NIC Project UKPNEN03 Deliverable D7

Appendix 7
Site Planning Tool methodology and reference design

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Optimise Prime

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1 Introduction

1.1 Document Purpose

This document presents the methodologies and reference design of the web-based Site Planning Tool developed as part of the Optimise Prime Network Innovation Competition project.

This document outlines the data sources, flows and analysis used to enable the function of the Site Planning Tool as well as detailing its substituent components. It presents illustrative outputs expected from the model.

The Site Planning Tool can be found on the UK Power Networks website at https://www.ukpowernetworks.co.uk/optimise-prime/site-planning-tool-introductionNULL.

1.2 Document Structure

Table 1 – Document Structure

Section	Title	Description
1	Introduction	Summary of the document purpose and structure
2	Architecture Outline	Overview of the aims of the model, and its inputs and outputs
3	Component Descriptions	Summary of the components of the model, their function and usage
4	Output of Load Optimisation	Examples of tool outputs and guidance on interpretation

2 Architecture Outline

2.1 Strategic goals

The Site Planning Tool aims to assist companies planning to electrify vehicles which charge at their sites, such as depots. The tool allows them to model the impact on the site's electrical load of different combinations of vehicles and charging infrastructure, highlighting where the use of smart charging could help them electrify more quickly and at a lower cost by reducing the need for connection upgrades.

The primary aims of the Site Planning Tool are to:

- Capture the energy requirements of depots considering their historical electricity consumption and their anticipated EV roll-out.
- Optimise energy consumption of depots throughout the day with the use of smart charging to achieve the preferred balance of capital and operational costs for a given investment timescale.
- Generate an optimal consumption profile to inform the development of profiled connection agreements between the depots and the appropriate DNO.

These aims will be satisfied by predicting the consequences of fleet electrification in terms of their daily power consumption. The model will be used prior to EV uptake, to allow fleet and site managers to better understand their connection requirements in advance of discussions with their DNO.

Once capacity predictions and potential connection profiles have been generated by the model, they will be processed by the DNO through the connection planning process, so the least cost method of connection can be offered. The outputs from the tool can also be used as the basis for agreeing a profiled connection agreement should demand patterns and local network constraints allow.

2.2 Structure of the tool

Figure 1 gives an overview of the different input types that make up the Asset Catalogue and are combined in Scenarios to create Results.

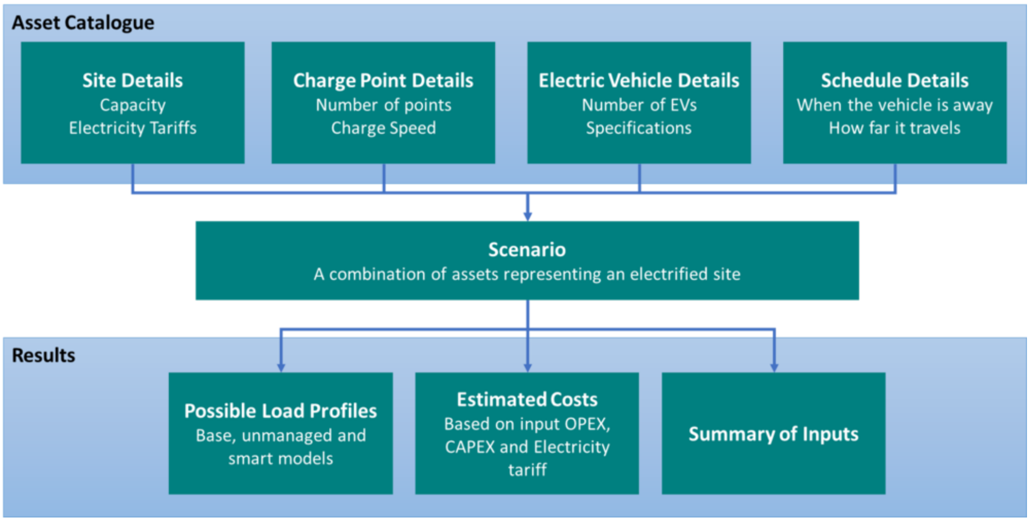

Figure 1 – Structure of the tool

2.3 Data input

The majority of data items are required to be defined by the user during the configuration of the model.

The following sections describe the items that are required to be entered in order to create a scenario. More detailed guidance on gathering the required data, including examples of inputs, can be found on the tool's help web pages at https://www.ukpowernetworks.co.uk/optimise-prime/site-planning-tool-introduction.

2.3.1 Depot

A depot is created for each physical site the user wishes to model, and requires the following inputs:

2.3.1.1 Historical electricity consumption

Historical electricity consumption will be used in the results (described in section 3.3) component of the Site Planning Tool to determine the power consumption of the depot prior to an initial or additional EV roll-out – referred to as background load.

In cases where there is an existing EV load at the site, the background load will be partly comprised of loads that are due to the charging of these vehicles; unless the EVs are sub-metered, their associated loads are effectively hidden in the background load. If the load from existing EVs is sub-metered it can be deducted from the background load in order to utilise the smart charging potential from existing EVs. The background load will be used in the Site Planning Tool to understand the total capacity requirements once the expected number of EVs and charge points are in place at the depot. This data will be provided by each individual depot from supplier half-hourly metering or Building Management Systems (BMS), with data covering a period of at least one week, although users are encouraged to use at least a year of data for more accurate results.

2.3.1.2 Existing connection agreements

The existing agreed connection capacity for each depot will be used to compare different charging scenarios against available capacity. The user is directed to find this data from their connection agreement, or by contacting their DNO.

2.3.1.3 Electricity tariff

Details of the electricity tariffs for each depot can be entered by the user in order to demonstrate whether load minimisation smart charging also reduces electricity costs for the user when charging is moved to different tariff times. The user can either enter fixed tariffs or time-of-use tariffs that vary during the day and/or by day of the week.

2.3.1.4 Per depot OPEX cost (£/Month)

An estimate of any monthly costs associated with electrifying a depot can be entered, for example a Chare Station Management System (CSMS) subscription or maintenance costs.

2.3.1.5 Per-site CAPEX costs (£)

The user can enter and estimate of any costs of installing infrastructure at a site level to support electrification of the fleet, for example connection upgrades or groundworks.

2.3.2 Electric Vehicle (EV) Type

Each unique model of vehicle that the user wishes to model must be entered as an electric vehicle type. Multiple instances of the same EV model can be added to a scenario. The following information is required:

2.3.2.1 Capacity of battery (kWh)

The battery capacity of the model is entered in kWh. The user is directed to a source of vehicle specifications in case they do not have this information available.

2.3.2.2 Maximum charge speed (kW)

The maximum charging speed of the vehicle in kW, this is also known as the charge rate or charge power. The user should use the AC charge speed, unless they are planning to install rapid DC chargers.

2.3.2.3 Range in miles

The vehicle range (the distance the EV can travel on a full charge) must be entered. The user is directed to https://ev-database.uk/ which gives several range estimates for each vehicle. It is recommended that the user chooses the lowest figure for their expected driving conditions in order to account for use of heating and air conditioning in inclement weather.

2.3.2.4 Fixed per unit CAPEX cost (£)

An optional estimate the purchase cost of each EV can be entered in order to calculate the full cost of fleet electrification.

2.3.2.5 Monthly per unit OPEX cost (£/month)

Recurring costs (vehicle lease, maintenance, etc.) can be entered per vehicle per month. This is an optional field.

2.3.3 Charge Point (CP) Type

Each unique model of CP that the user wishes to install at their site must be entered as a charge point type. Multiple instances of the same CP model can be added to a scenario. The following information is required:

2.3.3.1 Number of connectors

How many simultaneous charging sessions the CP can provide. This is usually the same as the number of physical connectors on the CP.

2.3.3.2 Maximum charging capacity (kW)

The maximum charge rate for the CP, this should be stated in the charge point specifications. Note that if the site only has a single-phase connection, or the user plans to connect the CP to a single phase, the charge point will be limited to a maximum of 7.4kW and this number should be entered here.

2.3.3.3 Maximum charge rate per connector (kW)

If the CP has more than one socket, each socket may be wired individually (and each can then provide the full charge rate simultaneously). Alternatively, the charge rate may be split between the active connectors. Choose the mode of operation here. If the user has not decided or does not know, the tool will assume that all sockets can charge at the maximum capacity.

2.3.3.4 Fixed per unit CAPEX cost (£)

How much each charge point will cost to purchase and install (optional field).

2.3.3.5 Monthly per unit OPEX cost (£)

How much recurring costs (charge point rental, maintenance, etc.) will be per charge point. This is an optional field.

2.3.4 Schedule

A schedule is created to show the half hour periods when the vehicle is away from the site and not able to charge (termed a trip). For each trip a mileage driven must be entered. Each day can have up to three trips. If the vehicle will not be plugged in between trips (e.g. they return briefly, or when vehicles are being charged alternately) they should be merged to create a longer trip.

2.3.5 Scenarios

A scenario is a combination of one Depot with multiple EVs, CPs and Schedules. Each EV and CP is based on an EV or CP type and each EV in a Scenario must be linked to a Schedule. A scenario can contain up to 500 EVs (with up to five EV types each on up to five schedules) and 500 CPs (of up to five CP types).

2.4 Data analysis

2.4.1 Charging scenarios

The Site Planning Tool processes the data to provide the user with three different charging/connection load scenarios reflecting increasing technological complexity of the control solution required. Given the raw and inputted data, the model can be used to produce capacity predictions for the following scenarios (Table 2):

Table 2 – Charging scenarios

Scenario	Description
Base	• No consideration of time dynamics of power use: this scenario only looks at the maximum possible power requirements resulting from installation of charge points at the site • Approximation of likely capacity requirements for a depot in absence of planning and smart technologies
Unmanaged	• Output is load profile assuming unmanaged charging of EVs • Approximation of likely capacity requirements for a depot in absence of smart technologies
EV load minimised	• Output is load profile assuming smart charging of EVs • Approximation of likely capacity requirements for a depot with control over charge points but minimum optimization efforts

2.4.2 Data flow

The following diagram (Figure 2) outlines the data flow and processing elements that produce the capacity requirement predictions from the raw data:

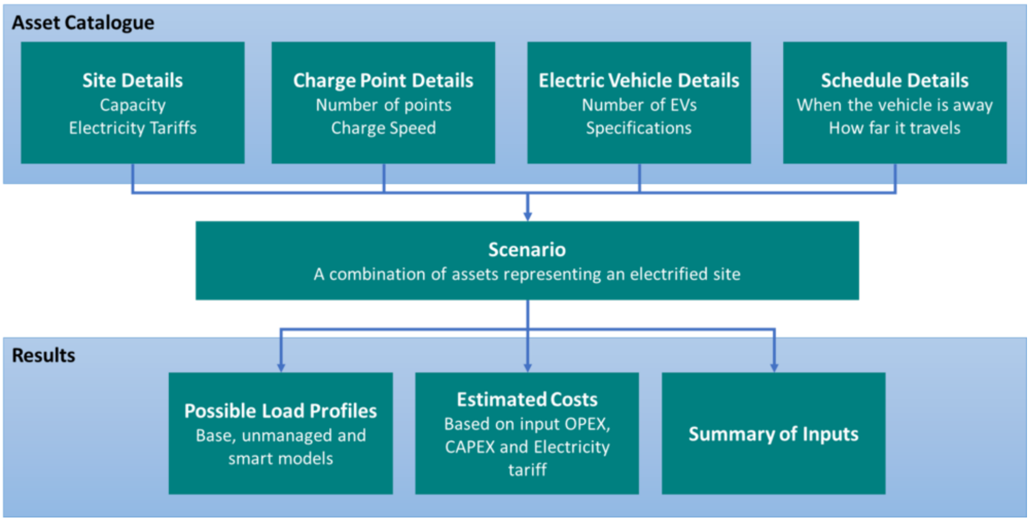

Figure 2 – Model data flow

2.5 Results

2.5.1 Presentation of results

The presentation of the results of the Site Planning Tool varies between scenarios:

Base

- The aggregated capacity requirements of the charge points are combined with the maximum historical depot load and graphically compared against the existing connection agreement capacity.
- The magnitude of predicted capacity overshoot is calculated, if any.

Unmanaged and EV load minimised

- The depot background load for a defined indicative day, typically the day of maximum historical load for the day type in question (weekday, Saturday or Sunday), is combined with the predicted EV unmanaged/load minimised charging loads for each day type and presented as time-series data.
- The aggregated loads are compared against the existing connection agreement capacity and the magnitude of any predicted overshoot is calculated.

2.5.2 Context of results

The aim of the Site Planning Tool is to guide depot operators through the process of planning for the electrification of their depots. It is intended to enable them to assess the capacity requirements for each depot and install the required EV charging infrastructure in the most cost-effective way. This could include through realising the benefits of profiled connections. This is done through the following steps:

1. The depot operator uses the base scenario to assess the maximum amount of capacity they would need to ask for in the absence of any managed charging.
2. The depot operator explores how their capacity requirements vary over the day considering both unmanaged and load balanced EV charging.
3. The depot operator enters into informed discussions with the DNO, understanding the benefits and drawbacks for submitting a connection application based on any one of the scenarios. The depot operator identifies a connection agreement which is consistent with their need to balance operational costs and requirements with connection upgrade costs and timescales, while meeting the requirements of the DNO.

Ultimately it is envisaged that the model will demonstrate the potential for significant capacity savings between the base scenario and EV load-minimised scenario, thus highlighting the benefits of using smart charging to adhere to a profiled connection. In consultation with the DNO planners, this should also translate into significant time and cost savings in reaching agreement to proceed with installation of new EV charging infrastructure at a depot. Facilitating this understanding is key to the roll out of profiled connections and encouraging more efficient use of the network.

2.6 Model execution and usage

The Site Planning Tool aims to help depots understand their capacity requirements. It is therefore expected to be used in the planning process when the depot operator is considering how to electrify its fleet. Once the preferred approach has been determined and agreed with the DNO, the model is not expected to be used again for that depot unless the operator is considering a material change to its capacity requirements – for example increasing the number of EVs based there or installing other low carbon technology. In the context of the Optimise Prime programme, the Site Planning Tool and its underlying calculation methodology was used throughout the trials to understand whether any of the depots in the study and the network could benefit from a profiled connection.

It is anticipated that the base, unmanaged and load minimised use-cases will be considered once at the beginning of the depot planning stage. If no element of the static data shown in Table 3 is subject to change throughout the connection planning process, it is only required to be inputted into the model once. If the depot wishes to change its connection agreement subsequently due to changed circumstances, e.g. new generation assets or a new set of EVs, the model should be re-run with this static data updated accordingly, and the connection process initiated again from the start with the DNO if required.

Table 3 – Static data

Static data
Existing vehicle fleet telematics
Vehicle information (make, model etc.)
Charge point information (make, model, rating etc.)
Energy tariff
Depot background load
Existing connection agreement capacity

The logical order of execution of each scenario is clarified in Figure 3 for the case of a depot that already has a connection agreement (agreed supply capacity, ASC) with the DNO.

For a new depot with no existing ASC, the process would be the same except that the option to work within the exiting ASC would not apply at each step.

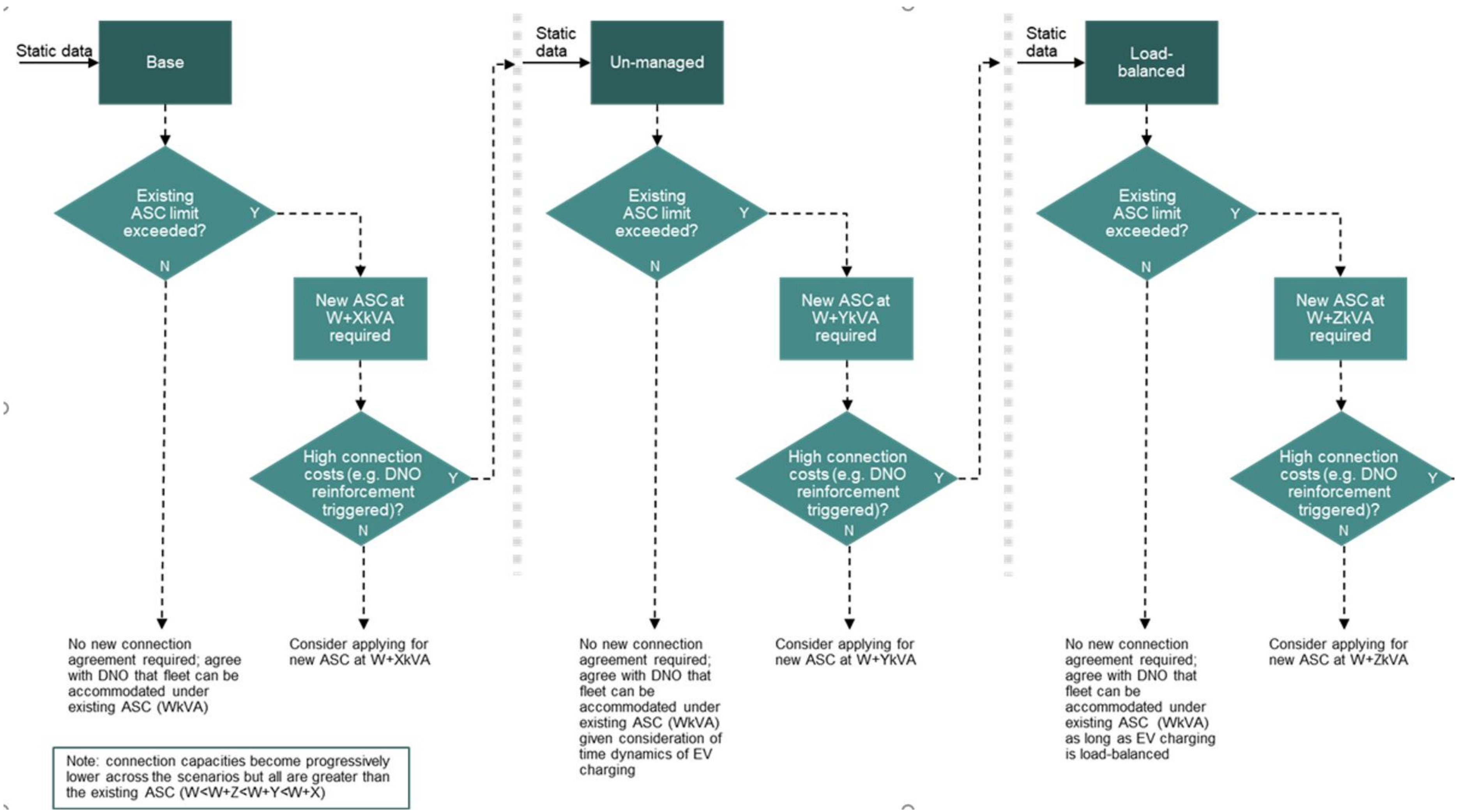

Figure 3 – Scenario execution sequencing

3 Component Descriptions

3.1 Catalogue and Schedules

To use the Site Planning Tool, the user must provide some details on the sites that they plan to electrify, the EVs and Charge Points they plan to use and the Schedules that the EVs will follow. This can be done in the Asset Catalogue section of the tool, described in Section 2.3.

The user can edit or delete existing assets using the menu to the right of each catalogue item. To estimate load, the user must provide as much detail as possible about the power consumption of the site and vehicles. Fields related to cost are generally optional and, if filled in, will provide a summary of the main costs of electrification.

3.2 Scenarios

Scenarios bring together a set of assets to simulate the impact of electrifying a site. To create a scenario, the user must specify a site and at least one site, charge point type, electric vehicle type and schedule. The user can specify multiple of each type when making a scenario.

Once a scenario is created it can be submitted for analysis based on three different models – base, unmanaged and load minimised. This analysis produces the optimal demand profile, including EV charging schedules for each model.

3.3 Result Calculation

3.3.1 MPAN aggregation

The result calculation also takes into consideration the meter point administration numbers (MPANs). This allows the user to consolidate total background load of sites with multiple meter points if required.

3.3.2 Example input

An example of the depot background load entered into the Site Planning Tool using the prescribed format is given in Figure 4.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	date	mpan_number	ptu_1	ptu_2	ptu_3	ptu_4	ptu_5	ptu_6	ptu_7	ptu_8	ptu_9	ptu_10	ptu_11	ptu_12
2	01/01/2017	S1200000000000	0.7	1.2	0.8	0.9	1.1	0.8	1	0.8	1	0.7	0.9	0.8
3	02/01/2017	S1200000000000	0.7	0.7	1.1	0.7	0.6	0.7	0.7	0.6	0.7	0.5	0.6	0.7
4	03/01/2017	S1200000000000	0.8	0.5	1.1	0.6	0.6	0.6	0.6	0.8	0.6	0.8	0.6	1
5	04/01/2017	S1200000000000	1	1.1	1	1.1	1.4	1.2	1.4	1.1	1	0.8	1.2	1.6
6	05/01/2017	S1200000000000	0.6	1	0.7	0.9	1.1	0.7	1.1	1.4	1.2	1.4	1.1	1.1
7	06/01/2017	S1200000000000	0.6	0.4	0.6	1	0.7	0.4	1	0.9	1	0.7	0.5	0.6
8	07/01/2017	S1200000000000	0.6	0.6	0.6	0.6	0.6	0.7	0.8	1	0.7	0.6	0.5	0.9
9	08/01/2017	S1200000000000	0.8	0.6	1	0.9	0.9	0.8	0.6	0.6	0.7	0.6	1	0.6
10	09/01/2017	S1200000000000	1.2	0.6	1	0.7	1	1	1	0.9	0.7	0.7	0.7	0.8
11	10/01/2017	S1200000000000	1.2	1.3	1	1.7	1.4	1	1.2	1.1	1.1	0.9	0.8	1.1
12	11/01/2017	S1200000000000	1.1	0.9	1.2	1.1	1.7	0.9	0.6	0.7	1.1	1	1	1.1
13	12/01/2017	S1200000000000	1.2	1	2	1.2	1.1	1.3	1.4	1.1	1.7	1.3	1.1	1.4
14	13/01/2017	S1200000000000	0.7	1.1	1.1	1.6	1.4	1	1	1.4	1.1	0.9	1.2	0.8
15	14/01/2017	S1200000000000	1.1	0.7	0.7	1.1	1.2	0.8	0.9	1.5	1.9	0.9	1.2	1.3
16	15/01/2017	S1200000000000	1.2	1.1	2	1.2	0.9	0.8	1	1	1.2	1.1	1	1.1
17	16/01/2017	S1200000000000	1	0.9	0.8	1.2	1	1.1	0.6	0.6	0.9	1	1.1	0.8
18	17/01/2017	S1200000000000	0.9	1.1	1.3	1.2	1.2	1.3	1.3	1	1.1	1.2	1.1	1.7
19	18/01/2017	S1200000000000	1	0.7	1.7	1.4	1.2	1.2	0.9	1	1.2	1	1.1	1.1
20	19/01/2017	S1200000000000	1.5	1	0.9	1.3	1.1	0.9	0.6	1	1	1.2	0.9	0.8
21	20/01/2017	S1200000000000	1.5	1	1.3	1.1	0.8	1.2	0.8	1.1	0.9	0.8	1.3	0.9
22	21/01/2017	S1200000000000	1.3	1.5	1.3	1.5	0.9	0.9	1.1	1	1.3	1.1	0.8	1.9
23	22/01/2017	S1200000000000	1.2	1.1	1.4	0.9	0.9	0.9	0.9	0.7	1.7	1.1	1.1	1
24	23/01/2017	S1200000000000	1.8	1.3	1.1	1	0.8	1.1	0.8	1.3	1.1	1.1	0.9	1
25	24/01/2017	S1200000000000	1	1.5	0.7	0.9	1.2	1.3	1.1	1.1	1	0.7	1.2	0.7

Figure 4 – Illustrative depot background load profile input

3.4 EV Load Calculation

The EV load for the unmanaged charging and load balancing case is calculated in consideration of the depot return time, the depot leave time, and the amount of charging required. The algorithms are as follows:

Unmanaged

For unmanaged charging, the model allows the user to assess the relative load requirements for both the conservative case of charging at the full capacity of each charge point (i.e. to allow all charge points to run at full power), or to simply add enough charge to meet the next day's operational mileage requirement. A summary of the calculation approach is provided in Figure 5.

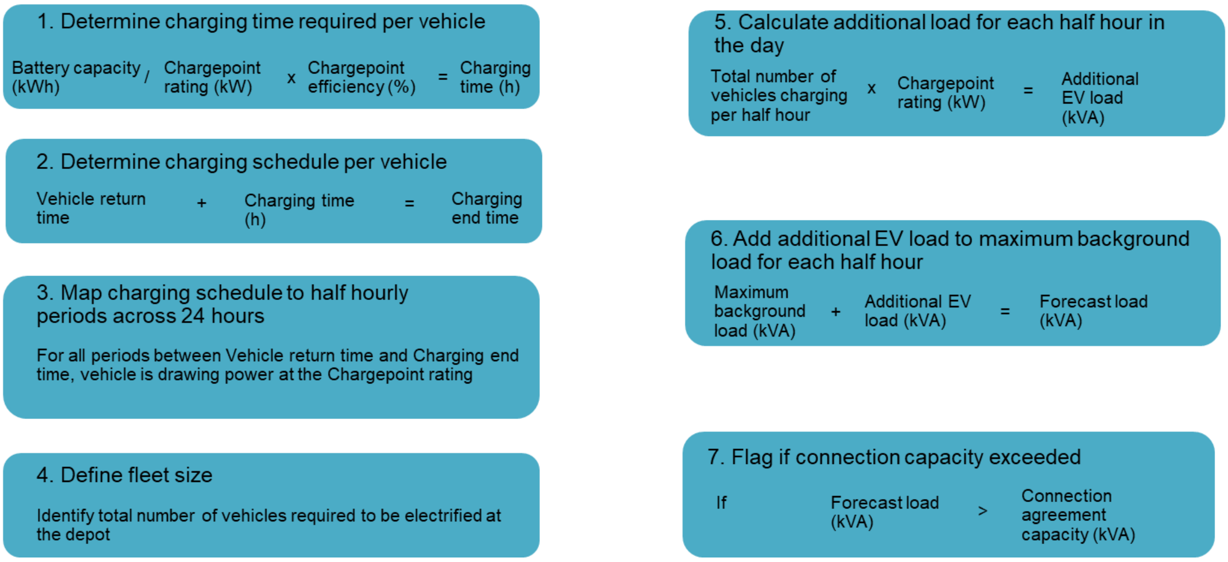

Figure 5 – Unmanaged calculation approach

EV load minimised

This scenario represents the minimisation of each individual EVs contribution to the total load in any one half-hourly time period. As such, the EV must be charged at the minimum rate possible to still facilitate the required charging in the time available. A summary of the calculation approach is provided in Figure 6.

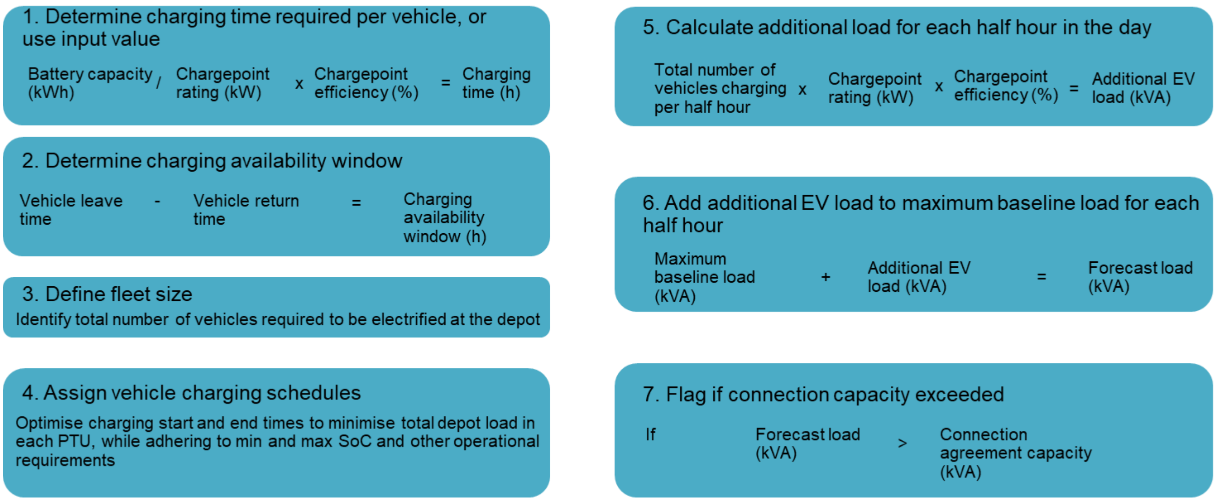

Figure 6 – EV load minimised calculation approach

3.5 Site Load Optimisation

In order to represent the capacity benefits enabled from smart charging, the EV Load Optimisation component of the model calculates EV load profiles in consideration of the depot background load (which can be modified by the user to include any behind the meter generation). This means that the EV load can be distributed to times when the depot load is lower (e.g. overnight) to minimise the amount of additional capacity required. The user can then manipulate the capacity constraint to mimic potential profiled connection agreements and determine their feasibility.

- To achieve adherence to varying capacity constraints, the EV load distribution is formulated as a Linear-Programming optimisation problem with the objective function of maximising fleet operations (i.e. minimising risk).

Subject to constraints:

1. Vehicles must not fall below a specified state-of-charge whilst being driven (20%).
2. Vehicles may not charge at a rate higher than that determined by the charge point rating and EV on-board charger.
3. Vehicles must not discharge electricity back to the building.
4. Vehicles must have received adequate charge to complete the next day's trips by the time it leaves the depot.
5. The total EV load (in each half-hour) added to the depot background load and that of any behind the meter generation must be less than the user defined connection capacity (in each half-hour).

Variables:

- The kW power draw from the charge point into each vehicle in each half-hour.

Framing the EV load allocation as an optimisation problem allows for the inclusion of objective functions that reflect business priorities. For example, a depot operator has the freedom to explore how different profiled connection agreements limit will affect the daily electricity costs based on their time-of-use tariff. Maximising fleet operations is where the depot operator wishes the vehicles to be fully charged as soon as possible, given the capacity constraints.

4 Output of load optimisation

The Site Planning Tool is designed to provide the user with load profiles that are achievable for a certain EV load, given a number of different charging scenarios. In addition to this, total consumption of electricity is multiplied by the tariff value in each half-hour, and then aggregated over the day in order to give the user an indication of the impact on electricity cost of the different charging scenarios, as shown in Figure 7.

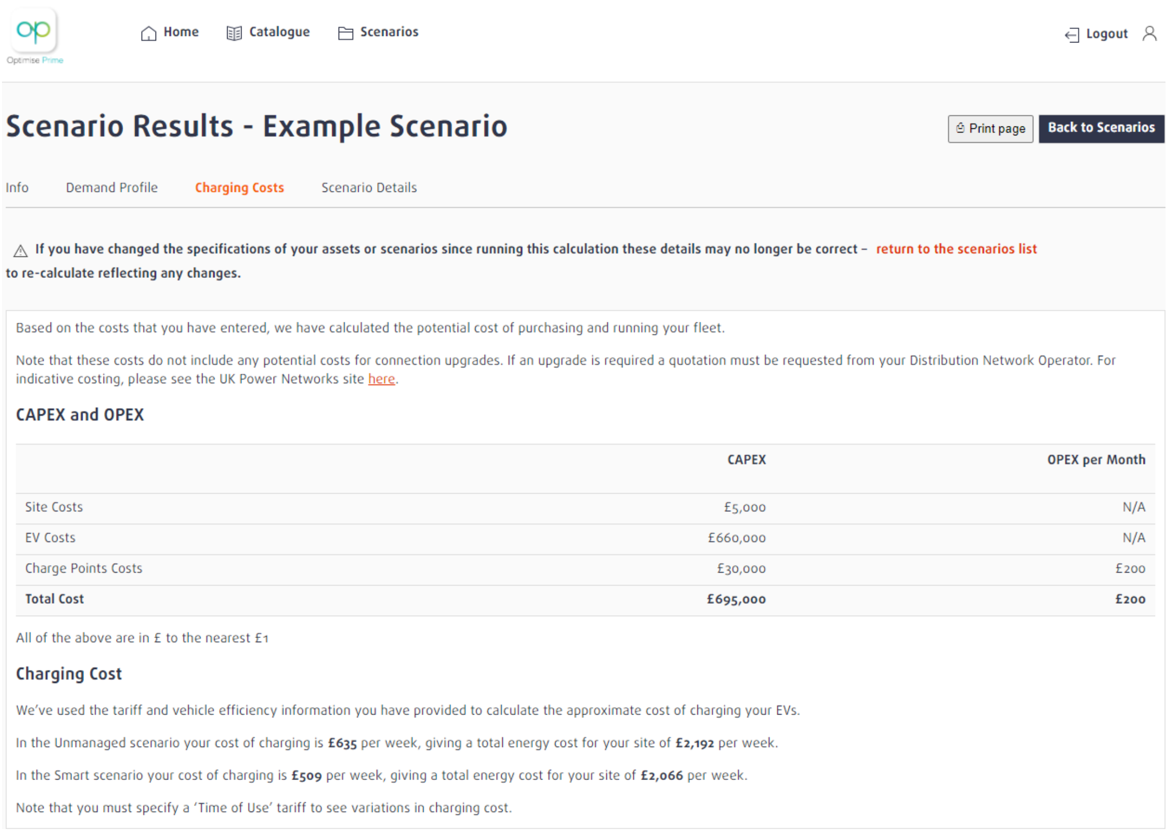

Figure 7 – Site planning tool cost output

4.1 Operations optimisation

The model ensures that the fleet always has sufficient charge for the following day's operations. The web-based tool will not return a result if it is not possible to charge all of the vehicles sufficiently within the available time.

4.2 Reporting

The results of the model are predominantly graphical. Example outputs for each of the use cases, as well as key points to note, are given in the following sections.

4.2.1 Base scenario

Figure 8 shows an example output for the base-case – in the web-based tool the base case load is presented as a single number, compared to the site ASC. As discussed in Section 3.4, the additional capacity requirements are calculated by summing up the CP ratings and adding this to the maximum depot load. This represents the worst possible scenario for the depot in terms of capacity usage – simulating an event where the depot is using its maximum historical load as well as using all installed CPs to their rated maximum capacity.

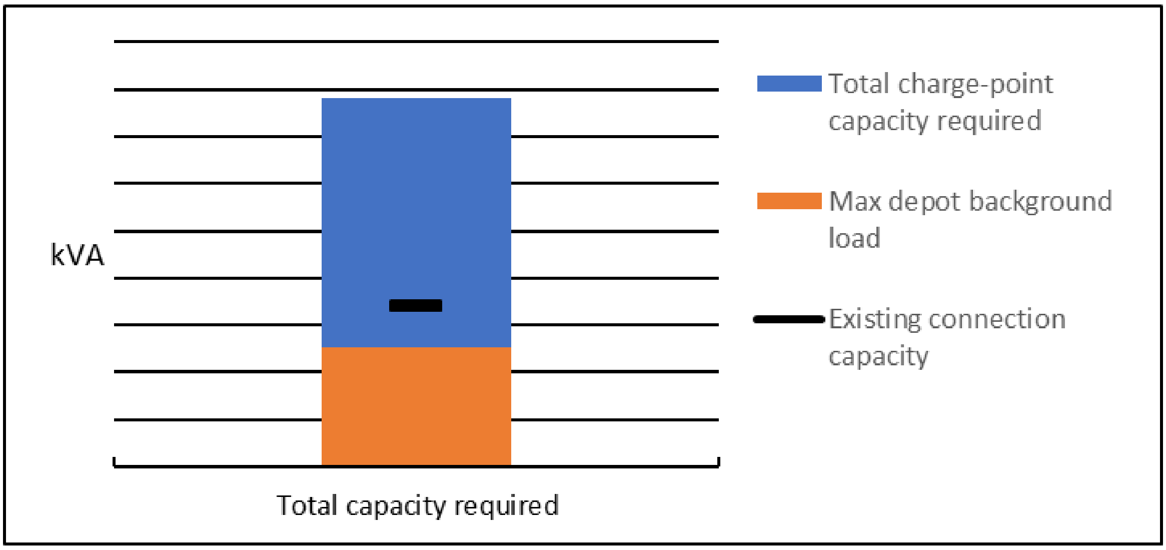

Figure 8 – Illustrative base scenario output

4.2.2 Unmanaged scenario

The output for the unmanaged charging case shows the charging activity of the EVs consolidated. It is added to the background load of the site and is presented graphically to the user to be compared against the existing capacity agreement, as shown in Figure 9. The web-based tool shows a single week view, generated by taking the maximum load for each half hour period of the week from the available data.

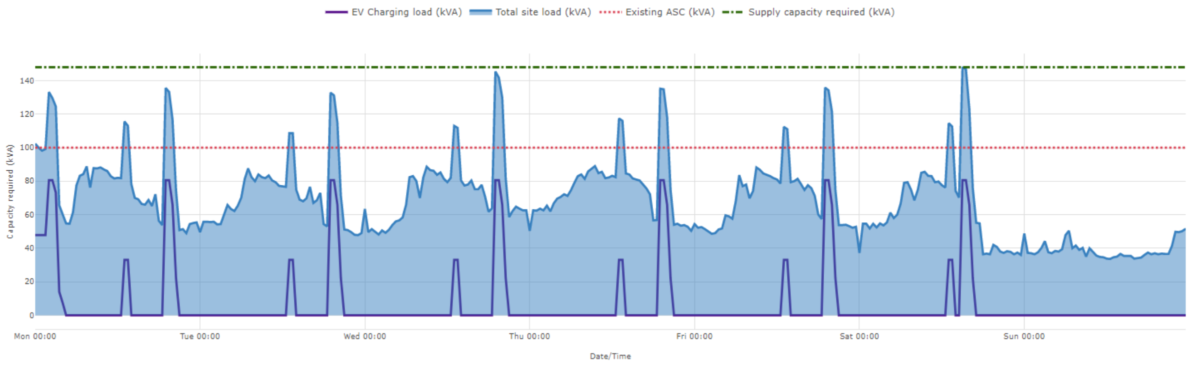

Figure 9 – Output of unmanaged scenario

In the example given it should be noted that:

- The total site load is shown by the light blue area, with the dark blue line showing the contribution of EV charging to the load
- The Green line shows the minimum capacity that would be needed for a firm connection to cover unmanaged charging at the site
- The red line shows the ASC entered by the user
- EVs charge to full as soon as they are plugged in.
- EVs start and end the week at 80% state of charge
- There is no regard for capacity constraints, hence the capacity breach.

4.2.3 EV load minimised scenario

In the site planning tool the load of each EV is summed and added to the background load are presented graphically to the user to be compared against the existing capacity agreement, as shown in Figure 10.

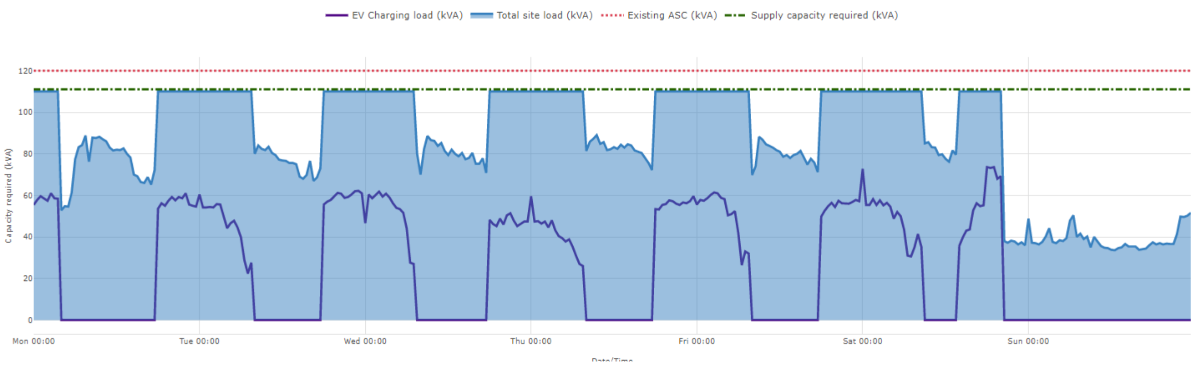

Figure 10 – EV load minimised EV charging (dark blue line) showing contribution to total depot load (light blue area)

In the example given it can be seen that:

- The total site load is shown by the light blue area, with the dark blue line showing the contribution of EV charging to the load.

- EVs can use the entire available period when they are plugged in to charge in order to minimise the contribution of EVs to the load.
- The optimisation is aimed at reducing the site’s peak load across the week (the green line) as far as possible. It may be possible to reduce load further at specific times.
- There is no regard for capacity constraints, hence, although decreased, capacity can still exceed the ASC (the red line). This will indicate that the user will need to consider a connection upgrade and cannot rely on smart charging alone.