Terawatt

**Unlocking the grid:**
A blueprint for fleet-scale EV charging

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A blueprint for fleet-scale EV charging

The US electrical grid faces a generational challenge: major new sources of industrial-scale demand are outpacing current mechanisms for grid expansion. With overall electricity demand in the US projected to rise by 20-25% by 2030[1] - driven by new AI data centers and doubling electric vehicle (EV) adoption - this era of load growth will contribute to meaningful upgrade costs if achieved solely via legacy methods of electrical service.

Terawatt exists to accelerate the transition to a cleaner world through electrification. We partner with the largest EV fleets – from autonomous and rideshare vehicles all the way up to class 8 commercial trucks – to deliver charging at fleet scale. Our technology and expertise in site development and operations unlock the ability to overcome grid constraints and add more charging stalls than traditional matching of utility service capacity to nameplate EV charger capacity would otherwise allow.

Through this approach, we show that it is practical to build sites that support fleet-level charging and use adaptive load management - software control of load within specific parameters - to operate safely within utility limits. Together with flexible service connections this provides a pathway for meeting future demand, increasing utilization of existing grid infrastructure without the need for expensive infrastructure upgrades, and driving down rates.


Terawatt LAX hub

Terawatt

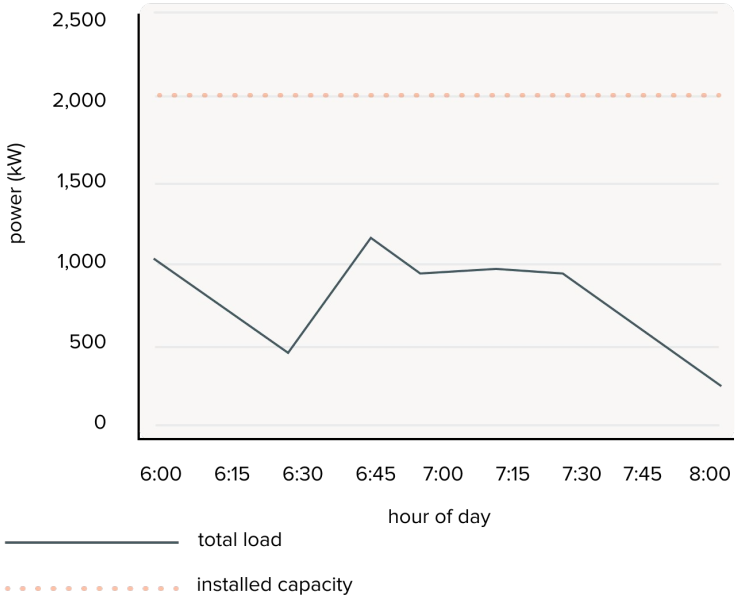
**The challenge: Fleet charging is different**

EV fleet operators require the fastest possible charging – which translates to the highest power – so their vehicles can maximize productive time on the road. While home chargers normally draw less than 20kW, commercial sites can have 60+ DC fast chargers and draw more than 10 MW at full power.

Developing fleet-scale EV charging therefore means confronting the reality of utility power constraints, especially in the urban and industrial locations where fleets typically require charging. Matching nameplate charger power to utility power often requires expensive utility upgrades that can take 3-5 years, contribute to rising electricity costs and leave significant amounts of power unused. This results in inefficient utilization of grid assets and capacity.

Fleet charging presents fundamentally different demand characteristics to other large-scale infrastructure. Unlike the consistent load profile of large load categories like data centers, EV charging sites demonstrate natural variation in power consumption over time. This load diversity is driven by varying arrival patterns of vehicles – and their charging curves, which often only reach peak levels for short periods.

Take a hypothetical site with ten EV charging stalls, each of which has a 200 kW nameplate charger. The total nameplate charger capacity is 2,000 kW. The distribution of charge sessions throughout the day together with the varying amounts of power required by vehicles at any given point in time results in much less load even when all stalls are in use. Leveraging fleet load diversity effectively while having the controls in place to ensure utility limits are not violated is the key to unlocking adaptive load management.




**10 x 200 kW EV Chargers EV Charging Load by Stall (kW)**

| Stall | 6:00 | 6:15 | 6:30 | 6:45 | 7:00 | 7:15 | 7:30 | 7:45 | 8:00 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 45 | 25 | 120 | 90 | 45 | 25 | 175 | 90 | |
| 2 | 120 | 90 | 45 | 25 | 120 | 90 | 45 | 25 | |
| 3 | 175 | 90 | | 120 | 90 | 45 | 25 | 175 | 90 |
| 4 | 90 | 120 | 90 | 45 | 25 | 120 | 90 | 45 | 25 |
| 5 | 90 | 45 | 25 | 120 | 90 | 45 | 25 | | |
| 6 | 120 | 90 | 45 | 25 | | 175 | 90 | | |
| 7 | 175 | 90 | | 120 | 90 | 45 | 25 | | |
| 8 | | | | 120 | 90 | 45 | 25 | | |
| 9 | | | | 175 | 90 | 175 | 90 | | |
| 10 | | | | 175 | 90 | | 120 | 90 | 45 |
| Total load | 815 | 550 | 325 | 1,015 | 730 | 765 | 710 | 425 | 160 |

unique EV charging session

Total load is less than nameplate capacity, even when all stalls are occupied.

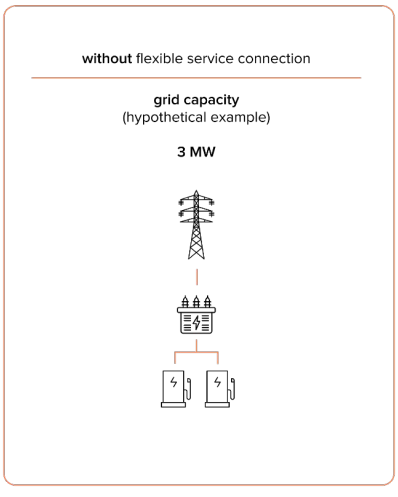
## The solution: An adaptive load management framework

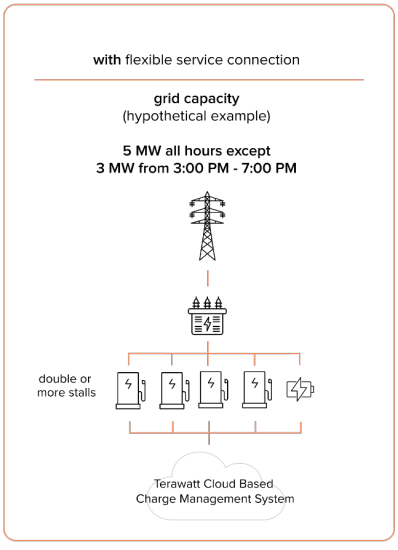
Through vertically integrated hardware and proprietary software, Terawatt leverages EV fleet load diversity to enable adaptive load management, with failsafes to protect the electrical integrity of the grid. As fleet sizes, charging speeds, and battery capacities increase, so does total demand. Developing a site that accounts for future demand requires both visibility into customer needs and the technical and operations capability to match them to available capacity.

Several utilities have implemented pilot programs that empower customers to use adaptive load management to unlock additional capacity. A current California rulemaking to "Modernize the Electric Grid for a High Distributed Energy Resources Future" seeks to formalize these programs for broader use and offers the following useful definitions[2].

> **Flexible Service Connection** is a means of connecting a customer to a utility's distribution system under specific capacity limits that vary over time for serving load.
>
> **Firm Capacity** is load or generation capacity that is contractually obligated and remains in place, as opposed to **Non-Firm Capacity** which the operator obligates to a customer based on updates to the operator's forecast or measured grid conditions.
>
> **Operating Envelope** is the series of operational limits, based on firm and non-firm capacities, within which customers may import and/or export power over a specified time frame. The operating envelope can be temporary when used as a bridging solution to grid upgrades, static as a predetermined firm schedule, variable periodically (e.g., changes on a day-ahead basis), or dynamic to update in near real-time.

Most flexible service connections implemented to date have used temporary and static operating envelopes, with a select few using variable operating envelopes. Together with adaptive load management these programs allow chargers to be installed with future power needs in mind and managed to lower near-term power limits. One example is the Load Control Management System (LCMS) Pilot created by Southern California Edison (SCE). This allows customers with higher power needs to sign up for a temporary static operating envelope defined by a load limit schedule (LLS) – restricting the power they can consume during the most stressed hours and seasons of the year, while opening up access to much higher power the rest of the time.



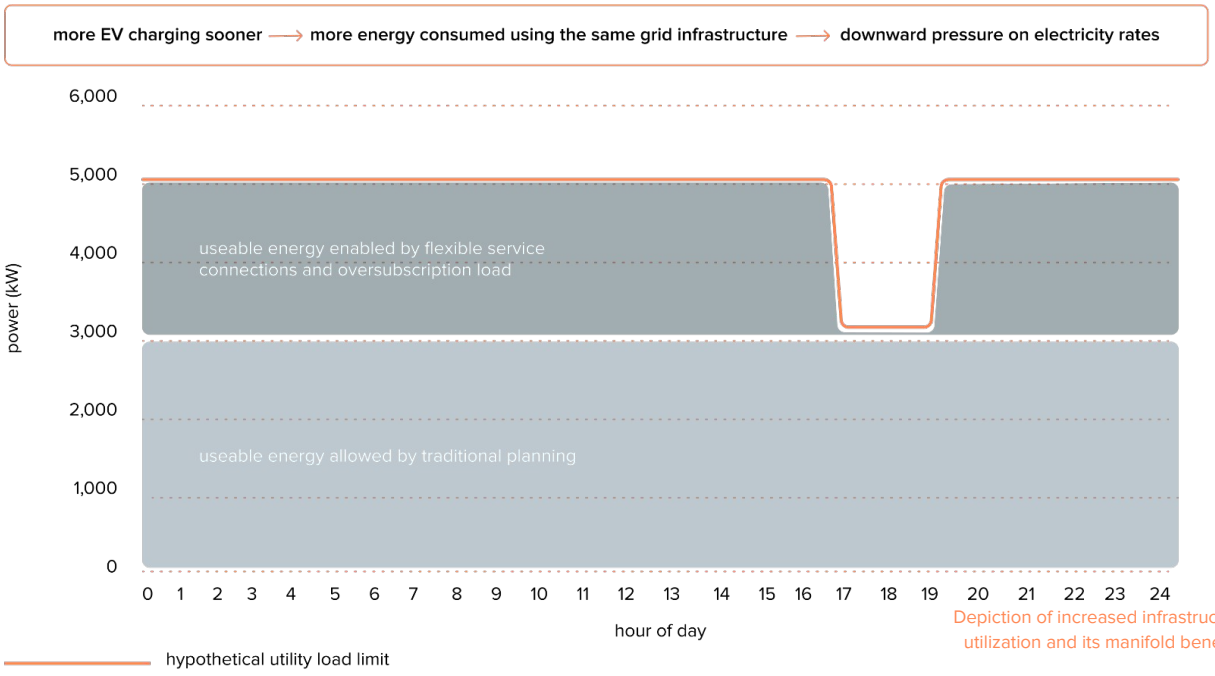

Terawatt's technology and operational expertise is a perfect match for flexible service connections

This means that sites can be energized in a matter of months, often with double the load that traditional restrictive planning would allow. Since sites are built to their maximum potential charging capacity behind the utility meter, when additional power becomes available it can be used without disrupting operations. This can be supplemented with distributed energy resources (DER) like solar and battery storage on site to unlock additional power capacity and further smooth out utility import during high-demand periods while lowering the energy costs required to serve the load. Should the flexible service connection meet the long-term operational needs of the site, customers should have the option to make them permanent and avoid further grid upgrades.

While flexible service connections can unlock capacity, they are not always feasible or available yet. Significant additional EV charging capacity can still be enabled due to fleet load diversity when implemented with adaptive load management. The operating envelope simplifies down to a fixed load limit at all times based on available utility power.

**Adaptive load management, with or without flexible service connections, unlocks 3 benefits:**

- **Accelerated deployment:** EV charging sites can come online sooner, since extensive utility upgrades are avoided or done in parallel;
- **Enhanced charging capacity:** More EV chargers can be installed per site, leveraging load diversity and management;
- **Grid efficiency and cost control:** Using available capacity and existing grid assets more efficiently puts downward pressure on utility rates while electrifying transport.




Depiction of increased infrastructure utilization and its manifold benefits.

With electricity costs rising faster than inflation[3], this highlights how fleet-level EV sites can be 'good neighbors' – increasing existing grid capacity utilization and driving down rates while reducing pollution and emissions – and the industry is increasingly coalescing around this approach[4].

**De-risking transportation electrification**

For a utility to enable adaptive load management and flexible service connections it must have confidence that the site will honor utility limits to avoid overstressing the grid. While power control systems (PCS) have been used to manage asset-level power output in distributed energy resources for some time, extending this to load control is an emerging challenge with standards and certifications still evolving.

Participating in a flexible service connection has many advantages for site development and enables early delivery of capacity, but requires thoughtful management for end users as not every customer can alter operations in line with the utility schedules.

**Terawatt's full-stack solution: securing capacity now**

Terawatt helps turn a potential liability into a foundational tool for grid management. We work with customers to model their charging needs over the lifetime of the site, including anticipated changes in their fleet, so that designs meet their requirements today but have flexibility to grow as their operations evolve. This is only possible with a deep understanding of fleet-level operations and a partnership approach derived from years of real-world charging experience.

Unlocking near-term capacity from programs like the LCMS pilot requires a level of precision and sophistication only achievable by a load management system engineered to strictly enforce the load limit schedule at all times. Terawatt's proprietary Charge Management System (CMS) is purpose built to maximize the value of EV charging for its customers using flexible service connections that translate utility limits into optimized fleet charging facilities. Our site in Rialto, CA is one of the first to participate in the LCMS program with SCE using this technology stack.

Part of SCE's requirements for LCMS participation is a control system certified to UL 3141, a new standard published in October 2024. While rooted in concepts that have existed in other codes and standards, the load control domain is not a natural extension of prior applications in the way inverter-based DER control is from UL 1741 CRD. Given its recent publication and the possibility of further changes by the time it is fully accepted and widely used, very few technology providers currently have certified products that cover use cases beyond solar or energy storage inverters – and very few National Recognized Testing Laboratories (NRTLs) are qualified and available to certify products to this standard.

Terawatt worked with a technology partner to certify a solution only eight months after the publication of UL 3141. We achieved this by taking a theoretical implementation from our strategic partner and deploying it in our state-of-the-art infrastructure testing environment to identify key areas to streamline. This environment and the tests that informed the system design were critical to the subsequent field deployment of the LCMS system.

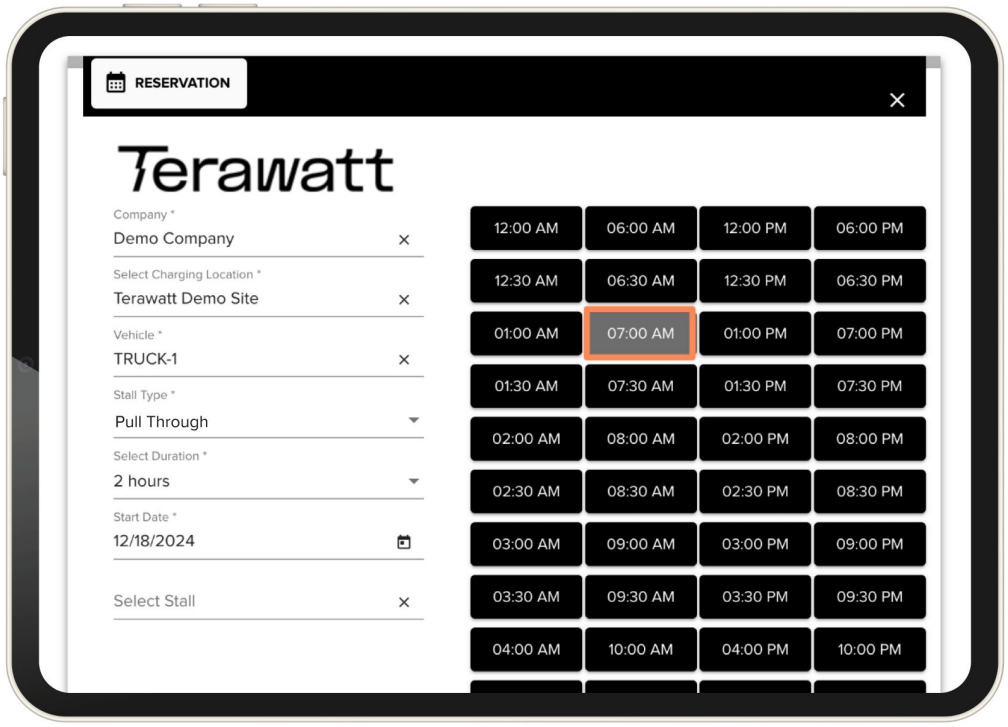
This rapid certification and real-world solution deployment required four phases of rigorous validation and testing to validate safety, reliability and consistency of customer experience: Hardware Validation, Software and Telemetry Validation, Hardware and Software Integration, and Site Acceptance Testing.

**Meeting customer expectations for seamless charging**

To balance the fleet experience at sites with variable power schedules, Terawatt's CMS manages site usage to ensure customers can charge when they arrive and we can deliver the maximum power their vehicle can consume. This is accomplished through two main features:

**Reservations:** We use an active reservation system to control usage and avoid queue times at our sites. Fleets must reserve a timeslot prior to arriving to guarantee availability. For sites with variable power, availability is adjusted based on the power accessible at the time.

**Enforcement:** At any given moment, the CMS software monitors real-time power usage, reservations, and live session data to throttle power to safe levels. If a site is approaching utility limits, we throttle – and can, if needed, pause – charging, deprioritizing customers who are past their reservation windows.




**Flexible solutions tuned to customer needs**

Terawatt also operates fleet charging sites where a single fleet owner uses the entire site without a reservation system. At these sites Terawatt's CMS distributes available power intelligently among the many live sessions, rebalancing in near real-time in response to changes in available utility power, EV State of Charge (SOC) and EVs actively charging. This level of dynamic control guarantees utility compliance without compromising fleet operations.

**A three-pillar strategy for accelerated, scalable EV charging infrastructure**

The level of electrification that is coming to light and heavy-duty transport will require a significant expansion of fleet-level charging and corresponding commitments from utilities, fleets and charging operators to build future-ready infrastructure. Three things can help deliver EV charging at fleet scale:

- **Prioritize flexible service connections for firm capacity with static operating envelopes:** Static operating envelopes, such as fixed seasonal schedules, offer the predictability EV fleets require to operate while reducing the complexity in telemetry and controls required to receive and enforce load limits from the utility. Focusing on simplicity and predictability will broaden the customer segment that can access flexible service connections.

- **Enable customer control using adaptive load management systems:** Utilities should empower customers by allowing charging locations to implement software-based adaptive load management systems when they demonstrate reliable enforcement of the utility-specified limits. Systems like Terawatt's CMS are proven to be capable of enforcing the load limits and using load diversity to install additional chargers, maximizing the use of existing grid assets and capacity.

- **Look beyond bridging solutions:** Customers should have the option to utilize flexible service connections as permanent solutions while maintaining customer choice to proceed with further upgrades for more power if desired. States such as California, New York, and Colorado are already working on moving beyond pilots to tariff-based flexible service connection programs that would be available to all customers. Even when a flexible service connection may not be feasible or available, software-based adaptive load management can still be used with a fixed utility load limit. The latter can be accomplished within existing tariffs now without needing to spin up new programs or requiring complex certifications and communications integrations[5].

## Conclusion

Solving fleet-level charging presents an opportunity to get customers energized quickly, drive economic growth, electrify historically polluting industries, and deliver more efficient utilization of existing infrastructure. With much of the nation's grid only operating at 40-60% load factor[6] and a significant expansion underway, site operators and utilities have the headroom, the opportunity and the incentives to deploy flexibility at all levels of the grid to support emerging demand.

The promise of adaptive load management – and the success of sites like Terawatt Rialto – are leading more utilities and state public service commissions to propose these programs. This is the fastest and most cost-effective way for the grid to deliver widespread electrification of transport, unlocking speed to power and the manifold societal and environmental benefits that brings. Terawatt provides the expertise and execution needed to turn these opportunities into reality.

1. https://www.icf.com/insights/energy/electricity-demand-expected-to-grow
2. https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M586/K143/586143237.PDF
3. https://www.eia.gov/todayinenergy/detail.php?id=65284
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6. https://www.latitudemedia.com/news/in-colorado-the-distributed-capacity-debate-centers-on-data-visibility/

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## Thank you

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