Lowering your emissions through innovation
in transport and energy infrastructure

Document 3 – Introduction to Load Management

In this document the concepts of load management and smart charging will be explained using depot charging of electric refuse vehicles for context.

The reader is expected to have read and understood the fundamentals of Electric Vehicle (EV) charging in Document 1 – Introduction to Electric Vehicle Charging.

1 Smart Charging vs Load Management

Smart charging and load management are two similar and overlapping technologies. However, there are differences between them which it is important to understand:

- Smart Charging – while the precise technical requirements for a "smart" chargepoint are still to be agreed as an industry standard, it can be described as

  "The ability for charging power to be modulated between zero and the maximum power in response to an external control signal".

  Put simply, a smart charger must be able to respond to a signal from a third-party controller to reduce charging power or even completely defer charging. This is seen as a key capability for EV charging infrastructure to ensure the electrification of transport is done in a managed way.

  An anticipated typical use case of the technology is likely to be responding to signals from a Distribution System Operator (DSO) in times of duress for the electricity network.

  The Office for Zero Emission Vehicles (OZEV) ran a consultation on EV smart charging in 2019 to which it released its response in July 2021[1]. Work is still ongoing to define the technical specification for a "smart" chargepoint. However, to achieve the core requirement of "smart" functionality, it is agreed that the chargepoint must have a data connection and be able to respond to remote control signals.

- Load Management - a technique whereby charging power is controlled at a local level to avoid exceeding the maximum capacity of a local electricity network connection. There are different levels of complexity of load management each with different methods, one of which utilises the "smart" functionality of chargepoints to control power remotely. We will explore load management in detail in this document.

  Note that as load management is not a standardised term, manufacturers and other industry stakeholders may use different terminology. Other names used include "load balancing", "power management", "charging management" and "energy management".

[1] Electric vehicle smart charging - GOV.UK (www.gov.uk)

2 The Levels of Load Management

2.1 Introduction to Load Management Levels

Although each have the objective of maximising the usage of the local electricity network connection capacity, there are various techniques used in load management. Cenex classifies load management systems into levels, which can be very useful when evaluating supplier proposals to distinguish and compare capabilities of different technologies.

Level 0	No load management
Level 1	Single chargepoint
Level 2	Multiple chargepoints – static
Level 3	Multiple chargepoints – dynamic
Level 4	Multiple chargepoints – dynamic, additional features

Increasing functionality

2.2 Load Management Level Descriptions

The descriptions of these levels are as follows:

2.2.1 Level 0 – No load management.

This system has the potential to overload the site supply. For example, if five 7 kW chargepoints were deployed at a site with a 30 kW capacity, if all chargepoints are in use at the same time then the site supply is likely to be overloaded.

2.2.2 Level 1 – Single chargepoint load management

This is the most basic form of load management whereby a single multiple outlet chargepoint manages the power available to each of its (typically two) outlets depending on the number of vehicles connected at any one time. An example is shown in Figure 1 where the available power at a twin outlet chargepoint is shared equally (11 kW) when two vehicles are connected but the full available power is used when only one vehicle is connected.

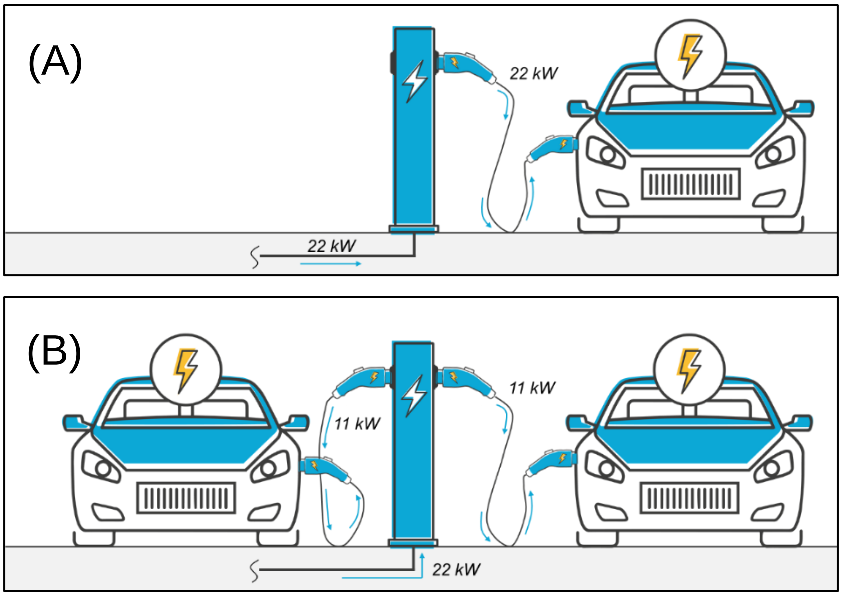

Figure 1: Level 1 Load Management

Note that it is still possible to overload a site supply with Level 1 load management if multiple chargepoints are deployed, since the control is local to a single chargepoint only.

As only the power used by a single chargepoint is controlled Level 1 load management has limited applicability.

2.2.3 Level 2 – Multiple chargepoints - static

This allows the load from multiple chargepoints connected to the same electrical distribution system to be controlled. However, the amount of power available to all chargepoints is pre-set. The power allocated to each charging outlet is then simply the total available power divided evenly by the number of charging outlets, regardless of the number of chargepoints which are charging at any one time. This is simple to configure but inefficient way to ensure site constraints are not exceeded.

Example:

- Available capacity for all chargepoints = 25 kW
- Number and rating of chargepoints to be deployed = 5 x 7 kW
- Load managed power = 5 kW per chargepoint.

In the above example each chargepoint would only deliver a maximum of 5 kW irrespective of the number of chargepoints in use.

- A Level 2 system is only really useable for a small number of chargepoints or where the available capacity is such that the pre-set charging power is not significantly lower than the chargepoint's rated power.
- A benefit of a static load management system can be that the electrical installation design for each chargepoint can be done for the reduced pre-set power. This can save costs for electronics and cabling.

2.2.4 Level 3 – Multiple chargepoints - dynamic

With a level 3 load management system the available capacity, accounting for the real-time on-site loads such as a building loads, is shared between the in-use chargepoints. This makes maximum use of the available power at any one time.

In the below examples of Figure 2 and Figure 3 the division of power between five 7 kW rated chargepoints sharing a network connection with multiple buildings is shown.

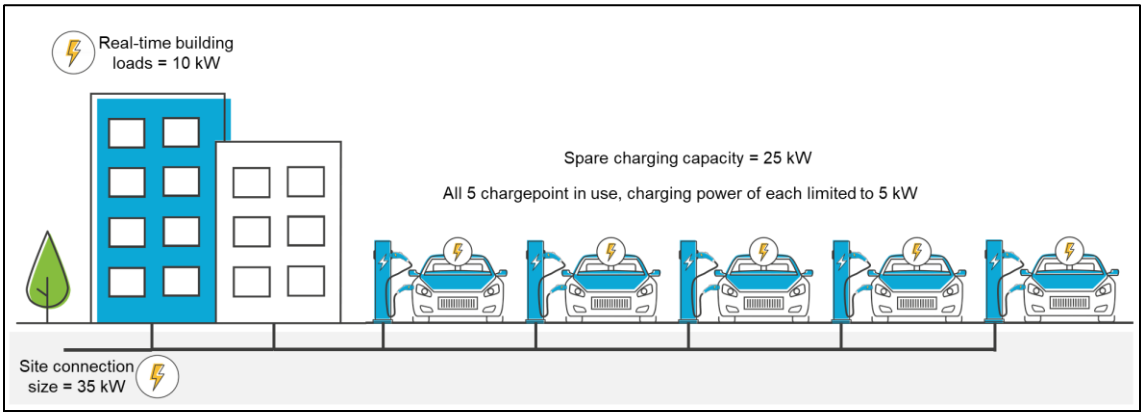

Figure 2: Level 3 Load Management System - All five chargepoints in use

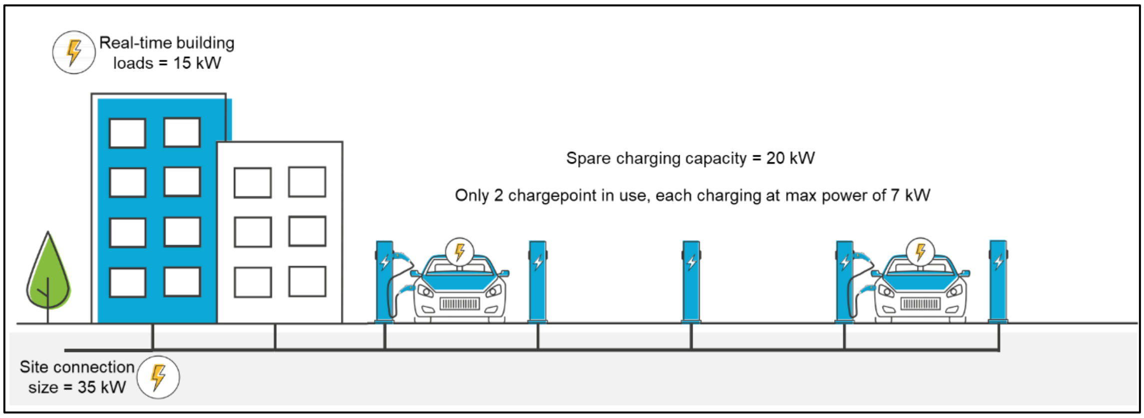

Figure 3: Level 3 Load Management System – Two of five chargepoints in use

- Level 3 load management maximises the use of the site's network connection and is therefore the minimum standard for sites with constrained connections and/or a significant number of chargepoints deployed.

There are two main ways in which dynamic load management systems can be achieved, which shall be discussed in section 3.

2.2.5 Level 4 – Multiple chargepoints – dynamic, additional features

Level 4 takes Level 3 dynamic load management and enhances it by integrating additional features either as part of the system providing load management or by integrating with third party systems. These functions include:

- Vehicle scheduling – Integrated vehicle fleet scheduling functionality to prioritise the distribution of power to individual chargepoints (and vehicles) based on energy requirements, departure times and priorities for each vehicle.
- Tariff optimisation - If the site is supplied with a half-hourly varying energy tariff, the charging system can load manage the chargepoints whilst optimising the cost of charging. This also requires vehicle scheduling to ensure that any optimisation done doesn't compromise fleet operability.
- Energy system integration – Integrating with platforms that use electric vehicle charging to provide flexibility for the energy system in return for financial reward to the EV operator. These systems rely on accessible energy system markets and there is rapid change ongoing in this space; currently opportunities are limited but as the UK transitions to electric vehicles and the energy system continues to decarbonise through greater use of renewables these systems will become more common.
- On-site renewables and battery storage – Deploying renewable generation and battery energy storage systems (BESS) on-site is another method by which local network constraints can be mitigated. However, these technologies can work alongside load management if the system is able to integrate the two. This concept will be discussed further in a future document.

2.3 Summary of Load Management Levels

Table 1 presents a summary of load management levels:

Table 1: Load Management Levels Summary

	Description	Benefits	Limitations	Suitable Applications
Level 0	No Load Management	None	No load management means that unmanaged charging can overload local network connection.	Should only be used where the local network connection is sufficiently large that there is no risk of the EV charging overloading the network connection.
Level 1	Single chargepoint load management	Maximise the use of power supplied and circuit design for twin output chargepoints.	Does not give any load management at a site level.	Could be used for a site deploying a small number of twin chargepoints but limited applicability for constrained sites.
Level 2	Static multi-chargepoint load management	Can be used to ensure site connection is not overloaded. Allows chargepoint circuits to be designed to load managed power, saving cost.	Does not optimise use of available power dynamically. Difficult to implement for sites with other non-EV loads; requires an assumption to be made on the total available power for EV charging up front.	Could be used for sites with a low number of EV chargepoints or where the total available power is not significantly less than the maximum charging demand for all chargers at full power. Easier to implement where there are no considerable non-EV loads.
Level 3	Dynamic multi-chargepoint load management	True optimisation of the use of available power, accounting for non-EV loads and the number of EVs requesting a charge, in real-time.	More complicated system to implement (see section 3 - How is Load Management Implemented?)	The minimum load management standard for sites where the constraints of the network connection and the number of chargepoints to be deployed would result in an unacceptable limitation in charging power for a Level 2 static load management system.
Level 4	Dynamic multi-chargepoint load management with additional functionality integration	Can offer a lower lifetime cost for chargepoint system.	The benefit of any additional functionality, as with load management, depends on the charging demand of the vehicles to be connected; lesser flexibility in charging will limit the benefit.	Most likely to be of interest for larger fleets with predictable vehicle usage and greater flexibility of when they are charged.

3 How is Load Management Implemented?

It is important to understand that there are multiple methods for implementing load management in a charging system. The options for Level 3 load management systems and above are covered in this section. Note that these options would also work for Level 2 static load management with no requirement to monitor real time non-EV site loads. Static load management however is often a configuration within the hardware that is set during the commissioning process.

3.1 – Hardware-based implementation

In hardware-based implementation a local central power control unit monitors demand and distributes the available power to the individual connected chargepoints. Once again, the terminology is not standardised and different suppliers will use various terms such as: “management unit”, “hub”, “charging power unit” for the “central unit” and “satellite” or “slaves” for the individual chargepoints. The principle, however, as shown in Figure 4, is the same.

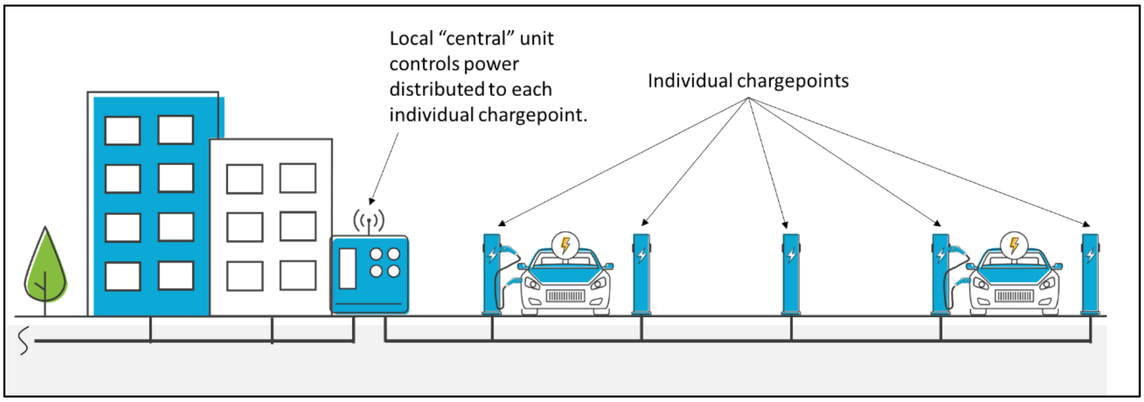

Figure 4: Local Implementation Load Management System

Note that Level 1 systems which control the use of power between multiple outlets on a single chargepoint are also a form of locally implemented load management.

With hardware-based systems it is likely that the central power unit is only compatible with chargepoints from the same manufacturer[2] and there may be a limitation to the number of chargepoints that can be deployed on the system. This can be both a benefit and a limitation. Simple procurement of an entire system from a single source without having to consider integration may be desirable however using a single supplier may create risks associated with interoperability with legacy hardware and redundancy of hardware should the supplier go out of business.

Example Providers

- The S-series products from Kempower[3] are examples of solutions that do both static (Level 2) and dynamic (Levels 3 and 4) multi chargepoint load management in this way.

[2] There are a few providers of third-party load management modules but these are typically suitable for single chargepoint domestic applications only.

[3] [Electric vehicle charging solutions | Weatherproof and scalable (kempower.com)](kempower.com)

3.2 Software-based implementation

In a software-based system each charger communicates with a chargepoint management-system (CPMS) that provides the load management functionality remotely. To achieve this, each chargepoint has an internet connection, typically making use of the mobile network.

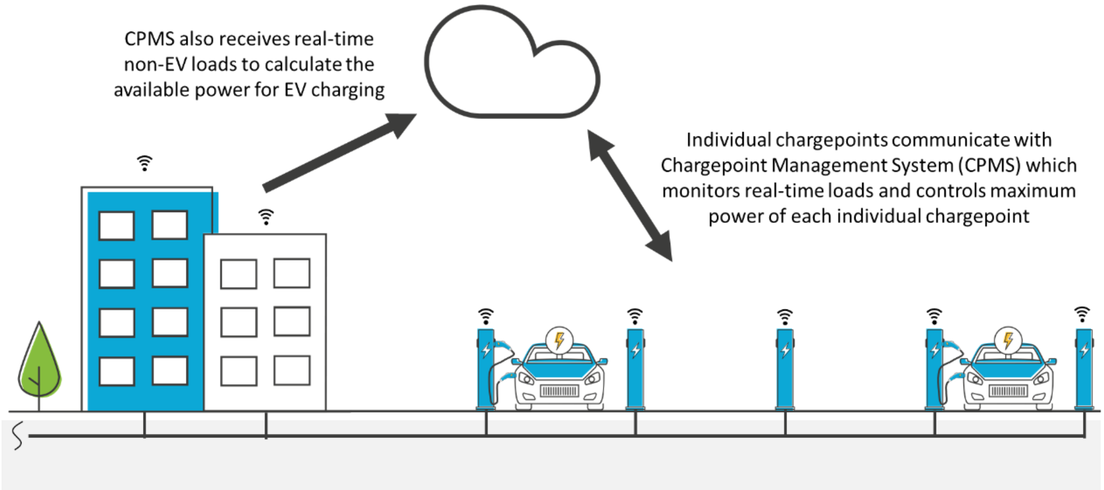

Figure 5: Software-based load management system

This type of load management implementation is often where the confusion between smart charging and load management originates. This is because with a cloud-based software solution controlling the charging power, the system is effectively using smart charging functionality for the purpose of avoiding issues with a local network connection, i.e. load management.

With software-based systems, the software provider may be proprietary to the chargepoint hardware manufacturer, or a third party.

> Third party systems often make use of Open Charge Point Protocol (OCPP) to communicate with the chargepoints. Theoretically, any OCPP compatible chargepoint can work with any OCPP compatible management system, meaning that chargepoints for eRCVs and other EVs can be load managed on one system. However, not all interpretations of OCPP are the same and it is therefore possible that some work will be required to connect a management system with a chargepoint type that has not been integrated by the supplier previously.
>
> However, it is possible, which typically makes software-based load management systems more flexible. The disadvantage is that two suppliers may be required; one for the hardware and a second for the software system.

It is important to note that a CPMS is a useful tool for a fleet manager and software-based load management systems may be provided as part of a wider CPMS solution for billing and authenticating users. Some will offer additional functionality reliant on software such as those listed in section 2.2.5 for Level 4 load management systems.

Example Providers

- The Mobility House's ChargePilot software provides dynamic load management, accounting for non-EV loads and even sources of generation, alongside other integrations[4]. The system

[4] ChargePilot | Product Details (mobilityhouse.com)

is readily compatible with a number of OCPP compliant chargepoints[5] from popular manufacturers such as ABB's Terra Line (CCS DC, 50-180 kW) and Alfen's Eve series (Type 2 AC, up to 22 kW). Any hardware that uses the CCS DC and Type 2 AC standards will be compatible with eRCVs and EVs alike that make use of these standards.

- Vector's vCharM software[6] for electric fleets integrates a CPMS with dynamic load management functionality. Again making use of OCPP allows the system to be "completely independent from charging station manufacturers".
- Ampeco's EV Charging Platform[7] is a software-based dynamic load management platform able to connect a number of chargepoint manufacturers hardware and integrating functionality to plan charging based on a varying energy tariff.

3.3 Hybrid Implementation

Some providers offer multiple chargepoint load management systems which are a hybrid of the hardware and software-based systems previously discussed. In this architecture, the chargepoints are each locally connected to a central module which acts as the interface between the chargepoints and the software-based load management system. The central module may be located on its own or built-in to a "master" chargepoint.

Example Providers

- NewMotion's "Dynamic Power Management" system[8] offers a dynamic load management system designed for workplaces using a single "Business Pro" chargepoint to provide the integration and control for up to 40 "Business Lite" chargepoints.
- The load management system offered by Mennekes[9] is another example, where the module for dynamic load management can be installed within a "master" chargepoint or be located on its own.

---

[5] The Mobility House 's ChargePilot – list of compatible chargepoints

[6] vCharM | Charging Station Management System | Vector

[7] Dynamic Load Management - Ampeco

[8] Dynamic Power Management for Business (newmotion.com)

[9] Mennekes Load Management

3.4 Summary of Load Management Implementations

Table 2 provides a summary of the pros and cons of the

Table 2: Load Management Implementation Summary

	Benefits	Limitations	Suitable Applications
Hardware-based systems	Easier procurement and management with chargepoint and load management hardware provided by a single supplier.	Proprietary systems that use the manufacturer's own chargepoints only. May have limitations on the number of chargepoints deployable to the system. If a chargepoint management system (CPMS) is also desired by the fleet manager, this may have to be procured separately. Some systems will only integrate AC charging or DC charging but not a combination of both.	Hardware-based load management systems can be a good option for a deployment on a site where the chargepoints will be co-located and the business has confidence that they will not need to expand or change the hardware significantly.
Software-based systems	Ability to integrate AC and DC chargepoints from different manufacturers. May make integrating with other Level 4 load management and general CPMS functions (billing, authentication) more simple.	Requires a billable and reliant internet connection, most likely via mobile network. This can be an issue in areas with poor signal such as underground car parks. Not all OCPP compliant chargepoints will have been readily integrated with third party load management systems. Need to procure hardware and load management system separately can make procurement more complex.	Software-based solutions are preferrable for a deployment where: the chargepoints may be installed at different locations on the site; there is a mix of AC and DC charging; or the customer wants to be able to select chargepoints from different manufacturers either now or in the future.
Hybrid systems	Can be the simplest system to procure as includes charging hardware, load management and CPMS software all in one. As the load management functionality is provided by the back-end software, Level 4 load management and CPMS functions may be integrated readily as per software-based systems.	Proprietary systems that use the manufacturer's own chargepoints only. May have limitations on the number of chargepoints deployable to the system. Requires a billable and reliant internet connection, most likely via mobile network, however only for the "master" unit and not for all chargepoints.	As expected, the benefits and limitations of hybrid systems are a combination of the hardware and software-based systems. They may be of interest to a customer who are looking for the increased integration of a software-based system and are happy to be tied into hardware from a single provider.

4 Load Management and Electric Refuse Collection Vehicles

Electric refuse collection vehicles have high daily energy demands. If their charging is not managed, the depot's network connection limit could easily be exceeded with only a small number of vehicles. A short example of why load management for electric refuse collection vehicles (eRCVs) can be important is shown here using the Dennis Eagle eCollect operated by Newport City Council.

The maximum energy usage for Newport's eCollect is approximately 200 kWh. Although the shifts are only 8 hours, leaving 16 hours per day available for charging, the average power required to recharge the battery is still therefore up to 12.5 kW, and could be less on days where energy usage is lower. However, if charging is completely unmanaged, the charging power will be the maximum the charging system can achieve – this will be the 40 kW DC charging allowed by the eCollect should a DC chargepoint capable of delivering at least 40 kW be deployed.

Considering this unmanaged example, the eCollect would be charged in approximately five hours at full power and then be parked fully charged awaiting the next shift for up to 11 hours. Not only is this bad for the vehicle's battery health[10], but when multiple electric waste fleet vehicles are deployed, the maximum power draw could easily exceed the depot's electricity network connection, which are often small in size.

Figure 6 shows a simplified[11] example of how the total site loads could vary when combined with a base non-EV load that is 25 kW during the day between 06:00 and 18:00 and then negligible overnight. The peak load of 65 kW when the eRCV returns to the depot is still acceptable for the 90 kW site limit (assuming overall combined power and safety factor of 0.9 on a 100 kVA connection[12]).

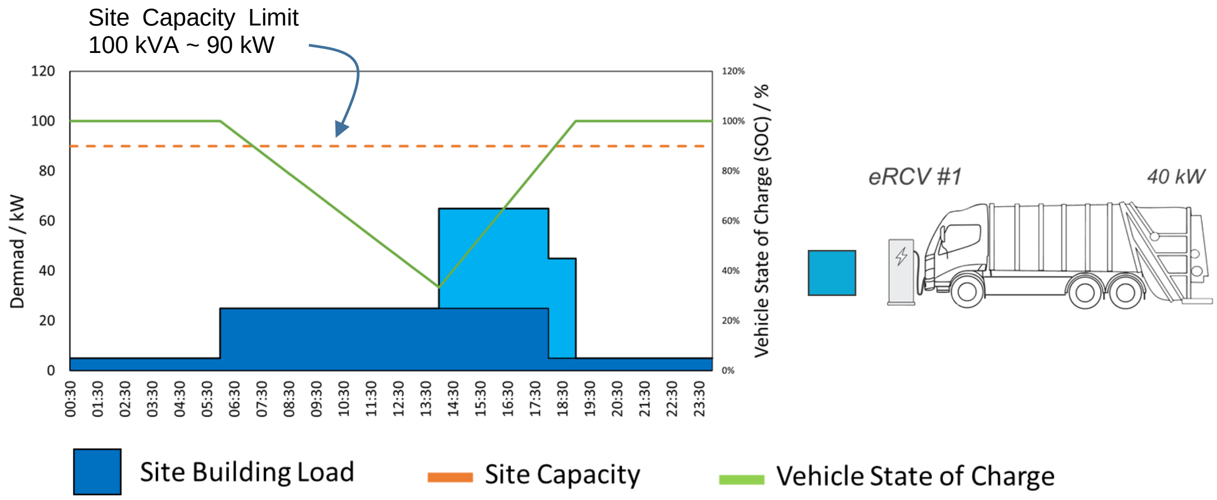

Figure 6: Single Vehicle Unmanaged Charging

However, this is just for a single vehicle use case. As soon as multiple vehicles are operational, unmanaged charging starts to create problems, as shown by Figure 7 where there is a four-hour period until the building load reduces at 18:00 where the site capacity is exceeded by 15 kW.

---

[10] One of the mechanisms for battery degradation is accelerated by storing the battery at very low or very high states of charge (SOC).

[11] This does not account for the vehicle's battery charging curve; in reality the battery will not be charged at a constant rate of 40 kW.

[12] More on power and safety factors as part of evaluating existing connections in document 3.

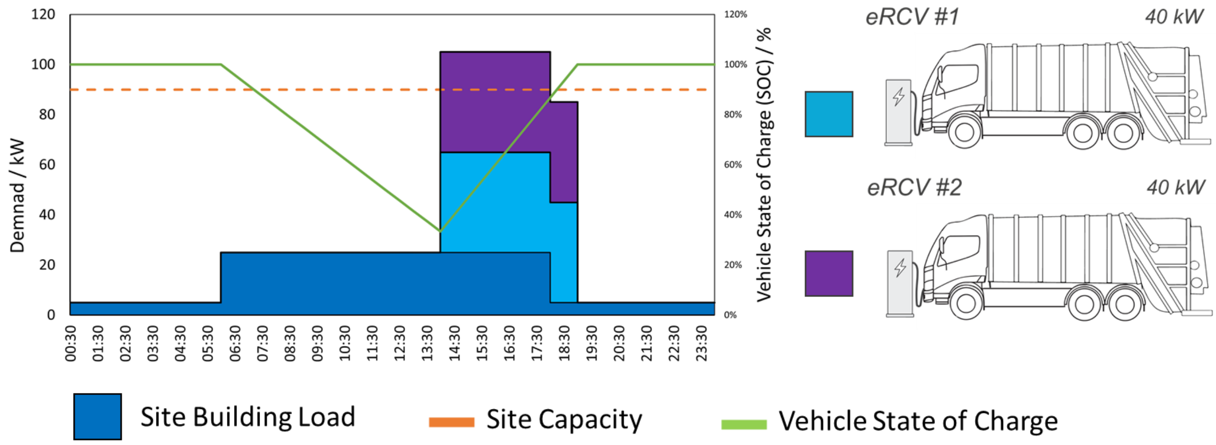

Figure 7: Two Vehicles Unmanaged Charging

This would only worsen for sites with more vehicles or a lower power network connection. In document 3 we will explore how load management and other strategies and technologies – such as the use of charge scheduling and on-site generation and storage - can be used to mitigate this risk for eRCV depots without needing to upgrade the network connection.

5 Procuring a Charging System with Load Management

The following is a top ten of key questions that sites need to ask either itself or potential suppliers once to procure a load managed charging system.

Table 3: Top Ten Load Management Procurement Questions

	Questions	Notes	☒
1	Is a load management system necessary to support the current charging deployment and future additions?	A site assessment needs to be conducted to understand whether load management is necessary – see document 3.	☐
2	How many chargepoints are required both now and in the future? Does the load management system have any limitation on number of deployable chargepoints?	Hardware-based load management systems - may have a maximum number of chargepoints that can be connected.	☐
3	Will all the chargepoints be located together? Does the load management system have any limitations if chargepoints are not located together?	Hardware-based load management system only.	☐
4	Is static load management sufficient or is a dynamic system required?	To understand this, a site assessment is required – see document 3.	☐
5	For a dynamic load management system, are non-EV loads accounted for and if so, how is this done? What additional hardware is required?	Non-EV loads will reduce the available power for EV charging. This may require the deployment of metering devices to measure the real-time loads for a dynamic system.	☐
6	Does the fleet manager require other functionality such as billing, user authentication and data collection from a chargepoint management system (CPMS)? If so, how is this integrated with load management?	Software-based load management systems may be integrated into a CPMS.	☐
7	Which chargepoint types are compatible with the load management system? Is any additional work required to configure them? Is there legacy charging hardware on site that needs to be integrated?	Hardware-based systems are typically proprieratry whereas software-based systems are often compatible with multiple chargepoint manufacturers.	☐
8	Is the charging required AC or DC or both?	It is important to understand whether the load management system is required to connect AC or DC or both before searching for suitable suppliers.	☐
9	Are other integrations such as tariff optimisation, vehicle scheduling and prioritisation, on-site generation and storage required?	Level 4 load management systems may have these enhanced integrations.	☐
10	What connectivity does the system require? Will there be any limitations due to the proposed locations for the charging infrastructure?	Software-based systems will need a data connection to connect to the back-end. This can be difficult to achieve reliably in areas with poor mobile signal.	☐