 35 charging spaces within a 2 km network catchment.

A secondary 5 km effect was also identified. While 2 km density determines the position of the utilisation peak, broader 5 km density influences the decline beyond the optimum, indicating competition between overlapping charging catchments.

These findings suggest that AC and DC infrastructure should be planned differently. AC infrastructure appears suited to neighbourhood-scale deployment and destination charging, whereas DC infrastructure should be planned as part of a coordinated network where charger spacing and clustering directly affect performance.

Key planning implications include:

- AC charging appears to function as local neighbourhood infrastructure with limited sensitivity to broader network density.
- DC charging exhibits an optimal density range, beyond which additional nearby infrastructure may reduce utilisation.
- Approximately 35 charging spaces within 2 km represents the highest-performing density observed in the current dataset.

- Broader network density within 5 km influences competition effects and should be considered in future deployment planning.
- Charger co-location improves performance but may require future availability management as utilisation increases.

Key takeaways

2 km defines the local behavioural catchment for DC utilisation, while 5 km captures broader network overlap and competitive pressure.

The co-location analysis explains how site design and dedicated parking affect whether that demand can be converted into useful charging throughput.

2. Report structure

This report focuses on two connected results:

1. Proximity-radius analysis: quadratic fit, method and assumptions, and map view of 2 km and 5 km service areas around council chargers.
2. Co-location analysis: utilisation as a function of charging spaces and dedicated parking, supported by simple availability / full-occupancy probability calculations.

Section	Core message	Recommended figures
Proximity modelling	DC performance follows a non-linear density relationship, with an indicative optimum around 35-40 nearby CS within 2 km.	Quadratic fit; nested 2 km / 5 km plot; 2 km and 5 km map overlays.
Spatial interpretation	2 km captures local behaviour; 5 km captures broader network overlap and competitive pressure.	Service-area map; overlapping catchment map; nested density curves.
Co-location / availability	Operational design matters: CS, dedicated parking, and charger type shape throughput and availability.	3 aligned bar charts; availability probability; fully occupied probability.
Policy implications	AC and DC should not be planned using the same spacing logic: AC is neighbourhood-oriented, while DC requires network optimisation.	Summary table; design archetype matrix.

3. Methodology and assumptions

3.1 Data Structure and Spatial Framework

The analysis combines charger session performance data, site metadata, and nearby charger network characteristics to investigate how local and regional charging infrastructure influences utilisation. The primary performance metrics are daily use-hours per charging space and daily energy delivered per charging space, allowing utilisation and throughput to be compared consistently across sites of different sizes.

The analysis was undertaken using both AC and DC charging infrastructure, with particular emphasis on DC chargers due to the stronger and more interpretable network effects observed in the data.

The primary variables used throughout the analysis include:

- **Performance metrics:** use_hr_day_per_cs and kwh_day_per_cs
- **Primary proximity variables:** nearby charging spaces (CS) and nearby charger site counts within 1 km, 2 km and 5 km catchments
- **Secondary network variables:** nearby installed power, charging capacity, nearest charger distance, and Neighbouring Utilisation Index (NUI)[1]
- **Context variables:** site maturity, charger type (AC/DC), and surrounding land-use indicators including apartments, shops, parks and beaches
- **GIS catchment layers:** 0–2 km, 2–5 km and 0–5 km service-area summaries, with population and socio-economic variables available for future refinement

3.2 Network-Based Catchment Delineation

Unlike traditional proximity studies that rely on Euclidean (straight-line) buffers, this study uses network-based service areas derived from the OpenStreetMap (OSM) road network. All proximity metrics, nearby charger counts, charging-space densities, nearest charger distances, and catchment summaries were calculated using road-network distances rather than geometric circles.

This approach provides a more realistic representation of charger accessibility by accounting for actual travel paths, road connectivity, one-way streets, physical barriers and urban road hierarchy. Consequently, the resulting catchments more closely reflect how EV drivers interact with charging infrastructure in practice.

The network-based approach is particularly important for interpreting charger competition and overlap effects, as it improves the spatial precision of density calculations and provides a more robust basis for future infrastructure planning and optimisation studies.

[1] Appendix A

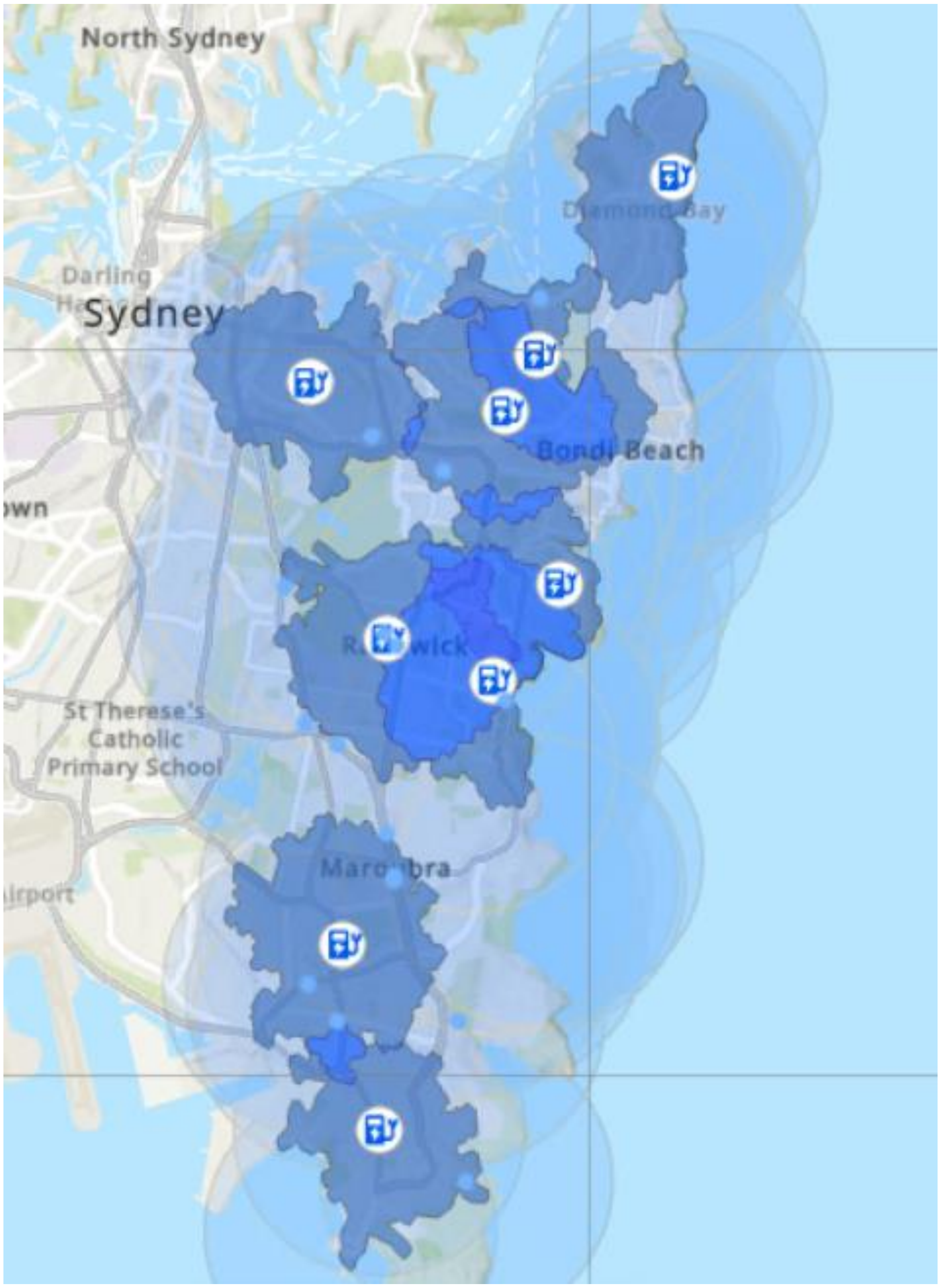


Figure 1. Precision comparison between Euclidean buffer and Road distance for 2km catchments of DC chargers

3.3 Why Charging Spaces Were Selected as the Primary Density Metric

Several proximity metrics were tested, including charger count, charging spaces, installed power and capacity. While charger count is intuitive and easy to communicate, it treats a single-port charger and a multi-port charging hub as equivalent.

Charging spaces provide a more operationally meaningful measure because they represent the number of simultaneous charging opportunities available within the surrounding network. As a result, charging spaces were adopted as the primary density variable throughout the analysis, with charger count retained as a sensitivity check.

This decision also aligns with the practical planning objective of understanding how much charging opportunity exists within a catchment rather than simply counting physical sites.

3.4 Radius Selection and Spatial Scales

Three spatial scales were examined:

- **1 km:** local neighbourhood catchment
- **2 km:** intermediate behavioural catchment
- **5 km:** broader network and competition context

The analysis found that different charger technologies appear to operate at different spatial scales. AC charging exhibited the strongest relationships at approximately 1 km, while DC charging displayed the clearest and most consistent relationships at approximately 2 km. The 5 km radius was found to provide important contextual information regarding broader network density and overlapping service areas.

3.5 Quadratic Modelling Framework

The central modelling question was whether increasing nearby charging infrastructure continuously improves utilisation, or whether benefits eventually diminish as neighbouring chargers begin competing for the same demand pool.

To investigate this behaviour, quadratic regression models were applied to charger density variables across multiple radii.

A quadratic relationship is particularly suitable because it can capture three distinct phases:

- **Low density:** additional chargers improve visibility, accessibility and network usefulness
- **Moderate density:** utilisation reaches an optimal operating range or "sweet spot"
- **High density:** nearby chargers increasingly compete for the same demand pool, resulting in saturation or declining utilisation

This framework provides a simple but interpretable method for identifying potential optimal charger densities and assessing whether network competition effects are present.

3.6 Interpretation and Limitations

The DC-only sample size is relatively small (n = 9), and therefore the estimated optimal density values should be interpreted as indicative planning insights rather than definitive thresholds.

However, confidence in the findings is strengthened by the consistency of the observed structure across:

- utilisation and energy metrics,

- charging-space and charger-count formulations,
- multiple modelling approaches,
- and nested 2 km and 5 km analyses.

Consequently, the focus of this study is not on identifying a precise optimal density value, but rather on demonstrating the existence of a meaningful relationship between charger density, utilisation and network competition effects.

Interpretation caution

The DC-only sample size is small (n = 9), so the optimum should be reported as indicative rather than definitive. The strength of the result is that the same structure appears across charging-space and site-count formulations, and across utilisation and energy metrics.

4. Proximity-radius analysis

4.1 Main finding: 2 km is the clearest behavioural radius for DC utilisation

The strongest and most interpretable DC-specific result is the 2 km charging-space model. Daily use-hours per charging space increase with local charging-space density up to approximately 35 charging spaces within 2 km, after which utilisation begins to decline. The energy model gives a similar optimum at approximately 37 charging spaces within 2 km.

Metric	Radius	Density variable	Indicative optimum	Model fit / interpretation
DC utilisation	2 km	Nearby charging spaces	~35.3 CS	Quadratic R2 approx. 0.48; strongest behavioural interpretation.
DC energy	2 km	Nearby charging spaces	~37.2 CS	Quadratic R2 approx. 0.36; similar optimum supports consistency.
DC utilisation sensitivity	2 km	Nearby site count	~22.9 sites	Quadratic R2 approx. 0.56; cleaner site-count sensitivity.
DC energy sensitivity	2 km	Nearby site count	~23.6 sites	Quadratic R2 approx. 0.52; aligns with ~25-site interpretation.

DC energy context	5 km	Nearby charging spaces	~213 CS	Quadratic R2 approx. 0.46; better treated as regional context, not local planning radius.

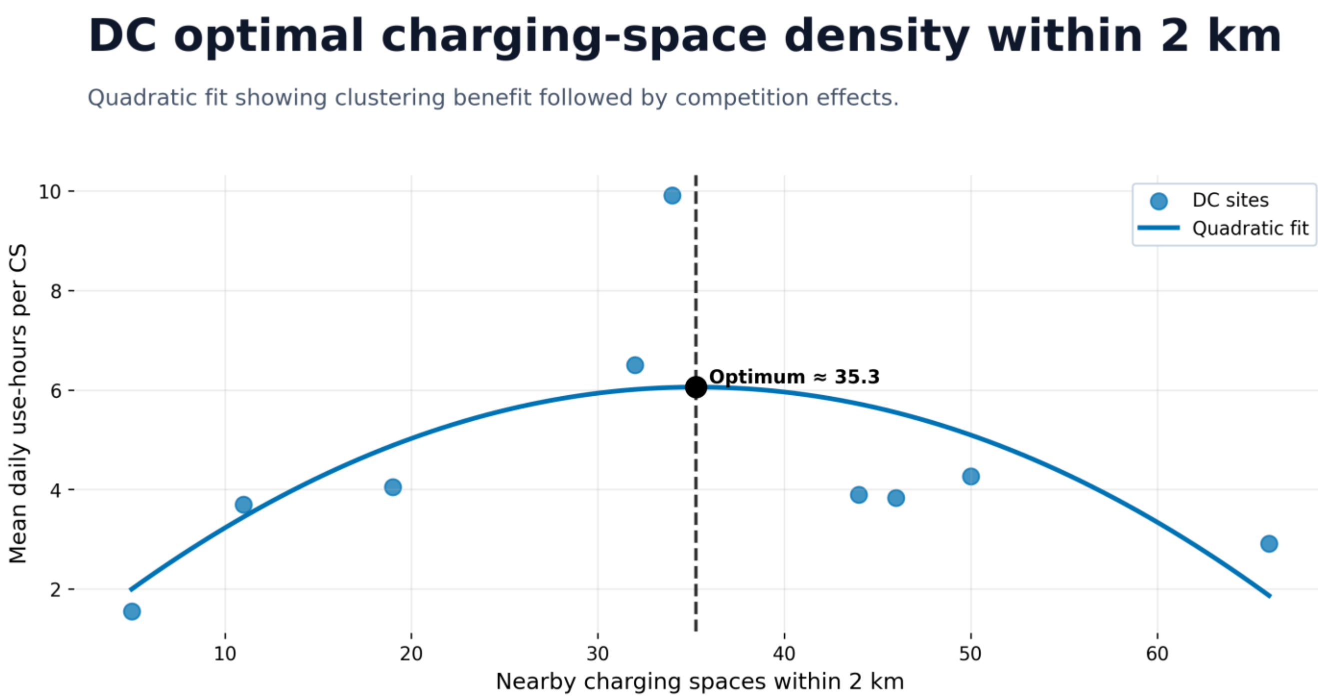


Figure 2. DC quadratic fit: daily use-hours per CS versus nearby charging spaces within 2 km.

4.2 Nested density result: 2 km defines the local peak, 5 km explains spread around it

The nested plots show that two sites can have similar 2 km density but different performance depending on the broader 5 km network context. This supports the interpretation that 2 km captures the local behavioural catchment, while 5 km captures wider overlap and competitive pressure from neighbouring clusters.

- 2 km density primarily determines the position of the utilisation peak.
- 5 km density helps explain why sites around or beyond the peak spread vertically in performance.
- Higher 5 km density is associated with lower utilisation for some sites on the right-hand side of the curve, suggesting broader competition or overlapping service areas.
- The result supports moving from simple gap mapping toward network-aware deployment planning.

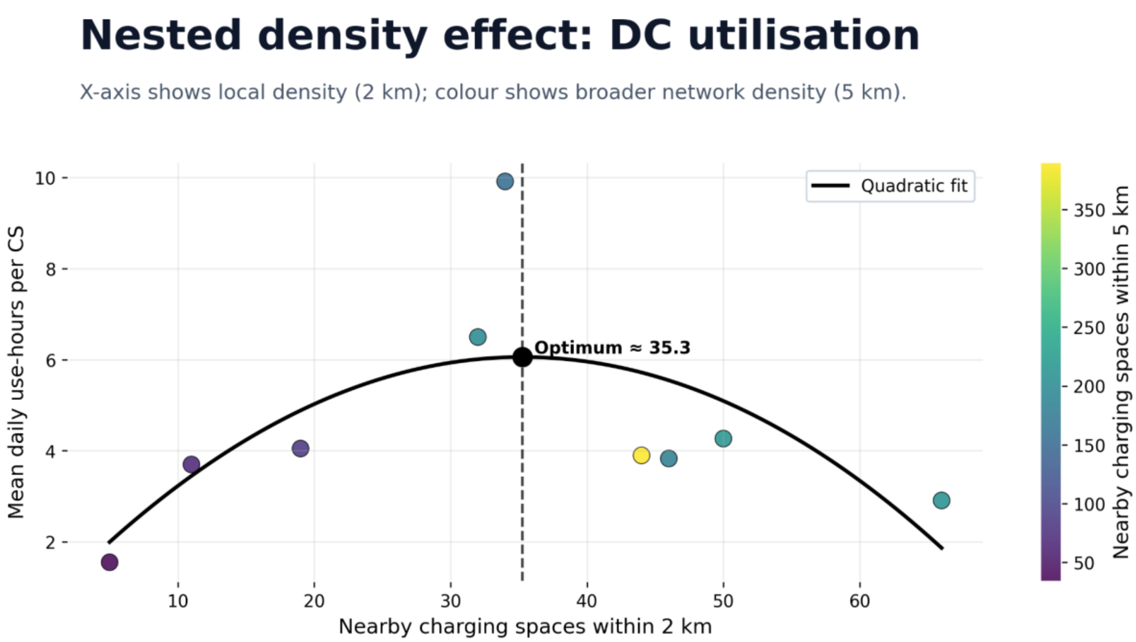


Figure 3. Nested density effect: DC utilisation versus 2 km charging-space density, with colour showing broader 5 km charging-space density.

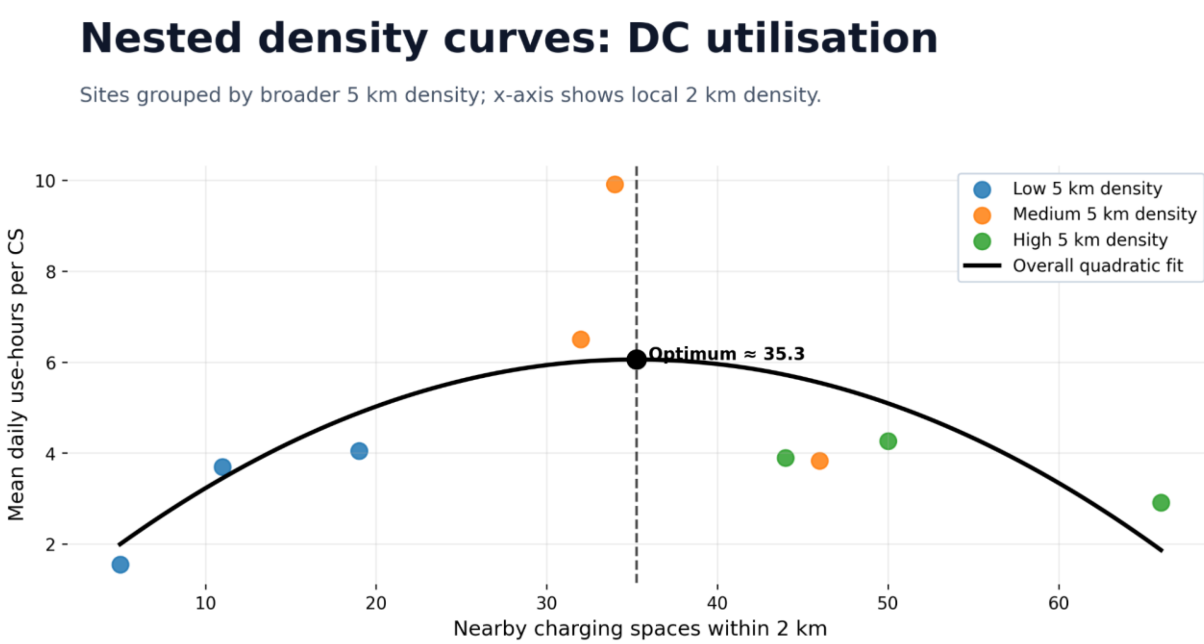


Figure 4. Nested density curves: DC sites grouped by broader 5 km density. This provides a clearer categorical view of how regional network context modifies the 2 km relationship.

4.3 AC Sites operates at neighbourhood scale (~1 km)

The AC analysis was undertaken to determine whether charger utilisation is influenced by surrounding charging infrastructure in a similar manner to DC charging.

The same methodology applied to DC chargers was used for AC chargers, including analysis of nearby charger density, nearest charger distance, utilisation, energy throughput and network catchment characteristics.

4.4 Spatial Behaviour of AC Chargers

The AC results reveal substantially weaker spatial structure than observed for DC chargers.

Across the network, AC sites with similar surrounding charger densities frequently exhibited very different utilisation outcomes. Likewise, high-performing and low-performing AC sites were observed across a broad range of local charger densities.

This suggests that AC utilisation is not strongly governed by surrounding network density.

Instead, AC performance appears to be influenced primarily by local site characteristics, including:

- Residential charging demand
- Apartment density
- Parking availability
- Destination attractiveness
- Dwell-time behaviour
- Local land-use characteristics

The strongest relationships were observed at approximately 1 km, indicating that AC charging largely operates as a local neighbourhood service rather than a network-scale service.

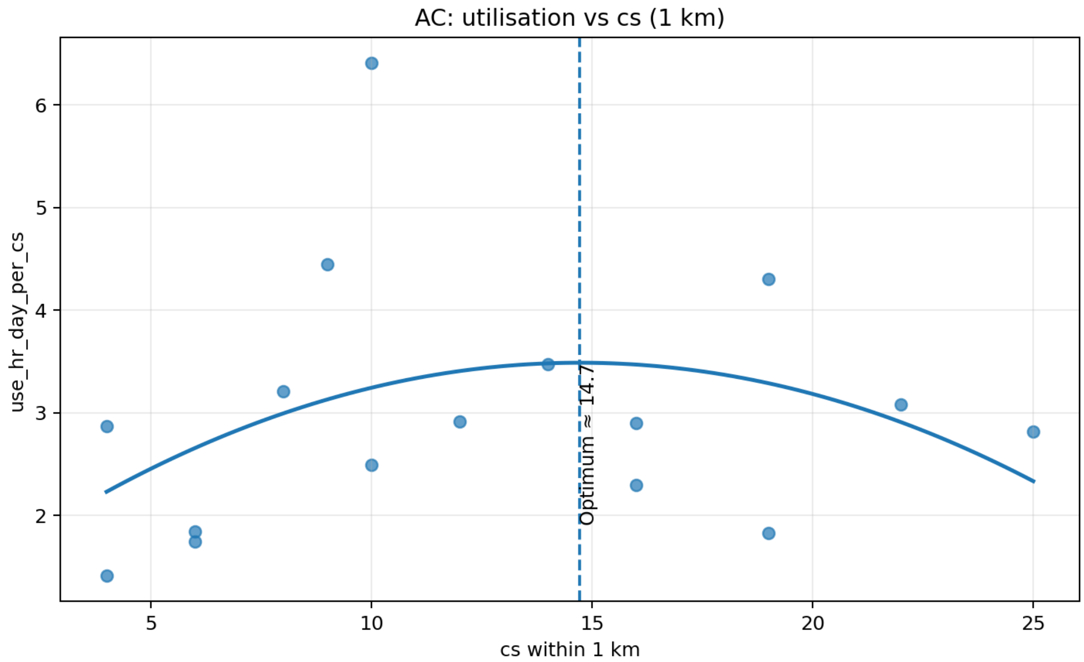


Figure 5. Nested density curves: AC sites grouped by broader 1 km density.

Find more detailed results on AC sites behavior on Appendix B.

4.5 Spatial maps

These maps, 2 km and 5 km radii around council chargers, should not be treated as decorative figures; they are the bridge between the regression result and the planning interpretation.

The precision of using open street mapping compared to Euclidian area mapping is clear in DC catchments and overlapping catchments areas.

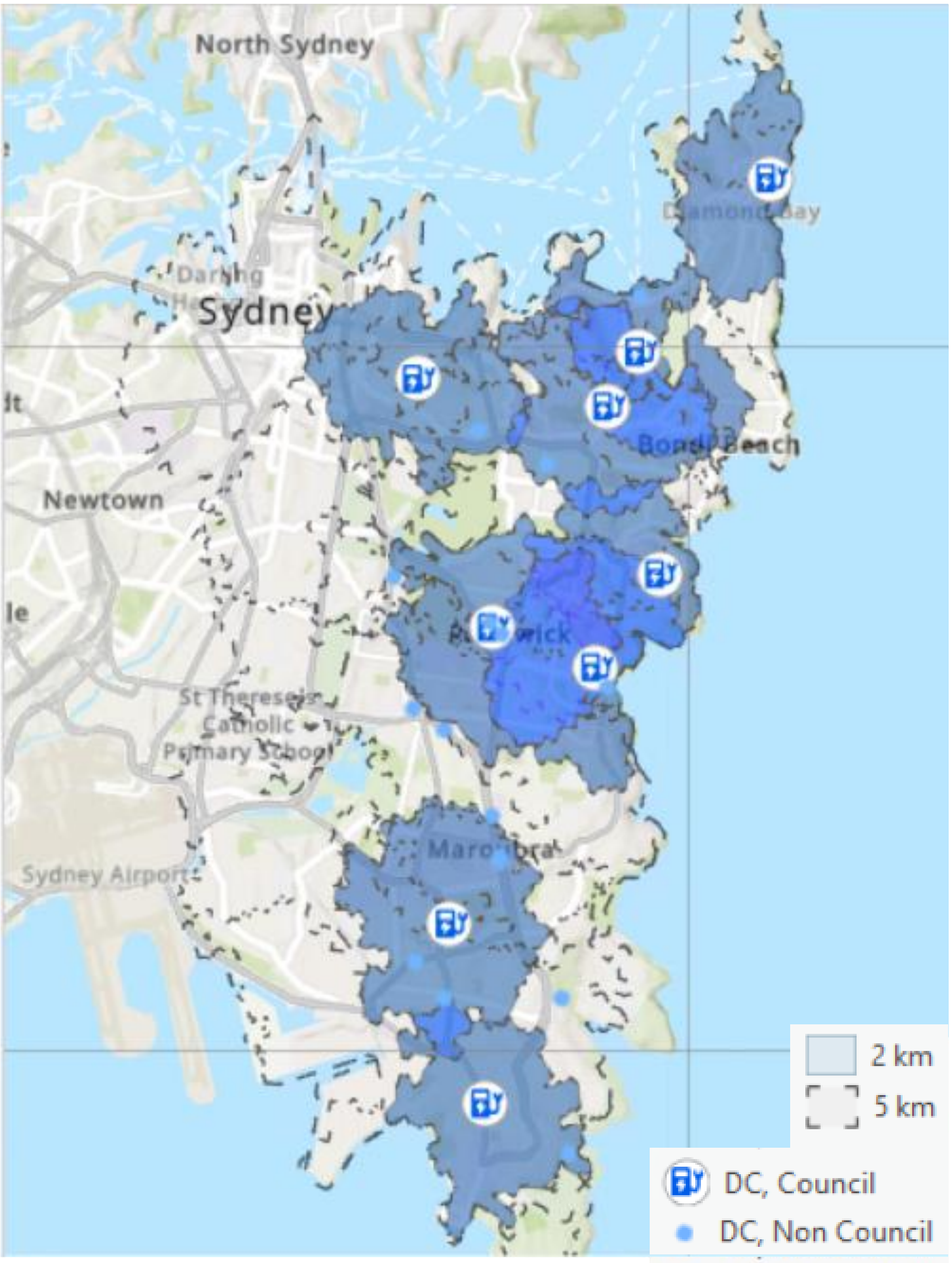


Figure 6. Combined overlap map showing 2 km local catchments and 5 km broader network context. Overlapping catchments between DC sites appear in darker blue.

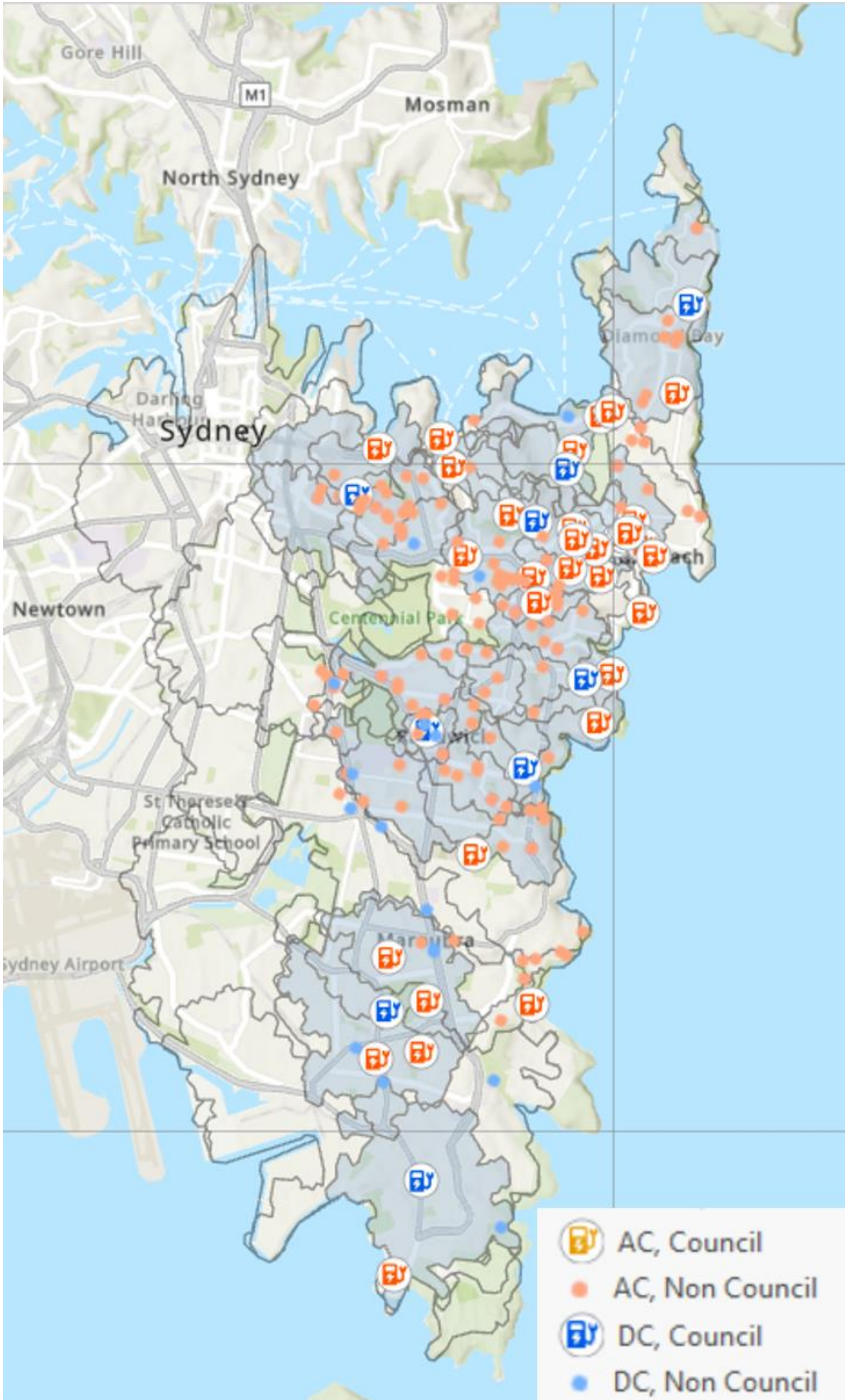


Figure 7. Whole Eastern Suburb Network. Combined overlap map showing 2 km local catchments and 5 km broader network context of DC sites.

5. Comparison of AC and DC Network Behaviour

5.1 Purpose

To understand whether charger proximity effects are consistent across charging technologies, the same spatial modelling framework was applied to both AC and DC infrastructure. Nearby charger density was evaluated at multiple radii using charger count, charging spaces (CS), and installed power as explanatory variables.

The objective was to determine whether charger utilisation is primarily influenced by local neighbourhood-scale effects or by broader network structure.

5.2 AC Charging Behaviour

Unlike DC charging, AC infrastructure did not exhibit a strong or consistent network-scale response. The strongest signal emerged at approximately 1 km, suggesting that AC charging operates primarily at a local neighbourhood scale.

The model indicates a broad optimum around:
• ~15 charging spaces within 1 km
• ~10 chargers within 1 km
• ~250 kW installed power within 1 km

However, the relationship is relatively weak compared with the DC network, with substantial variation between sites. This suggests that AC utilisation is influenced more strongly by local site characteristics than by broader charger density alone.

AC energy delivery demonstrated stronger relationships with nearby infrastructure density than charger occupancy, suggesting users distribute charging demand across multiple nearby AC chargers.

5.3 AC and DC behaves differently

The modelling suggests that AC and DC chargers should not be interpreted through the same spatial lens. AC charging appears more local and neighbourhood-based, while DC charging is more sensitive to broader network and ecosystem effects. This distinction is useful for policy because it implies different deployment strategies.

Network type	Dominant scale indicated by current models	Interpretation	Planning implication

AC	~1 km in contextual models; simple density trends are flatter	Neighbourhood / dwell-time charging; more dependent on site quality, local demand and parking access than broad network density.	Consider neighbourhood-scale AC hubs with good parking control rather than many very closely spaced small sites.
DC	2 km for utilisation peak; 5 km for wider energy/network context	Energy-hub / corridor-style behaviour; influenced by nearby charging ecosystem and overlapping demand pools.	Optimise spacing and density across local clusters; avoid assuming more nearby DC chargers always improves utilisation.
All network	5 km contextual models perform strongly	Whole charging ecosystem effect; AC and DC together reflect a broader supply/demand environment.	Use broader ecosystem modelling for strategic planning, but preserve AC/DC separation for deployment decisions.

How to word this carefully

The results do not prove a universal hub-size rule. They indicate that AC and DC networks have different dominant spatial behaviours. AC saturation at shorter radii is consistent with neighbourhood charging logic, while broader DC effects are consistent with network-optimised spacing and corridor/hub planning.

5.4 Whole-Network Analysis

The combined network exhibits a broad optimum around ~15 charging spaces within 1 km. At larger scales, an optimum around ~220 charging spaces within 5 km was identified, although interpretation is less clear because AC and DC infrastructure serve different charging behaviours.

The combined-network analysis acts primarily as a validation exercise. It confirms density effects exist across the overall network but does not provide the same behavioural clarity as analysing AC and DC separately.

5.5 Interpretation

AC chargers:
• Operate primarily at neighbourhood scale (~1 km).
• Performance appears strongly influenced by local demand and site design.
• Dedicated parking provision remains a key determinant of utilisation.

DC chargers:

• Exhibit strongest relationships around 2 km.
• Show evidence of clustering benefits followed by competition effects.
• Broader 5 km density influences how rapidly utilisation declines beyond the optimum.

5.6 Policy Implications

AC planning is primarily a local placement problem focused on accessibility and destination convenience.

DC planning is primarily a network optimisation problem. Moderate clustering improves utilisation, while excessive concentration may introduce competition between nearby sites. Planning should therefore consider both local catchment density (~2 km) and broader network context (~5 km).

This distinction provides a useful framework for future public charging deployment strategies.

6. Co-location and availability analysis

6.1 Why this analysis was added

The proximity model explains how the surrounding network affects a charger. The co-location analysis explains how the site itself is designed. This was added in direct response to the request to examine utilisation as a function of the number of charging spaces at council sites.

The analysis groups sites into seven operational archetypes based on charging spaces, dedicated parking spaces and charger type. This makes the result more interpretable than a generic AC/DC comparison because it links infrastructure design to observed utilisation and user availability.

Category	Interpretation	Policy relevance
1CS / 0DS AC	Single non-dedicated AC charger	Low-cost distributed charging, but higher full-occupancy risk.
2CS / 1DS AC	Two charging spaces with only partial dedication	May underperform because parking access is not aligned with charger count.
2CS / 2DS AC	Fully dedicated two-space AC site	Shows value of matching dedicated parking to charging spaces.
2CS / 2DS DC	Fully dedicated two-space DC site	Highest throughput and turnover, but congestion risk begins to appear.
4CS / 4DS AC	Small AC hub	Stable long-dwell charging with high availability.
4CS / 4DS DC	Small DC hub	Promising but currently based on limited site numbers.
6CS / 6DS AC	Large AC hub	Scale and turnover can partly compensate for lower AC power.

6.2 Observed performance by operational category

The three aligned bar charts should be presented together. The x-axis is identical in all three figures, which lets the reader compare energy, use-hours and sessions without needing to relearn the categories.

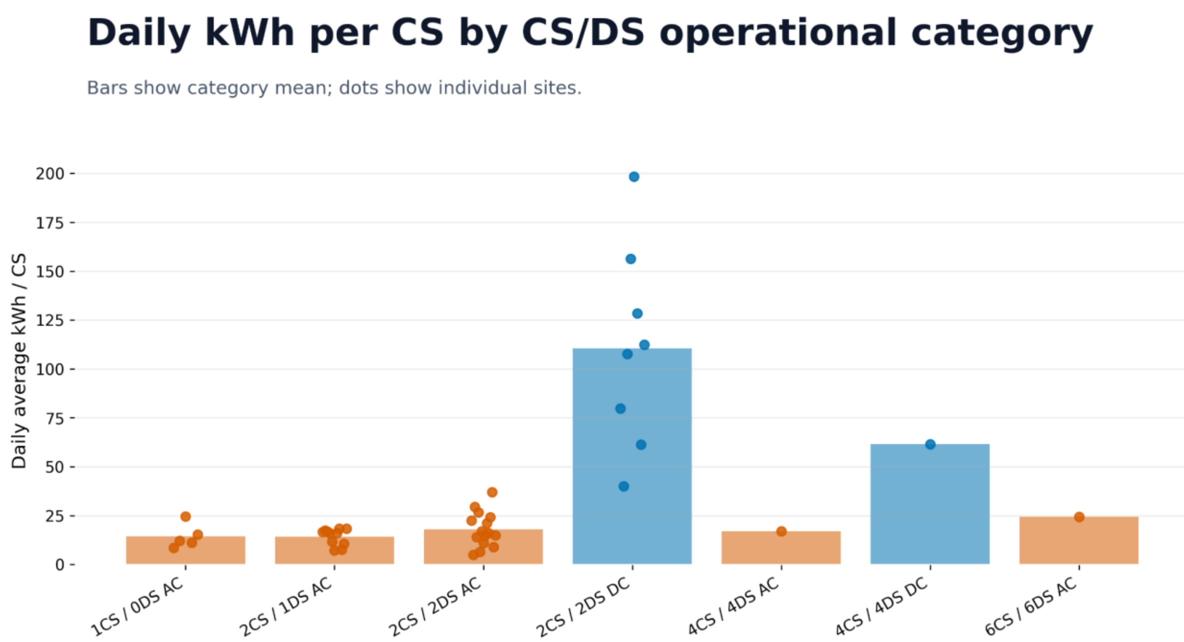


Figure 8. Daily kWh per CS by CS/DS operational category. Bars show category means and points show individual sites.

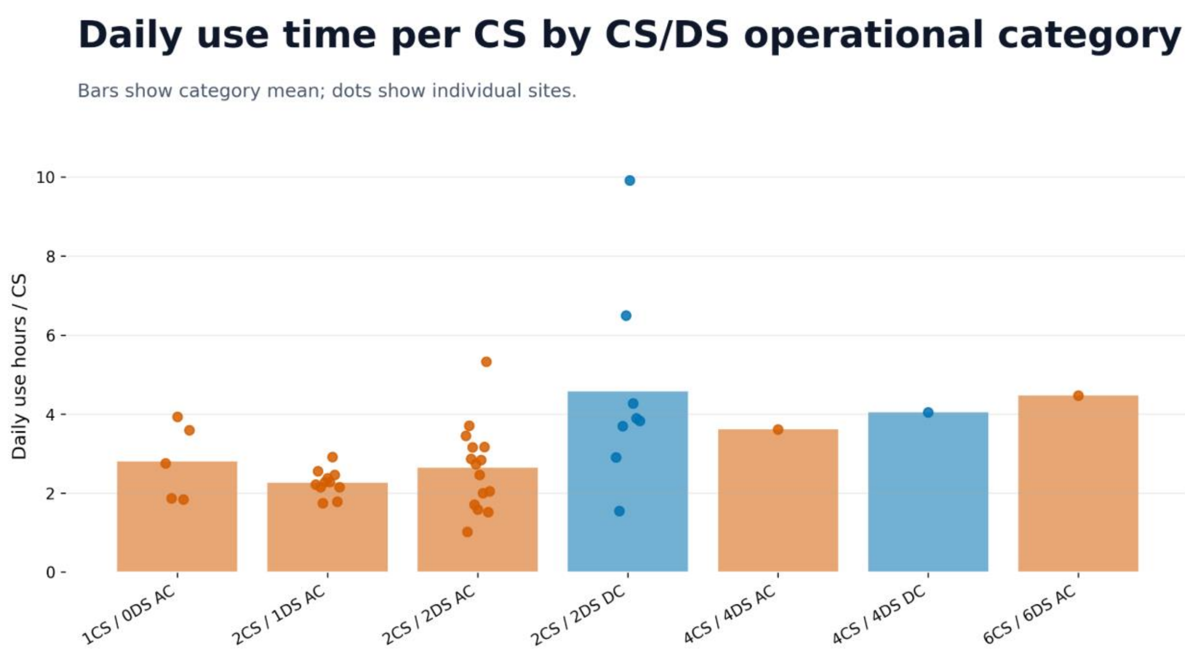


Figure 9. Daily use-hours per CS by CS/DS operational category. This shows occupancy behaviour independent of charger power.

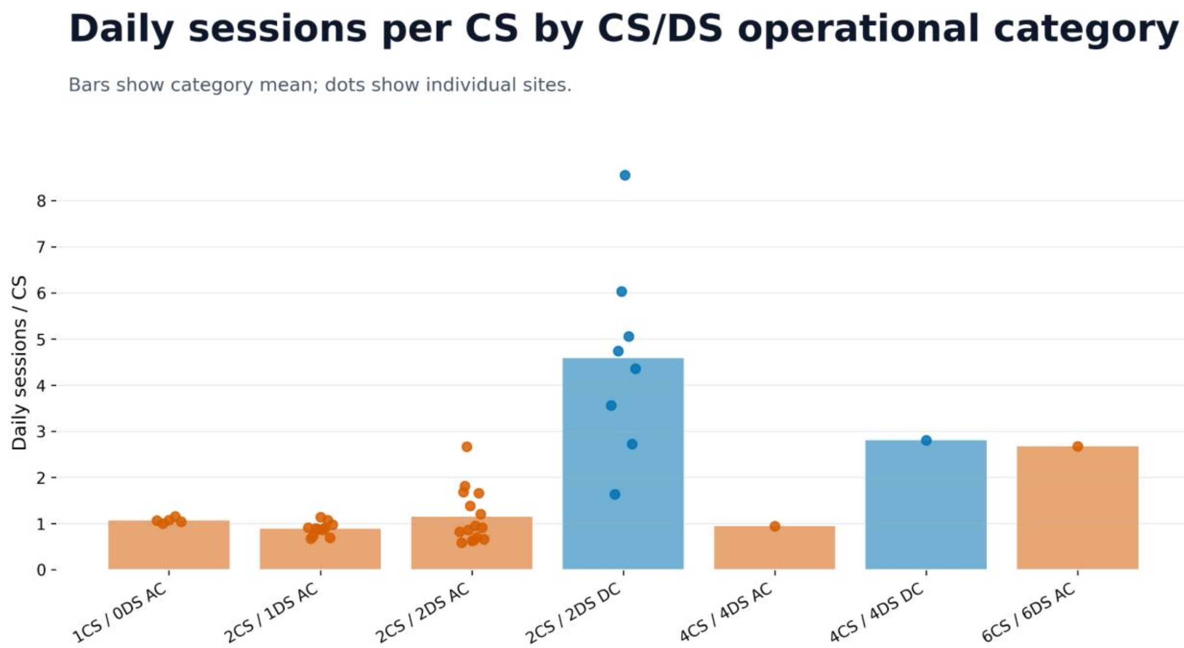


Figure 10. Daily sessions per CS by CS/DS operational category. This captures turnover and user activity.

6.3 Interpretation of co-location results

- Dedicated parking appears critical for multi-port AC performance. The 2CS / 2DS AC category performs better than the 2CS / 1DS AC category, suggesting that adding chargers without matching parking control may dilute operational efficiency.
- Single-port non-dedicated AC chargers can still achieve meaningful use. This suggests pole-mounted or low-cost kerbside AC charging can remain viable, but it comes with lower reliability and higher full-occupancy risk.
- Dedicated dual-port DC sites deliver the highest energy throughput and session turnover. The slight reduction in availability for these sites should be interpreted as a sign of high demand and strong utilisation rather than poor design.
- Large AC hubs show that co-location can improve AC performance. A 6CS / 6DS AC site achieves strong turnover and sustained use-hours, suggesting that high-density AC hubs can support local dwell-time charging in dense urban settings.

6.4 Availability and full-occupancy probability

The availability calculation translates observed utilisation into a user-facing reliability metric. If U is the observed utilisation fraction per charging space and n is the number of charging spaces, the probability that all charging spaces are busy is U^n. The probability that at least one space is available is therefore 1 - U^n.

This should be presented as a companion to the utilisation plots rather than used to re-weight the observed performance metrics. Dedicated parking should be used mainly as a category variable, while charging spaces should be the main denominator for the probability model. Active-port versions can be retained as a sensitivity check.

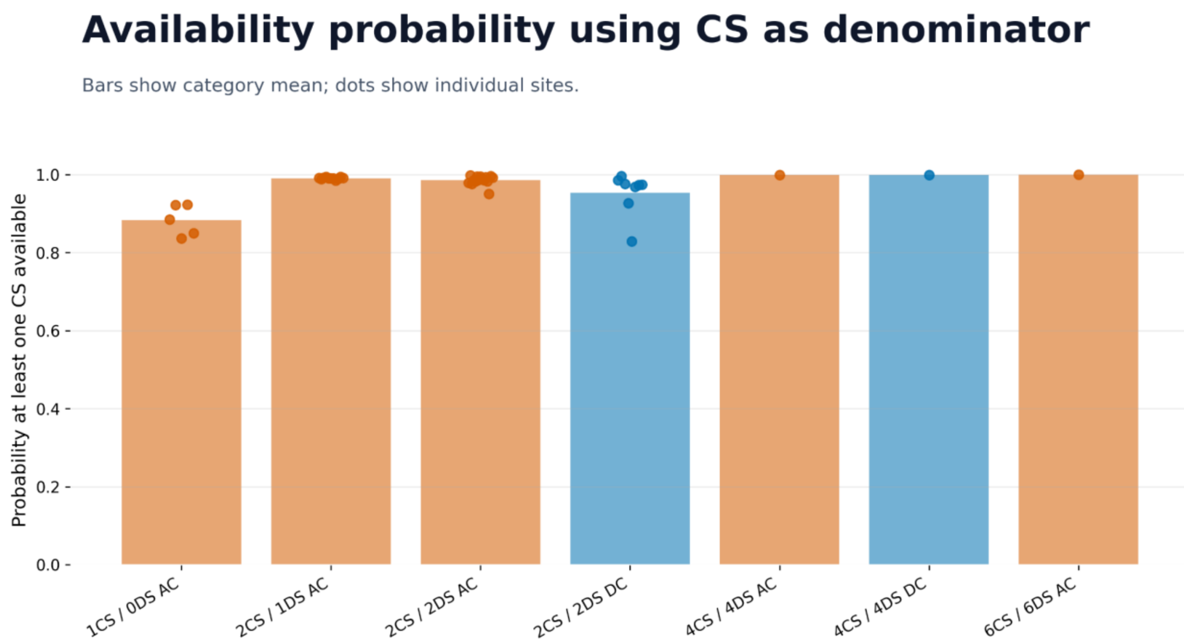


Figure 11. Probability that at least one charging space is available, using CS as the denominator.

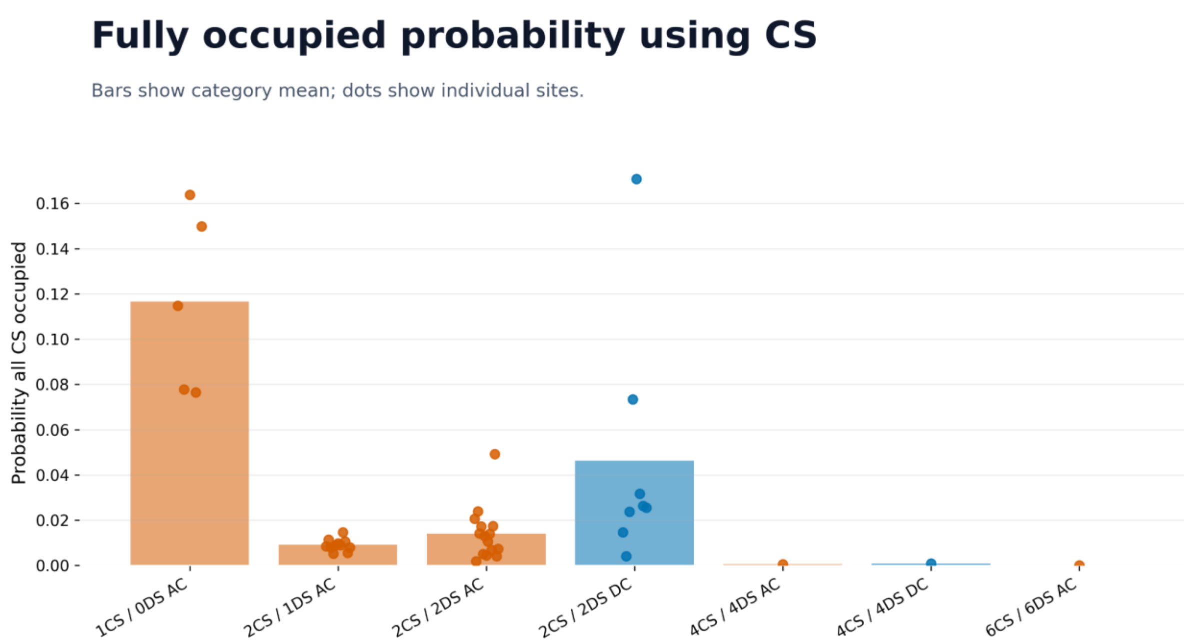


Figure 12. Probability that all charging spaces are occupied, using CS as the denominator.

Availability interpretation

The strongest policy message is the non-linear reliability benefit of co-location. Moving from one charging space to two sharply reduces the probability that a site is fully occupied. Additional charging spaces continue to improve reliability, but with diminishing marginal gains.

7. Policy and planning implications

- Move from charger-gap mapping to network-aware deployment. The proximity result indicates that chargers interact with nearby infrastructure and should not be treated as isolated assets.
- Use 2 km as the primary behavioural lens for DC utilisation. The indicative optimum around 35-40 nearby CS within 2 km provides a practical starting point for identifying under-supplied, optimally supplied and potentially saturated local DC markets.
- Use 5 km as a broader competition and ecosystem lens. 5 km should not replace 2 km for local behavioural interpretation, but it is valuable for identifying overlapping clusters and broader network pressure.
- Plan AC and DC differently. AC appears more local and dwell-time oriented; DC appears more network and corridor oriented. A single spacing rule is unlikely to suit both charger types.
- Match charger deployment with parking control. The co-location results indicate that dedicated parking can materially affect whether installed charging spaces translate into actual usable charging opportunities.
- Treat high DC utilisation as both a success and a warning signal. High utilisation improves productivity, but if availability begins to fall, future deployment should consider either hub expansion or nearby spatially optimised additions.

8. Limitations

- The DC-only sample size is small (n = 9). Model outputs should be framed as indicative evidence and planning insight, not a final predictive model.
- Nearby charger density variables are correlated with one another. Count, charging spaces, power and capacity should not all be included in the same regression without careful model design.
- NUI is a partial behavioural measure because full utilisation data are not available for every non-council charger. It is therefore best treated as a secondary signal rather than the main competition metric.
- The current co-location analysis is categorical and explanatory. It identifies patterns in site archetypes but should not be over-interpreted as causal without additional controls and larger samples.
- Apartment share, rental share, SEIFA and population layers have been assembled and are useful for future explanation, but should not dominate this short deliverable because the manager's immediate request is proximity radius and co-location.

9. Future work after this deliverable

- Add apartment share, rental share, population density, IRSD/IRSAD/IER and EV uptake as explanatory layers after the main proximity story is finalised.
- Develop a competition index combining 2 km local density, 5 km regional density, NUI and overlap between service areas.
- Classify sites into planning archetypes such as underserved high-demand areas, demand clusters, oversupplied clusters and isolated low-demand locations.
- Validate the 2 km and 5 km interpretation using GIS service-area overlap maps and ring-level population/dwelling indicators.
- Extend the analysis beyond the current council network and test whether the 35-40 CS / 2 km DC optimum persists with additional CPO data.

Appendix A. Nearby Utilisation Index (NUI)

Step 1 — Distance preparation

A full distance matrix between every council charger and every other charger in the network has been generated. The output is a lookup table.

Step 2 — Define neighbouring chargers

Radius based (500 m–2 km), k-nearest stations (k=1,3,5), and distance-decay weighting w=1/d

Step 3 — Build neighbour utilisation index

NUI_i = Σ (U_j × w_ij) representing how busy surrounding chargers are

The distance matrix already includes all chargers (council + non-council) , but the utilisation term in the index only exists for council sites. To handle this, I has been separated two effects:

1. Accessibility / competition presence effect
   Non-council chargers still contribute to competition because drivers can choose them.
   So they will be included in neighbour definitions (distance bands / k-nearest / density counts, this captures *availability pressure*.

2. Observed demand interaction effect
   The weighted utilisation component (NUI) will only use chargers where we have session data (council network).
   This captures *behavioural interaction* between monitored sites.

So effectively the model becomes:

Site utilisation = a + b_1(nearby charger density) + b_2(neighbour utilisation)

- density term → competition opportunity (including private chargers)
- utilisation term → observed demand spillover (only council chargers)

This way missing utilisation data won't bias the results, it just moves into a different explanatory variable instead of being treated as zero.

It also lets us distinguish whether a site is quiet because competitors exist, or because nearby chargers are actually busy.

Appendix B. AC Charging behaviour

The AC analysis was undertaken to determine whether charger utilisation is influenced by surrounding charging infrastructure in a similar manner to DC charging.

The same methodology applied to DC chargers was used for AC chargers, including analysis of nearby charger density, nearest charger distance, utilisation, energy throughput and network catchment characteristics.

4.2 Spatial Behaviour of AC Chargers

The AC results reveal substantially weaker spatial structure than observed for DC chargers.

Across the network, AC sites with similar surrounding charger densities frequently exhibited very different utilisation outcomes. Likewise, high-performing and low-performing AC sites were observed across a broad range of local charger densities.

This suggests that AC utilisation is not strongly governed by surrounding network density.

Instead, AC performance appears to be influenced primarily by local site characteristics, including:

- Residential charging demand
- Apartment density
- Parking availability
- Destination attractiveness
- Dwell-time behaviour
- Local land-use characteristics

The strongest relationships were observed at approximately 1 km, indicating that AC charging largely operates as a local neighbourhood service rather than a network-scale service.

Figure X. AC utilisation versus nearby charger density and nearest charger distance.

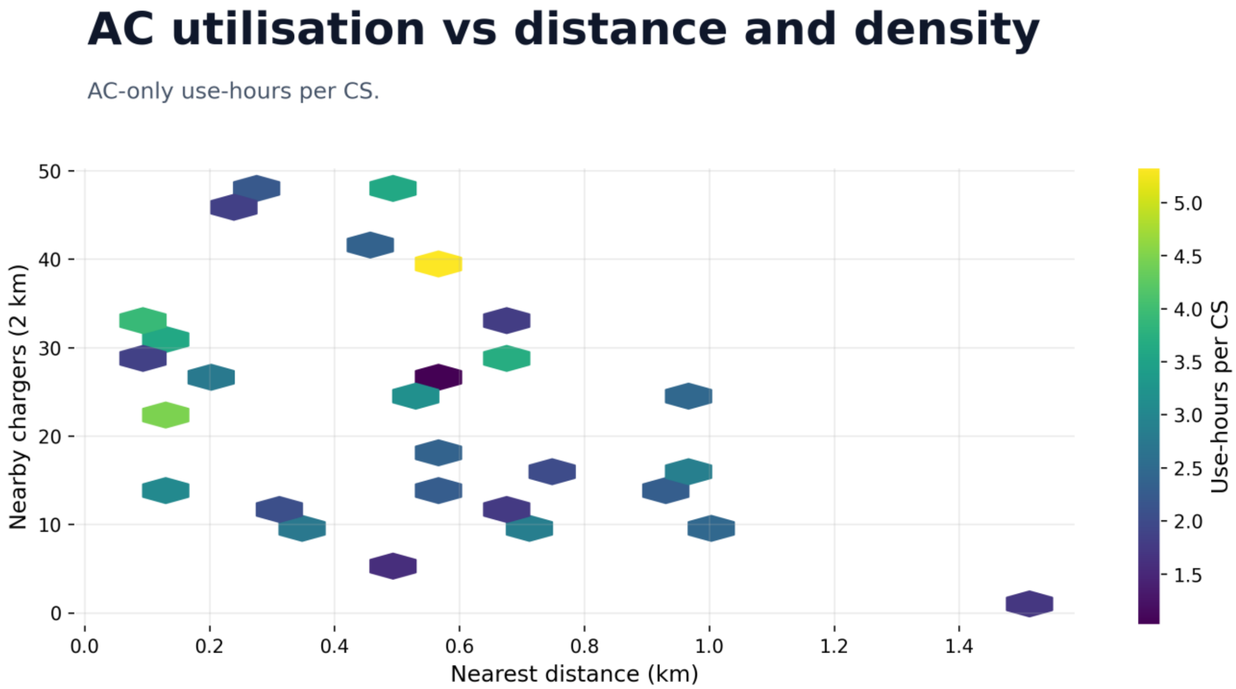
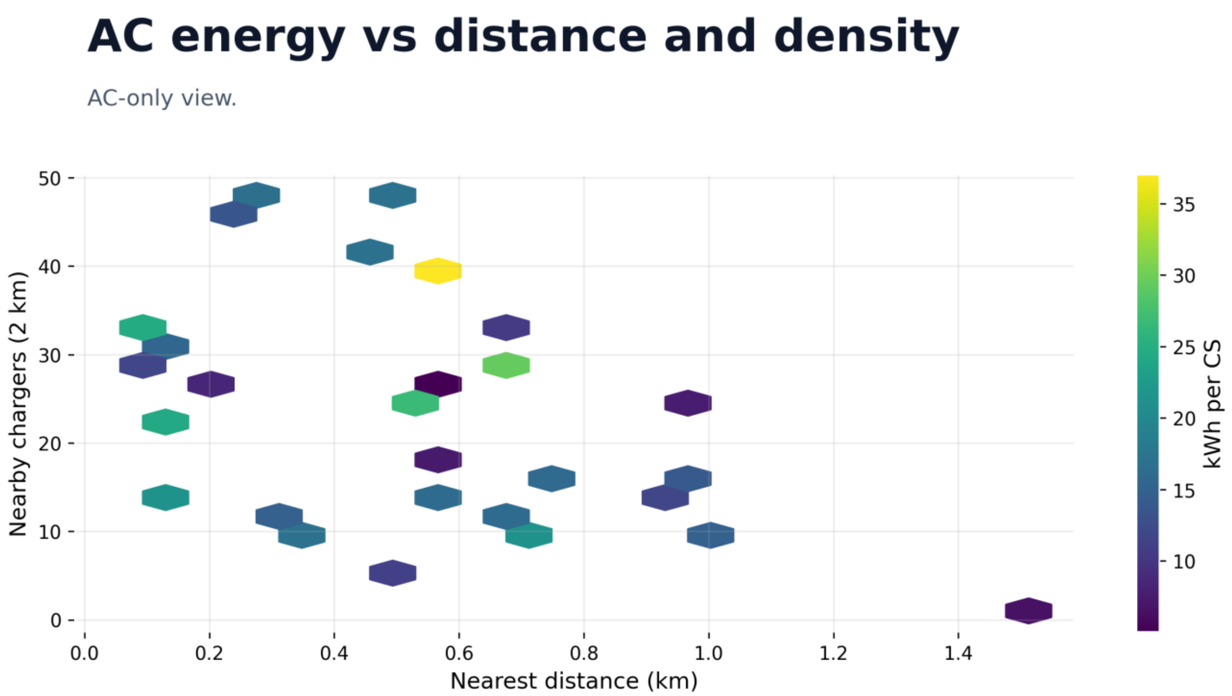


Figure X. AC energy delivery versus nearby charger density and nearest charger distance.



Operational Performance of AC Sites

Additional analysis grouped AC chargers by operational configuration, including charging spaces (CS) and dedicated parking spaces (DS).

Several notable patterns emerged:

• Dedicated parking significantly improves multi-port AC performance.

• 2CS / 2DS sites consistently outperform 2CS / 1DS sites.

• Single-port AC chargers can still achieve meaningful utilisation despite limited infrastructure.

• Larger AC hubs (e.g. 6CS / 6DS) demonstrate substantially higher turnover and energy delivery.

These findings suggest that parking allocation is a critical design parameter for AC charging infrastructure.

Planning Interpretation

The AC results suggest that increasing charger density alone does not guarantee higher utilisation.

Instead, successful AC deployment appears to depend more heavily on matching charger provision to local demand and ensuring sufficient dedicated parking access.

The evidence supports a neighbourhood charging model, where AC infrastructure is distributed across local destinations and residential areas rather than optimised through broader network clustering.

The absence of a strong density-driven optimum contrasts with the DC results presented in the following section and highlights a fundamental difference between AC and DC charging behaviour.

Figure X. AC energy vs charging spaces (1 km)

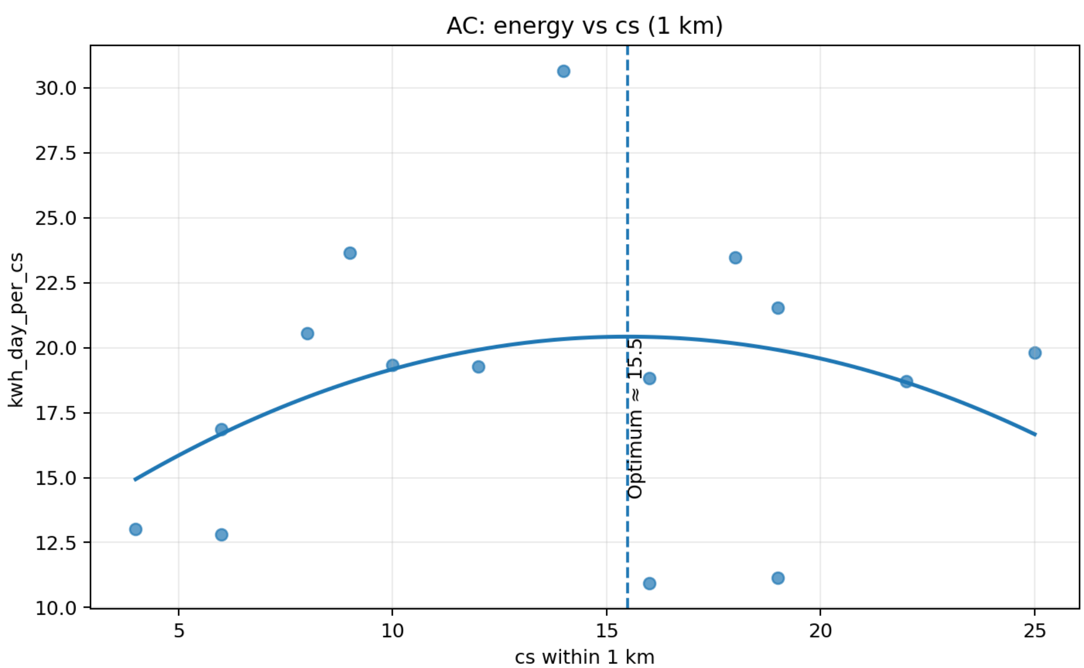


Figure X. Spatial Map for AC network catchment (1 km)