Isle of Wight E-tourism: alternative solutions to network reinforcement

Final report

for

Scottish and Southern Electricity Networks

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Executive Summary

This study builds on previous work Element Energy has completed for Scottish and Southern Electricity Networks (SSEN) on E-tourism. The focus of the previous study was on predicting electric vehicle (EV) charging demand at typical tourist sites across the Isle of Wight in 2030 and identifying areas where current electricity network infrastructure may be insufficient as a result of the growing demand from E-tourism[1]. Typically increases in electricity demand are accommodated by network reinforcement, however, these upgrades are expensive and may take several years to complete. This study assesses alternatives to network reinforcement that can be employed to deal with the challenge of increased electricity demand from tourist EV charging. We have selected two key use cases to investigate in this study.

1. The Woodland Resort: an upcoming eco-tourism resort which will be situated on the north west of the island.
2. The Needles: a landmark and tourist attraction on the westernmost tip of the island.

These have been selected as sites where tourist EV charging in 2030 is likely to lead to increases in electricity load beyond the network capacity. The contexts of these sites are also quite different, meaning different solutions are likely to be applicable at each. A summary of the findings of the network analysis for each site is summarised in Table 1 below.

Table 1: A summary of the findings from the network analysis of secondary substations. Green: no demand constraints expected; amber: small/short demand constraints expected; red: large, long duration demand constraints expected[2].

Case study	Secondary substation	Current network status	Days of constraint expected in 2030
Woodland Resort	Lucketts		161
The Needles	Alum Bay Pleasure Park		60

Following a literature review of seven alternative solutions to network capacity upgrades, a short list of five alternative solutions were assessed at the two case studies. They are:

- Smart charging
- Local generation
- Energy storage
- Combined generation and storage
- Novel EV charging options (this will include valet and ticketed charging, overnight charging services, and park and ride)

For the Woodland Resort, and the Needles, the applicability of each solution was assessed. At both sites, smart charging offers an effective and cost-efficient method to reduce site peak demand. At the Woodland Resort, overnight charging demand could be shifted later into the evening to avoid large peaks in the load. This could reduce the peak load from EV charging by up to 55%. At the Needles, delaying charging is not possible due to the shorter time visitors spend on site. However, some benefit from smart charging may still be possible

[1] Element Energy, E-tourism: charging demand by electric vehicles on the Isle of Wight, SSEN, 2021. Link to report
[2] Note generation constraints are not considered in this table.

by using dynamic charging rates, which would limit the power drawn by each vehicle when there is limited spare capacity on the network. Our analysis demonstrated that the peak EV charging load of the Needles could be reduced by 20% on a peak August day while still delivering vehicles 9 kWh of energy, sufficient for 45 km of additional range.

In addition to smart charging, our analysis suggested that battery storage could accommodate the peak EV charging load at the Woodland Resort, drawing from the transformers installed at the site to serve the site's base demand. At the Needles, tourist visits are strongly influenced by season and weather. Therefore, there is likely to be a good correlation between available solar generation capacity and tourist EV charging demand. Hence, charging demand can broadly be matched with solar generation, which can be combined with battery storage to meet charging demands when weather conditions result in lower solar generation capacity.

A variety of novel EV charging options were considered for the Woodland Resort and the Needles. These solutions have the potential to provide effective EV charging peak load reduction, however, not all of these solutions are applicable to both sites. The novel EV charging options, along with all the other short-listed solutions, are detailed in section 4.

Alongside applying each solution to the two use cases, the applicability of the short-listed alternative solutions have been applied to general EV charging sites influenced by E-tourism. This analysis, summarised in Table 2, found that there are several viable solutions to mitigate network reinforcement caused by increased demand from E-tourism. The priority of the solutions in Table 2 denotes the order in which they should be considered by sites as potential solutions to network capacity issues. Smart charging is likely to be the most cost-effective alternative to network upgrades, however this is only true for sites where it can be effectively applied. The applications and benefits of novel EV charging are wide ranging and uncertain due to it being an emerging option. However, as it is likely to cost significantly less than installing local generation or battery storage systems, it may be a more cost-effective option for avoiding network upgrades in certain contexts. In areas where neither smart charging or novel EV charging would be sufficient, combined generation and storage is the next most likely option for accommodating EV charging without upgrading the electricity network. Energy storage systems alone are generally less applicable than combined generation and storage, but may have some potential applications.

Table 2: Summary table of the short-listed alternative solutions and their potential applications. Green: enabler of solution; amber: neutral; red: potential barrier to solution.

Priority	Alternative solution	Cost	Headroom released	Practical feasibility	Applications
1	Smart charging				Sites where significant overnight EV charging demand is expected Sites with limited network capacity but large demand for EV charging during the day
2	Novel EV charging				Sites which need to be booked in advance where EV charging could be booked at the same time Sites where a park and ride arrangement could be implemented Sites with limited space or network capacity available for EV charging Towns with limited on-street charging availability
3	Combined generation and storage				Sites which are busiest when the weather is good Sites where the majority of EV charging demand occurs during the day Alternatively, sites with evening peaks of short duration and predictable occurrence, so can be reliably managed by energy storage of daily solar generation
4	Energy storage				Sites where additional transformer capacity can be cost effectively replaced by battery storage Sites with peaks of short duration and predictable occurrence, so can be reliably managed by energy storage
5	Local generation				Unlikely to be a solution by itself due to intermittent nature of solar power

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Acronyms & Glossary

BESS	Battery energy storage system
CAPEX	Capital expenditure
DNO	Distribution network operator
EV	Electric vehicle
EVCP	Electric vehicle charging point
Island	Isle of Wight
LCOE	Levelized cost of energy
LV network	Low voltage electricity network
OPEX	Operational expenditure
PPA	Power purchase agreement
PV	Photovoltaic
SSEN	Scottish and Southern Electricity Networks
TPO	Third-party ownership

1 Introduction

1.1 Objectives of this study

This study builds on previous work Element Energy completed for SSEN on E-tourism. The focus of the previous study in this project was on predicting electric vehicle (EV) charging demand at typical tourist sites across the Isle of Wight in 2030 and identifying areas where current electricity network infrastructure may be insufficient to serve the increased demand from tourist EV charging[3]. Typically increases in electricity demand are accommodated by network reinforcement – installing additional cables and transformers to accommodate this increased electricity load – however these upgrades are expensive and typically take several years to complete. This study aims to assess alternative measures to network reinforcement that can be employed to deal with the challenge of increased electricity demand from tourist EV charging.

The key objectives of this study are:

- Review existing and emerging alternative solutions to network reinforcement for accommodating increases in tourist EV charging demand
- Use case studies on the Isle of Wight to determine where and how these alternative solutions may be deployed
- Draw more general conclusions on how these solutions can be used based on their suitability at case studies on the island

The key year for this study is 2030, when the UK government plans to end the sale of petrol and diesel cars and vans. By this time there will be a significant number of EVs on the road and many tourist EVs visiting popular destinations, which may not have sufficient network infrastructure to accommodate the additional electricity load from tourist EV charging.

1.2 Overview of case studies

In this study two key use cases have been selected on the Isle of Wight. Their locations are shown on a map of the island in Figure 1:

1. The Woodland Resort: an upcoming eco-tourism resort which will be situated on the north west of the island.
2. The Needles: a landmark and tourist attraction on the westernmost tip of the island.

These have been selected as sites where tourist EV charging in 2030 is likely to lead to increases in electricity load beyond the network capacity. The contexts of these sites are also quite different, meaning different solutions are likely to be applicable at each. For example, there are expected to be a significant number of overnight visitors at the Woodland Resort, while visits to the Needles will occur only during the daytime. As the ultimate aim of this study is to understand how alternative solutions to network reinforcement can be used more generally to deal with increases in tourist EV charging, findings from these sites will be used to inform the contexts in which different solutions could be suitable.

[3] Element Energy, E-tourism: charging demand by electric vehicles on the Isle of Wight, SSEN, 2021. Link to report

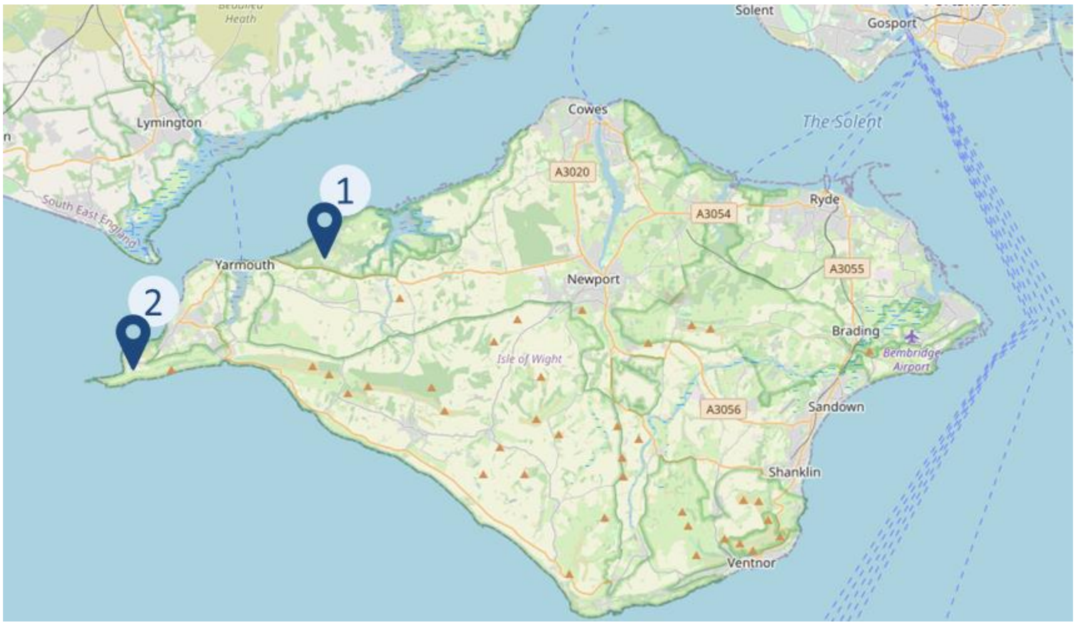

Figure 1: Map of the Isle of Wight indicating the locations two tourist sites selected as case studies. © OpenStreetMap contributors.

1.3 About this report

The purpose of report is to describe work undertaken in the project and present conclusions from the analysis of alternative solutions to network reinforcement at the two case studies. The additional electricity demand from tourist EV charging at each site is outlined in Section 2. The findings from the literature review of alternative solutions considered in the study are presented in Section 3. The suitability of these solutions is then assessed at each site in Section 4, and conclusions are drawn on how these solutions could be used to reduce network reinforcement costs at sites with similar characteristics in Section 5.

2 Network impact of tourist EV charging

In order to determine how effective alternative solutions could be at managing increased load from tourist EV charging, the size of this increase in load first needed to be understood. Figure 2 summarises the process used to predict demand from tourist EV charging at each of the case studies, and the effect that this increased demand could have on the electricity network. As the purpose of this study is to understand the different alternative solutions available, the process of predicting network impact of tourist EV charging will not be described in detail. A full description of this process is available in the previous SSEN Isle of Wight E-tourism study[4].

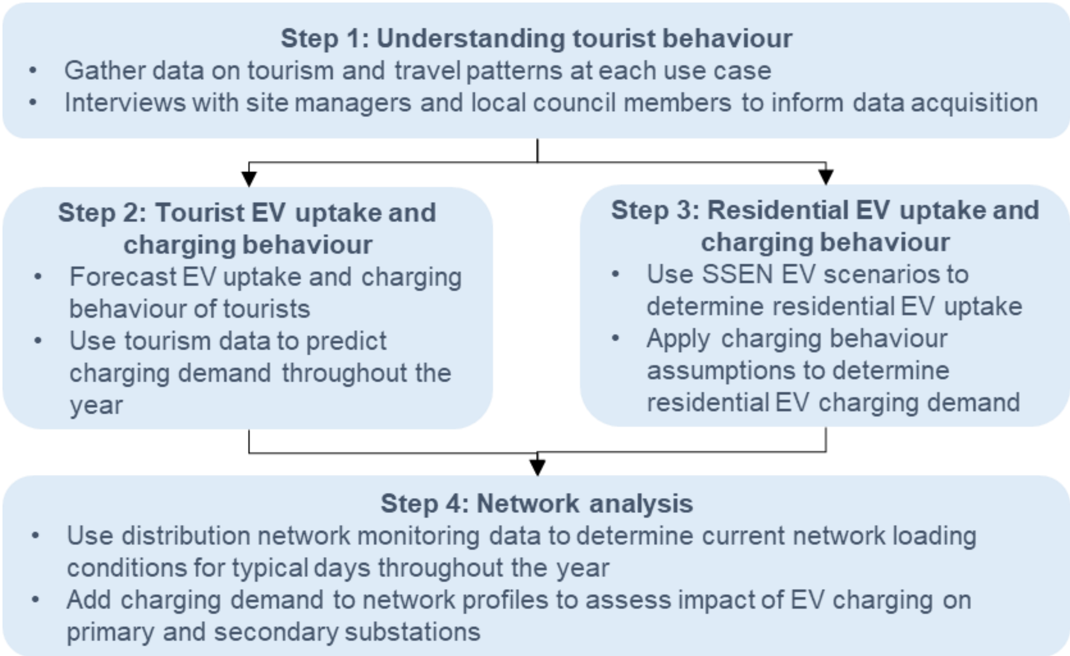

Figure 2: A schematic diagram of the steps required to predict tourist EV charging demand and network impact at each of the case studies.

A schematic diagram of local network infrastructure, also known as the electricity distribution network, is shown in Figure 3. The distribution network takes in very high voltage electricity from the national electricity transmission network and transforms it into 230 V electricity for use in households and businesses. This is achieved through a series of transformers (also known as substations), which step higher voltage electricity down to lower voltage electricity for more local distribution. Distribution network operators (DNOs) are responsible for maintaining the cables and transformers that make up the distribution network, and there are six DNOs responsible for the distribution network in different regions of the country. The local electricity network on the Isle of Wight is owned, operated and maintained by SSEN.

The focus of this study is on secondary substations, which take electricity from the 11 kV low voltage (LV) network and transform it into 230 V electricity for domestic use. The tourist sites studied in this work are all served by secondary substations, so understanding the electricity load on the relevant secondary substations allows for the electricity load of the corresponding tourist sites to be studied.

[4] Element Energy, E-tourism: charging demand by electric vehicles on the Isle of Wight, SSEN, 2021. [Link to report]

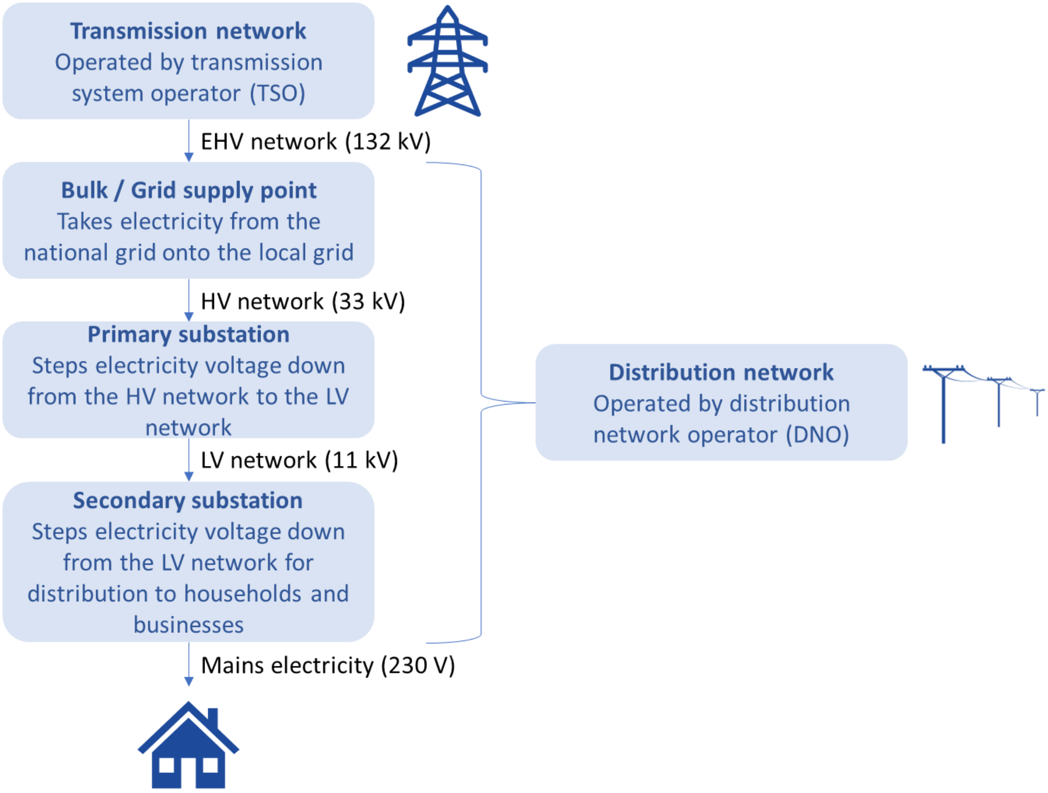

Figure 3: A schematic diagram of the electricity network.

2.1 Woodland Resort

2.1.1 Context

The Woodland Resort is a new eco-wellness resort that is currently under development in the northwest of the island that plans to place sustainability at the centre of all its activities. The Woodland Resort will accommodate overnight guests in addition to offering an on-site café, restaurant, and spa and wellness centre to attract day visitors. In high season, the resort expects to attract approximately 500 visitors per day, which includes 150-200 visitors staying overnight.

Figure 4: An artistic impression of the tree houses at the Woodland Resort. (Source: Woodland Resort).

In keeping with its sustainability ethos, the 150-bay car park will be installed with at least 10 electric vehicle charging points (EVCPs)[5]. Furthermore, the Woodland Resort plans to make EVs available for guests to rent. They are currently considering placing 5 rental EVs in Yarmouth, so tourists can pick up these EVs when they arrive on the island and utilise them

[5] The power of the EVCPs is yet to be decided.

across the island, charging them at the Woodland Resort. The resort also plans to have approximately 50 e-bikes and 50 e-scooters, all contributing to the EV charging demand at the site.

The predicted EV charging demand from tourism at the Woodland Resort was covered in detail in the previous SSEN Isle of Wight E-tourism study[6]. This section will provide a brief recap of the key findings of this analysis for the Woodland Resort.

2.1.2 Tourist EV charging demand analysis

As the Woodland Resort is not currently in operation, historic data for the variation in number of visitors to the site is not available. Therefore, the expected number of tourists to visit the site was modelled based on the maximum number of tourists the resort expects to serve per day in peak season, 500 visitors, including 195 staying overnight. This was then scaled by the percentage of tourists that travel to the Isle of Wight by car and the average stay on the island. Finally, the expected number of tourists per day was applied to a profile of visitors arriving on the island to capture the seasonal variation in the tourist demand that is likely to be experienced by the Woodland Resort. Details of these calculations can be found in the original report[6]. The final profile for the expected tourist demand at the Woodland Resort is presented in Figure 5.

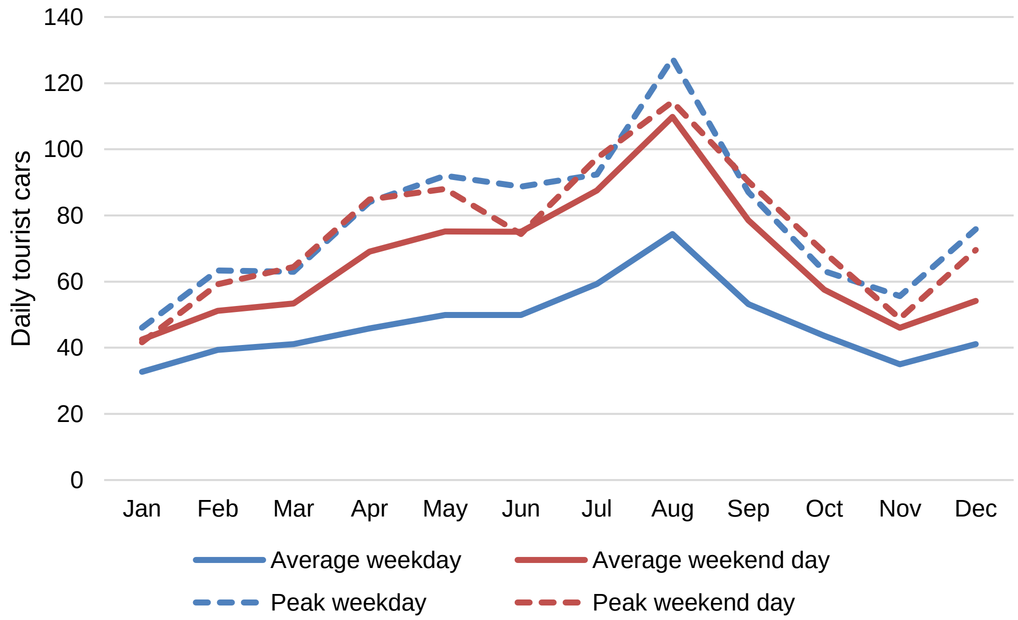

Figure 5: A graph of the daily tourist car visits to the Woodland Resort on average and peak weekdays and weekends.

Based on the EV charging assumptions made in the previous report, the expected EV charging demand from tourists is 118 kWh on an average August weekday and 248 kWh on a peak August weekend day. It is expected that tourists that visit the Woodland Resort just for a day trip will charge using slow/fast daytime charging, whereas tourists that stay at the Woodland Resort will likely make daytime excursions to other attractions on the island, returning to charge their car overnight. Therefore, the two different behaviours have been considered separately and appropriate charging profiles applied to reflect each behaviour

[6] Element Energy, E-tourism: charging demand by electric vehicles on the Isle of Wight, SSEN, 2021. [Link to report]

type. The demand profiles for daytime and overnight charging are aggregated in Figure 6 to produce the total expected tourist EV charging demand profile at the Woodland Resort.

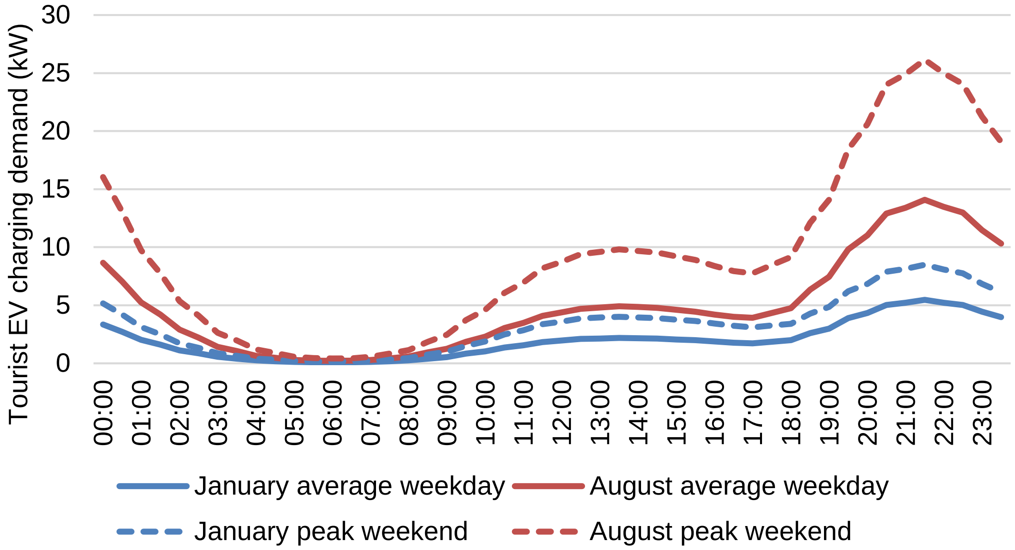

Figure 6: A graph showing the expected EV charging demand created by tourists at the Woodland Resort in 2030.

As it is expected that tourists will be more likely to charge if they are staying overnight than if they are on a day trip, the evening peak dominates the profile, with a maximum charging demand of 26 kW occurring between 21:00-22:00.

The previous study also analysed the projected residential EV charging demand at each relevant substation to account for its impact on the future load. The Woodland Resort is being developed in a remote area of the Isle of Wight where there are very few residential buildings. As such, the projected load from residential EV charging is minimal, amounting to 12 kWh per day with a peak of 1.2 kW, occurring between 19:00-20:00.

2.1.3 Network impact findings

Situated in a rural area, Lucketts, the secondary substation serving the resort, is a small pole mounted transformer, with a rating of only 15 kW[7]. Because the substation serving the Woodland Resort is a pole mounted transformer, a maximum demand indicator is not available at this substation. Therefore, the base load profile for this substation has been calculated by scaling the demand on the primary substation, Shalfleet, by the number of customers on the Lucketts substation (0.1%). This approach suggests there is a maximum demand of 6.2 kW, and hence a spare capacity of 8.8 kW for EV charging demand.

Based on this analysis the projected load from The Woodland Resort exceeds the firm capacity marginally on an average August weekend and exceeds the firm capacity substantially on a peak August weekend. This is illustrated in Figure 7. Over a calendar year in 2030, it is expected that as a result of tourist and residential EV charging demand, the transformer rating of Lucketts substation will be exceeded on 161 days.

[7] The Woodland Resort are investigating upgrading their connection irrespective of EV demand on site to account for the additional inflexible load their new site will place on the network.

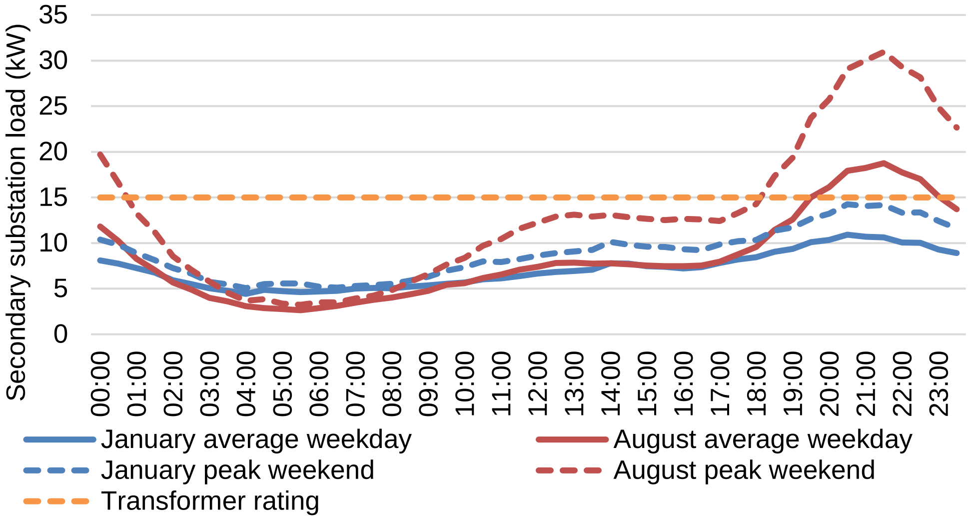

Figure 7: A graph showing predicted load on the Woodland Resort secondary substation in 2030, accounting for tourist and residential EV charging.

Based on the projected EV charging demand in 2030, it will be necessary to reinforce or upgrade the substation at the Woodland Resort to increase its firm capacity. However, because a large proportion of the EV charging demand that occurs at this site is overnight charging, the use of managed smart charging can help reduce the peak demand of charging, delaying and minimising the reinforcement costs. As part of the previous study a sensitivity analysis was conducted for the Woodland Resort to investigate the effect smart charging could have on minimising the impact of tourist EV charging on the distribution network. This analysis will be discussed in more detail in section 4 of this report.

2.2 Needles

2.2.1 Context

The Needles is a chalk rock formation of the westernmost extremity of the Isle of Wight marked by a lighthouse. It has long been a draw for tourists offering views of the rocks and lighthouse; boat trips for close up views; two gun batteries and a rocket testing station from its time as an artillery base; the Needles Landmark Attraction, a small amusement park at the top of the cliff; and a chairlift, transporting tourists between the park and the beach. The Needles is situated near Alum Bay and is approximately 8km from Yarmouth ferry terminal.

Figure 8: View of the Needles (Source Vecteezy.com).

2.2.2 Tourism statistics

For this site, the Needles site managers were able to provide data from 2019 and 2021 on the number of cars that visited the Needles in the seven months between April and October when the site is fully open and the number of coaches that visited year long. In order to exclude the impact of COVID-19 from our modelling, the following analysis is based on the 2019 data. To estimate the number of visits that occurred outside the tourist season, coach visits were used – however based on estimates from the site managers demand from cars outside the peak season is very low so EV charging demand at these times is likely to be negligible. Based on this data, the number of tourists visiting the Needles is summarised in Table 3 below.

Table 3: A table summarising the key statistics for the number of tourists visiting the Needles.

The Needles tourism stats overview	
Number of tourist cars visiting per year	86,824
Average daily tourist car visits	238
Peak daily tourist car visits	1,325

Due to the detailed data provided by the Needles site managers on the number of tourists that visit the Needles each day by car, the monthly variation in tourist demand was determined to a high level of confidence for average and peak weekday and weekend days. This is illustrated in Figure 9.

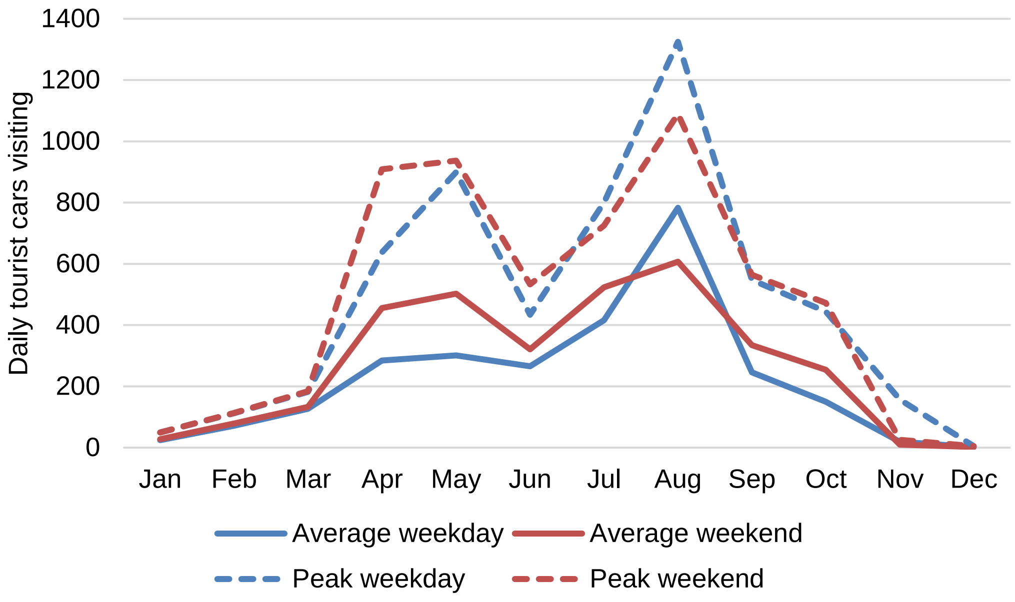

Figure 9: Graph of the daily tourist car visits to the Needles on average and peak weekdays and weekend days.

Tourist visits on weekdays and weekends follow the same monthly trend with two peaks, the first over the Easter/May bank holiday and the second larger peak occurring during the school summer holidays in August. At the end of the summer period (from September), the number of visits declines rapidly and remains low throughout the off-season. Despite not having definitive data on the number of cars visiting in the off-season, this can be confidently inferred from the number of coach visits during this period. For most of the year, weekends were busier than weekdays, however this trend is reversed in August due to the high number of visits on the bank holiday.

2.2.3 Tourist EV charging demand

Table 4 summarises key assumptions that have been made to estimate the total charging demand of a tourist EV at the Needles. Assumptions on EV uptake projections and electricity consumption are presented in detail in the previous report in this project[8].

Table 4: A table summarising the key assumptions made to calculate the expected charging demand from a tourist EV.

	Average day	Peak day
Average daily distance travelled (km)	60	60
Energy expended by distance travelled (kWh)	11.4	11.4
Time spent charging at site (hours)	2.5	3
Share of EVs using rapid on-site charging per day	0%	0%
Share of EVs using slow/fast on-site charging per day	30%	60%
Share of EVs using overnight charging per day	0%	0%
Share of EVs not charging at site	70%	40%

[8] Element Energy for SSEN, E-tourism: charging demand by electric vehicles on the Isle of Wight, 2021. Link to report

Given the number of tourists that are expected to visit the Needles on an average and peak day, listed in Table 3, as well as the assumptions on the percentage of tourists that will charge at the Woodland Resort, the expected EV charging demand from tourists is 1,418 kWh on an average August weekday and 4,800 kWh on a peak August weekday.

It is assumed that all charging at the Needles will be slow/fast daytime charging, as this matches the behaviour of EV drivers at the site, visiting during daytime opening hours for 2-3 hours. Based on this, a slow/fast charging profile has been applied to the demand of the Needles to produce the total expected tourist EV charging demand profile at the Needles. Building throughout the morning, the demand peaks at 622 kW between 13:00-14:00. This is equivalent to 29 x 22 kW chargers, or 89 x 7 kW chargers. Figure 10 illustrates the profile of charging demand scaled to reflect the quantity of charging demand created by tourists.

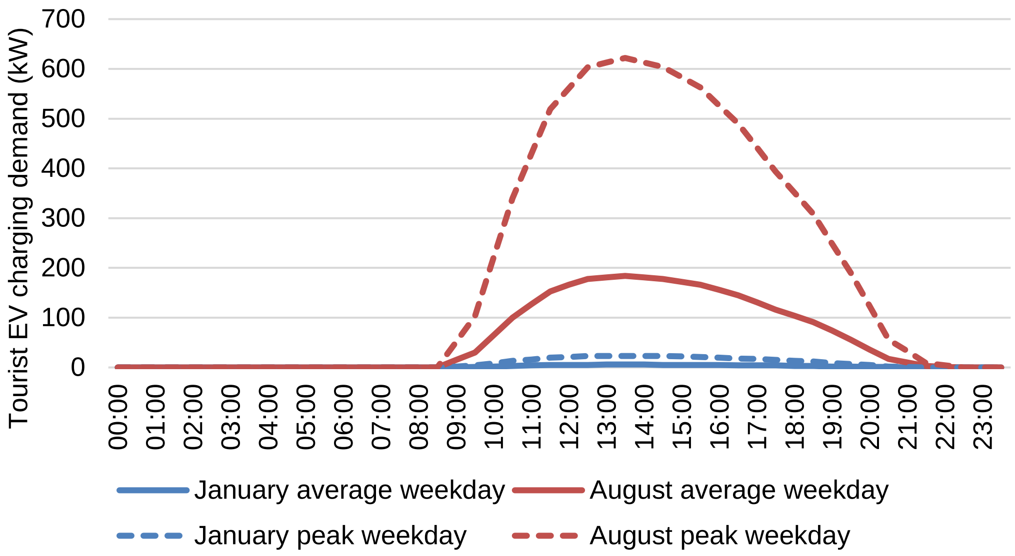

Figure 10: A graph showing the expected EV charging demand created by tourists at the Needles in 2030.

2.2.4 Network impact findings

2019 network monitoring data from Freshwater primary, which serves the Needles car park's secondary substation, were used to calculate half-hourly base network load profiles for the average and peak weekdays and weekend days each month of the year. As equivalent monitoring data is not available for secondary substations, the primary substation load profiles were scaled down to create approximate load profiles for the secondary substation serving the Needles car park, based on the maximum demand at the secondary substation. Given the available capacity of 115 kW here[9], it may be feasible to run 5 x 22kW chargers or 16 x 7 kW chargers simultaneously without having to manage constraints on the local network. The relevant information for the distribution network at the Needles is summarised in Table 5, and base network load profiles for the secondary substation that serves the Needles are shown in Figure 11.

[9] Power on the electricity network is typically measured in units of kVA. For simplicity, values have been converted into units of kW throughout this report.

Table 5: Summary of distribution network information for the Needles use case.

Primary substation name	Freshwater
Maximum demand (MW)	5.6
Firm capacity (MW)[10]	15.0
Secondary substation name	Alum Bay Pleasure Park
Maximum demand indicator (kW)	200
Transformer rating (kW)[11]	315

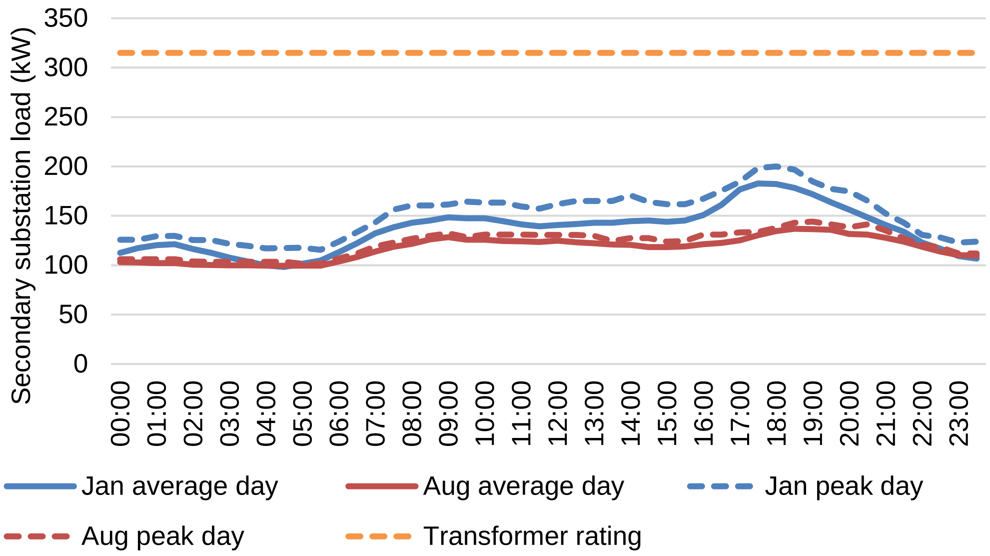

Figure 11: A graph showing the base network load on the secondary substation serving the Needles.

Predicted network load with added tourist EV charging in 2030 is shown in Figure 12. It suggests that the load on the distribution network exceeds the firm capacity substantially on peak August days. Over a calendar year in 2030, it is expected that as a result of tourist EV charging demand, the thermal constraints of the substation serving the Needles car park will be exceeded on 60 days.

[10] Firm capacity is a measure of the maximum power that can be safely provided by a primary substation.
[11] The transformer rating is a measure of the maximum power that can safely be provided by a secondary substation.

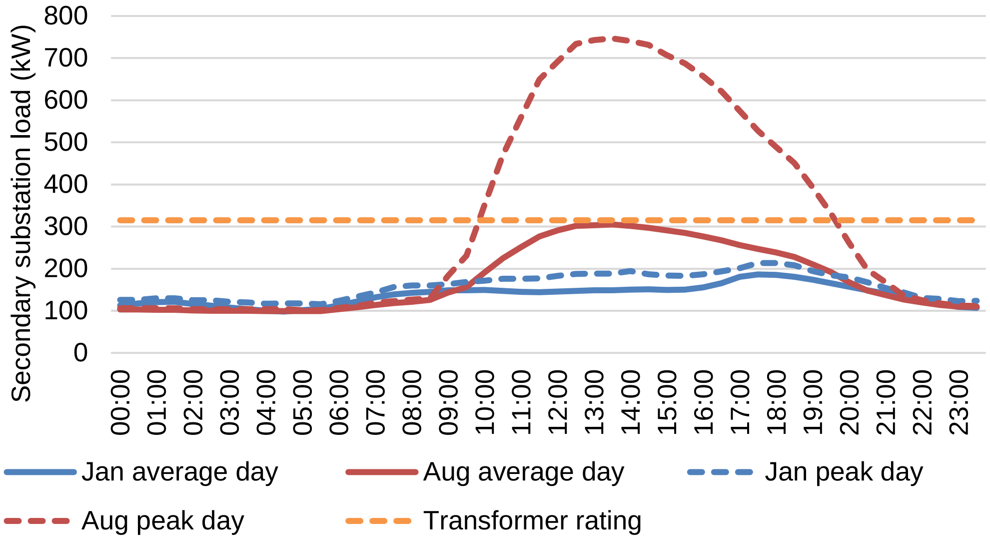

Figure 12: A graph showing the predicted load on the secondary substation serving the Needles in 2030, accounting for tourist EV charging.

Based on the projected EV charging demand in 2030, it will be necessary to reinforce or upgrade the substation at the Needles to increase its firm capacity. However, because the majority of demand on busy days is caused by EV charging demand, alternative solutions to substation upgrades at the Needles may be viable. These will be investigated in more detail in section 4.

3 Literature review findings

Results of the literature review into alternative solutions to network reinforcement are presented in this section. Through discussion with SSEN the following long list of alternative solutions was agreed to be the focus of the literature review:

- Smart charging – shifting demand
- Smart charging – dynamic charging rates
- Local generation
- Energy storage
- Combined generation and storage
- Novel EV charging solutions
- Flexible connections
- Network based solutions

This section will expand on the potential for each of these solutions to reduce network reinforcement costs, high-level costs of each solution, and any points around practical feasibility. Findings from this analysis will be used to determine a short list of alternative solutions taken forwards for the case study-specific analysis detailed in Section 4. Network based solutions have been included in this list for reference, however as the focus of this report is on solutions that can be deployed by tourist sites rather than DNOs, their potential benefits and costs will not be assessed.

3.1 Assessment of the alternative solutions

Smart charging

Smart charging refers to a method of EV charging where the power drawn can be controlled. One method that can be used to control charging is using a signal from the distribution network operator (DNO) that limits load from EV charging at peak times and prevents it from exceeding levels that can be accommodated by network transformers and cables. There are two key ways that smart charging could be applied to tourist EV charging:

1. **Shifting demand:** do not start charging as soon as the vehicle is plugged in and instead delay the start of charging if there is insufficient capacity available on the network. This method is suitable for drivers who are plugged in for a long time, e.g. those parking and charging overnight, as they can still receive enough energy for further travel even if the start of their charge is delayed by a few hours.
2. **Dynamic charging rates:** vary charging rates based on available network capacity and number of people charging so that drivers still gain some energy at busy times but at a slower rate than the charger’s maximum power. Suited to drivers plugged in for short times where delaying their charging would not be feasible, so they can still get some energy.

While shifting demand has greater potential to reduce peak load and avoid network upgrades, its practical feasibility depends strongly on the length of stay and time of charging. Large benefits for people charging overnight as they are plugged in for a long time and electricity demand is typically very low overnight, meaning there is likely to be sufficient capacity and electricity can be a lot cheaper than at peak times. This method is less useful for people who are only charging for a short time (e.g. those visiting a tourist site during the day), as it may not be possible to shift demand to a time when there is lots of capacity available.

No definitive figures are available for additional costs of installing smart chargers compared to chargers without load management capabilities, however these are likely to be low compared to costs of other interventions such as installing local generation or energy storage systems. While smart charging predominantly occurs in private settings today (e.g. users charging their own car at home), studies have shown that there are real benefits to be had from public smart charging. Element Energy completed a literature review of public smart charging trials as part of UK Power Networks' Charge Collective project, which highlighted key barriers and opportunities for public smart charging. There is potential for smart charging to improve the business case of charge point operators and many EV drivers support the use of smart charging to optimise the use of renewable energy; however, some studies have demonstrated concerns over range anxiety as smart charging takes direct control of the charging event away from EV drivers[12]. While the focus of this study was on public smart charging in residential areas, many of these concerns will also apply to tourist locations where smart charging could be implemented.

Local generation

Local generation refers to generating energy at or near the location where it will be used rather than using electricity produced by larger generators connected to the national electricity transmission network. Increasingly these small-scale generators create renewable energy, such as small wind farms and solar panel installations. These renewable energy sources tend to be low-cost and can provide extra power locally while minimising expensive cable and transformer upgrades that would be needed on the distribution network if additional power were to be provided from the transmission network. Currently the prevailing local generation technology of low carbon energy on the Isle of Wight is solar photovoltaic (PV) energy. Of the 96MWp of low carbon local peak capacity of the island, 91MWp (95%) comes from solar PV installations (as of 2018)[13].

The cost of commercial scale solar PV has dropped rapidly and is projected to continue to do so out until 2050. Figure 13 illustrates the US National Renewable Energy Laboratory's (NREL) projections of the capital expenditure (CAPEX) for commercial scale solar PV[14]. Based on their central scenario, the CAPEX associated with commercial solar PV is set to fall by 48% between 2020-2030 and a further 23% between 2030-2050.

The low current and projected future decreasing cost of solar PV, means that as a source of generation it can offer an attractive levelized cost of energy (LCOE), the annualised lifetime cost of an energy generation technology per MWh of annual generation, if adequately utilised.

There are examples in literature of home EV charging drawing on solar PV to reduce home electricity bills, such as the Myenergi Zappi EV smart charger[15], which optimises an EV's charging schedule to align with home rooftop solar PV generation, maximising self-consumption. However, when reviewing the literature specifically for public charging there are very few examples of public EV chargers that deploy local generation, such as solar PV, alongside public charge points without the addition of energy storage. This is because, to achieve a competitive LCOE for commercial solar PV, an energy storage system is required

[12] Element Energy for UK Power Networks, Charge Collective, 2022. Link to report
[13] Ellis Ridett, Realising the Isle of Wight's aspiration for renewable energy power generation and local consumption, University of Southampton, 2020.
[14] NREL, Annual Technology Baseline, 2022
[15] Myenergi, Zappi EV charger.

to increase the utilisation of solar PV for public EV charging. This will be explored in more detail in the discussion of combined generation and storage.

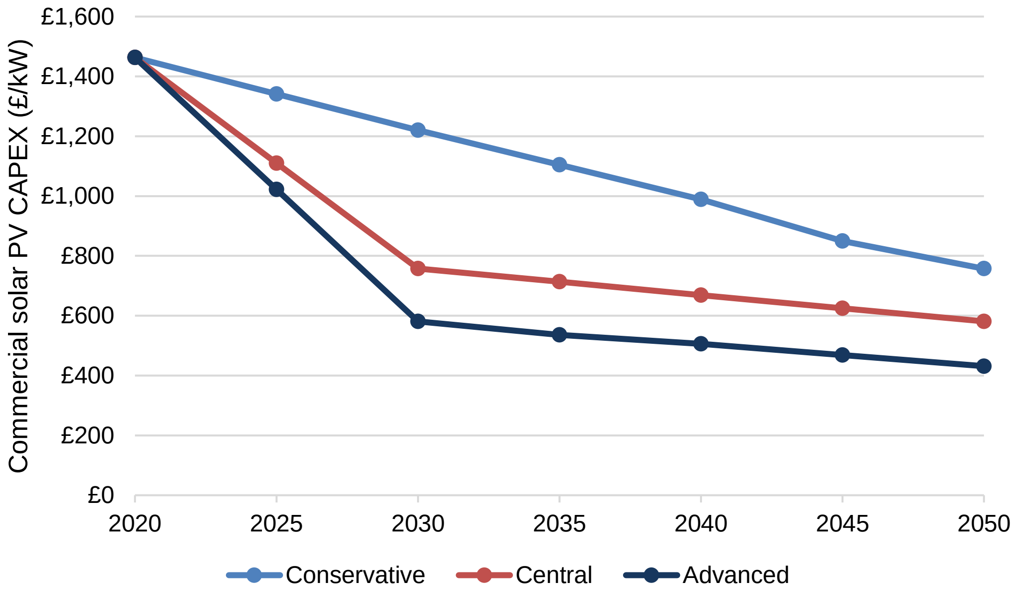

Figure 13: A graph of NREL's CAPEX projections for commercial scale solar PV in £/kW of peak generation capacity.

Energy storage

Large batteries, known as battery energy storage systems (BESS), can be used to provide extra power at times of high demand, and charge up at times of low demand. This technique is known as load balancing and is well suited to reducing the peak demand of EV charging sites to below the site's firm capacity, provided the EV charging load is intermittent. Load balancing with BESS is a technique adopted regularly both at large charging hubs and more recently for individual rapid charge points. This approach can enable charging sites to avoid costly network connections, which outweigh the cost of a BESS, as well as speeding up the deployment of EV chargers at the sites. The capabilities of a BESS are dependent on both the energy and the power capacity of a BESS. BESS are often described based on their energy storage capacity (the amount of energy they can hold, typically quoted in units of kWh or MWh), and their C-rate, a measurement for the rate at which a BESS charges/discharges[16], which with energy storage describes the power capacity of the BESS. Different loads require different energy capacities and C-rates to be adequately shifted, avoiding network reinforcement. This is dependent on the magnitude and profile shape of the load.

Examples where battery energy storage systems have been deployed onsite at large charging hubs include South Mimms Welcome Break Motorway Services on the outskirts of London where a 0.5C 500kWh BESS has been installed alongside 12 Tesla Supercharger charge points[17]. This BESS reduces the site's peak load on the electricity network while providing other balancing services for National Grid ESO.

[16] A BESS with a given C-rate is capable of (dis)charging in 1/C hours. For example, a BESS with a C-rate of 1C means the battery will fully (dis)charge in one hour; for a C-rate of 0.5C, the battery will fully (dis)charge in 2 hours; for a C-rate of 2C, the battery will fully (dis)charge in 0.5 hours; etc.
[17] Open Energi, Battery storage project a 'blueprint' for EV charging infrastructure globally, 2017.

As with solar PV, battery storage costs have dropped rapidly in the last decade and will continue to do so out to 2050, halving in price over that time in the central cost case. Figure 14 illustrates commercial-scale BESS cost projections for a 0.5C BESS per unit of power capacity based on NREL's data[14].

While, due to their current high CAPEX, the benefits of battery storage must be calculated on a case-by-case basis, based on network upgrade costs or other solutions, as the cost of BESS decreases, they will become an increasingly attractive option for avoiding network upgrades when installing EV charging hubs. The case for battery storage can be improved further when it is collocated with on-site generation, which will be discussed next.

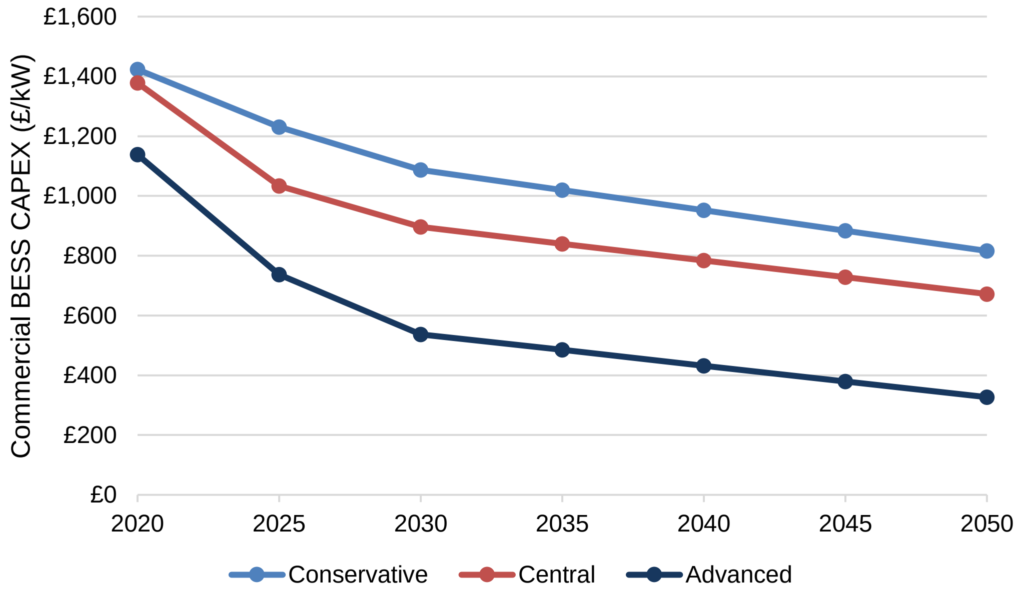

Figure 14: A graph of NREL's CAPEX projections for 2-hour (0.5C) commercial scale battery energy storage system in £/kW of power capacity.

Combined generation and storage

Using both local generation and battery storage can provide more benefits than each individually and potentially lower costs. Solar provides capacity during the day and excess generation capacity can be used to charge an energy storage system. Battery storage allows for gaps in solar generation to be smoothed and some additional capacity overnight when solar generation is unavailable.

The combination of these solutions has the potential to serve as a use case with less solar capacity and a smaller battery than if either method was deployed by itself, which can reduce costs. In addition, solar PV and battery storage can share costly power components, such as inverters, which can further considerably reduce costs.

Many rapid charging hubs across the country already use a combination of solar generation and battery storage. One of the best examples of this in the UK is Energy Superhub Oxford, which is Europe's most powerful EV charging hub. The hub combines 10 MW of on-site generation with up to 50 MW of battery power, to reduce the peak demand of 38 fast and ultra-rapid chargers[18]. Smaller sites are also adopting this approach to minimise network capacity requirements. Princes Street Hub in Dundee combines 36 kW of solar PV with

[18] Energy Superhub Oxford, Europe's most powerful electric vehicle charging hub is heading to Oxford, 2021.

90kWh of storage to serve 6 x 50kW and 3 x 22kW EV charging units[19]. Pop-up installations are even being developed, which may be of use to remote destinations which have a spike in tourist demand for a few months of the year[20]. An example of one of these pop-up installations was deployed in Surrey in 2022[21].

Novel EV charging solutions

Novel EV charging solutions refers to several emerging charging methods which allow for flexibility in where and when vehicles are charged. These additional opportunities for creating flexibility in EV demand could be useful for reducing peak load on the local network and mitigating the need for expensive upgrades to the network. There are several options of interest identified through the literature review:

- Valet charging: this solution involves a courier taking customer vehicles to an off-site location for charging. This service can be set up to optimise throughput and utilisation if there are a limited number of chargers available. These chargers can also be connected to a different part of the network to the site of interest if local network capacity at the site is limited. The main costs associated with this service arise from the need to hire couriers to take cars to and from chargers and manage the charge points.[22]
- Ticketed charging: this is a unique solution that is particularly suited to tourist attractions. If a site has attractions that need to be booked in advance, then customers could be offered the ability to book charging in advance, in addition to booking parking for the site. This would allow sites to impose strict limits on how many people charge at one time, preventing load limits of the local electricity network from being exceeded. Costs will likely be minimal compared to solutions like valet charging, as the main changes needed are to the site's booking infrastructure.
- Park and ride: sites that are already operating a park and ride scheme could choose to install chargers at their park and ride location rather than installing charging at the site itself. This could further encourage less cars to come to the site, reducing congestion. Costs are likely to be similar to installing charging at the site itself, and more chargers could be installed if there is more network capacity at the park and ride site than the site itself. Sites without a current park and ride facility may find that introducing one provides the best solution for them, and their visitors. Again, the cost of installing chargers is likely to be similar, but there may be savings compared with the cost of network reinforcements.
- Overnight charging: this refers to services run by companies such as Charge Fairy where EVs without access to charging are recharged by a charger-equipped van overnight.[23] This solution could be used to delay charging that would happen during the day to the overnight period. However, this is only applicable to sites where vehicles will stay overnight. Costs will have to be determined by getting a quote with a supplier.

Due to the emerging nature of these solutions, there is little information currently available on their costs and ability to reduce peak load on the electricity network. However, since most of the solutions do not require purchasing of specialised equipment, their costs will likely not

[19] Drive Dundee Electric, Princes Street.
[20] Papilio3 | Pop-Up Mini Solar Car Park & EV Charging Hub
[21] Zap Map, Solar car park and EV charging hub revealed at Surrey Research Park, 2022.
[22] Lai et al., Charging Electric Vehicles with Valet: a Novel Business Model to Promote Transportation Electrification, 2021. Link to paper
[23] Charge Fairy

be as high as measures such as local generation and energy storage. Understanding their feasibility will require real world trials of these measures, but from an initial assessment it seems like these solutions should be applicable to a wide range of tourist sites.

Flexible connections

Typical connections to the electricity grid are agreements between the customer and the network operator stating that the customer can draw power from the grid up to a fixed maximum level. Flexible connections differ from typical grid connections by allowing the times of the connection or the level of power to be varied.[24] These connections are typically used to allow for generation sources to connect to the network under an active network management scheme, whereby some generation sources may have to be turned off if there is not enough demand to match supply and avoid reverse power flows which can damage the cables and transformers on the electricity grid. However, these connections can also be applied to sources of demand, in this case EV charging. One possible flexible connection type would be timed connections, where the load drawn by EV charging could be limited at busy times to avoid exceeding the limits of cables or transformers on the local electricity network. Flexible connections can also be made which would ordinarily exceed the maximum safe load, provided the DNO will be able to procure flexibility from other customers – meaning that these other customers would reduce the power they are drawing from the grid to free up capacity.

While these connections would have the potential to reduce load from EV charging in some circumstances, the size of these reductions is likely to be small compared to other measures. Additionally, the feasibility of these connections will depend on the characteristics of the local area, for example flexibility procurement will require sources of flexibility on the local network that can be utilised. The cost of these connections is set by the DNO and are likely to be lower than a fixed connection if a flexible connection can be designed to fit customer's needs and avoid the need for network reinforcement.

Network based solutions

While the focus of this study is on customer-side alternatives to network reinforcement, there are some options available to DNOs that are worth mentioning. Of these the most important is accurate monitoring of the low voltage (LV) network – without this it is very difficult to determine what areas of the local network need attention and where alternative solutions could be most effective. The cost of the technology for this monitoring is relatively low, however data processing, storage, and utilisation costs are important to consider.

Active transformer cooling is an alternative to network reinforcement that can be applied by DNOs. This typically involves drawing cool air past transformers, or drawing hot air away from them, in order to cool them down and counteract the effects of resistive heating from electricity being drawn through the transformers. In areas with a high density of substations, meshing can be used which would allow customers to be served by multiple different pathways. This can split load for each customer between several substations and prevent large loads at point sources from causing constraints, however may not be suitable to the local network on the Isle of Wight if there is a low density of substations.

3.2 Ranking and short listing of solutions

Based on the findings of the literature review, the suitability of the different consumer-side alternative solutions has been summarised in Table 6 below. The most important factor in

[24] Energy Networks Association, Flexibility Connections: Explainer and Q&A, 2021. Link to report

determining the short list of solution was determined to be the level of headroom released, as measures with the highest potential to release headroom will have the greatest chance of preventing network reinforcement. After this, cost and practical feasibility factors were examined to determine which solutions should be included in the short list. Based on these criteria, the short list of five alternative solutions to be assessed at the two case studies is as follows:

- Smart charging
- Local generation
- Energy storage
- Combined generation and storage
- Novel EV charging options (this will include valet and ticketed charging, overnight charging services, and park and ride – note; not all of these options will be applicable to both sites)

Table 6: Comparison of the solutions.

Solution	Cost	Headroom released	Practical feasibility
Smart charging – shifting demand	Low	Significant	Complex
Smart charging – dynamic charging rates	Low	Moderate	Normal
Local generation	High	Significant	Complex
Energy storage	High	Moderate	Normal
Combined generation and storage	High	Significant	Complex
Novel EV charging	Medium	Moderate	Simple
Flexible connections	High	Limited	Normal

4 Alternative solutions at each case study

In this section more detailed analysis will be presented to demonstrate how short-listed solutions could be used at the 2 case studies. Each section will focus on the applicability of the five short listed alternative solutions to the two case studies. Additionally, ownership models of any technologies will be discussed for each of the solutions where relevant.

4.1 Smart charging

Applicability of the solution

At the Woodland Resort, overnight charging demand could be shifted later into the evening to avoid large peak in load. Charging profiles derived from UK Power Networks' Project Shift, assuming a 70% consumer acceptance rate of smart charging, have been used to assess the potential benefit from smart charging at the resort[25]. Peak load from EV charging could be reduced by up to 55% by deploying smart charging, as illustrated in Figure 15. This solution would reduce the days of constraint expected in 2030 at the Woodland Resort from 161 days to 52 days.

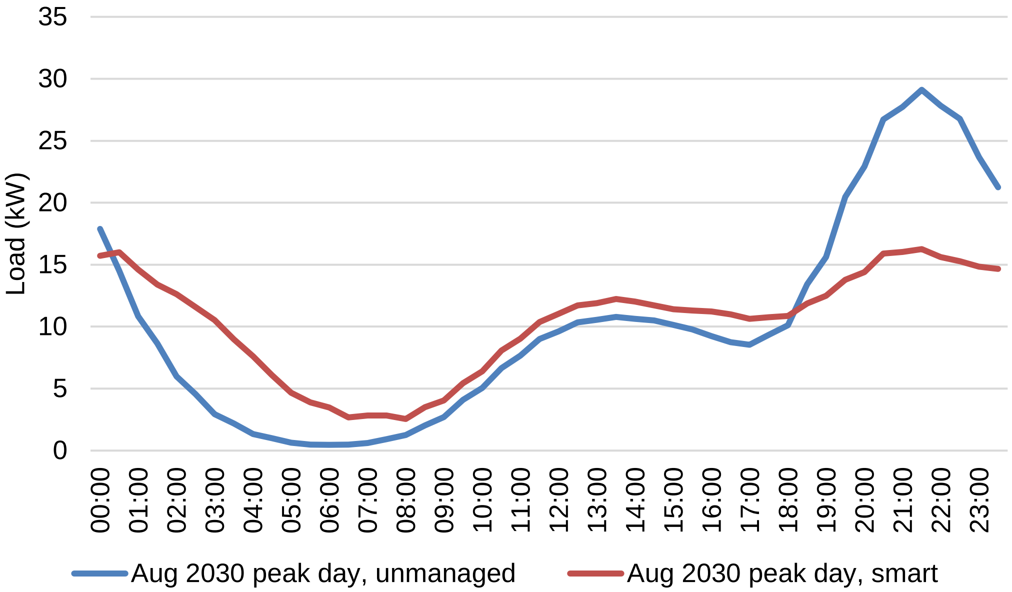

Figure 15: Projected 2030 peak day unmanaged and smart charging load profiles at the Woodland Resort.

Delaying charging is not possible at the Needles due to the shorter time visitors spend on site compared to people staying overnight at the Woodland Resort. However, some benefit from smart charging may still be possible by using dynamic charging rates, which would limit the power drawn by each vehicle when there is limited spare capacity on the network. An example of this is shown below in Figure 16, where peak load has been limited to 500 kW. Installing 22 kW chargers would allow for faster charging away from peak times, and slower charging when all chargers are in use. Our analysis suggests that vehicles could still receive 9 kWh of energy under this lower peak load regime, sufficient for 45 km of additional range. While this would not remove the need to upgrade the secondary substation serving the Needles, which has a capacity of 315kW, it could greatly reduce the upgrade required at the site.

[25] UK Power Networks, Project Shift, 2022. [Link to report]

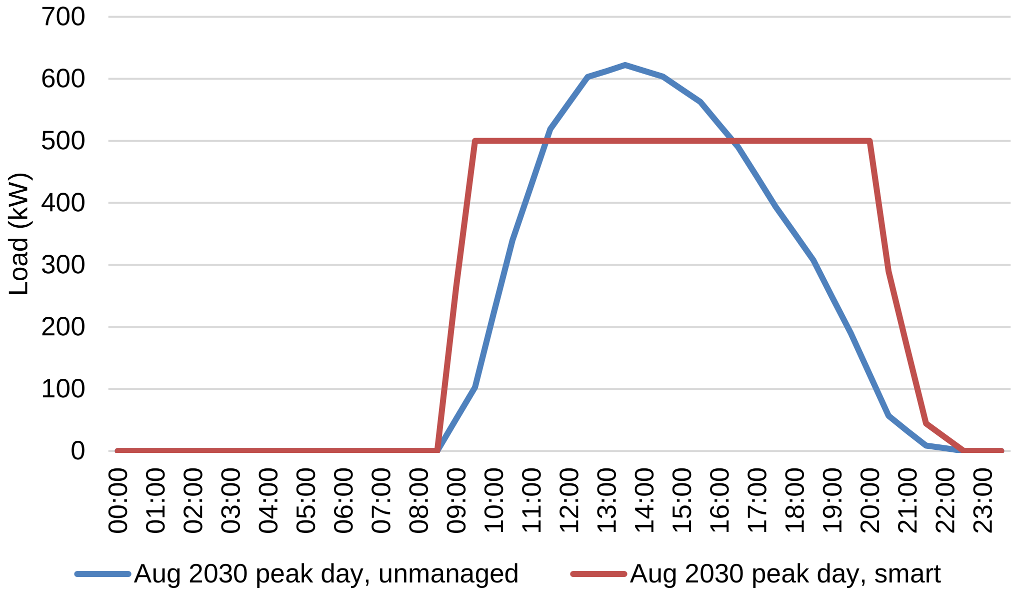

Figure 16: Projected 2030 peak day unmanaged and smart charging load profiles at the Needles.

Ownership models

Several ownership models exist for fast and rapid EV charging hubs, dividing the CAPEX and operational expenditure (OPEX) of purchasing, installing, and maintaining EV chargers. The two main parties involved in such ownership models are the site owner (either Isle of Wight Council or the tourist attraction site) and the EV charger supplier. As a result, the revenue is split between these two parties, and the split between them depends on the ownership model. Some typical ownership models are detailed in Table 7 below.

Table 7: Ownership models for EV fast & rapid charging hubs.

	CAPEX			OPEX				
Ownership model	**Hardware**	**Install**	**Ground & Grid**	**Back office**	**Electricity**	**Maintenance**	**Revenue**	**Contract length**
Own & Operate	Site	Site	Site	Site	Site	Site	All to site	-
External operator	Site	Site	Site	Supplier	Site	Supplier	Majority to site	-
Concession A	Site	Supplier	Supplier	Supplier	Supplier	Supplier	Share to site	
Concession B	Supplier	Site	Site	Supplier	Supplier	Supplier	Share to site + min payment	5-10 years
Concession C	Supplier	Supplier	Site	Supplier	Supplier	Supplier	Share to site	
Lease model	Supplier	Supplier	Supplier	Supplier	Supplier	Supplier	Share to site	15-25 years

4.2 Local generation

Applicability of the solution

Typical generation profiles for solar PV, the leading form of local generation in the Isle of Wight, were derived from data collected by UK Power Networks (UKPN)[26]. Solar generation profiles were produced for a typical best, average, and worst case day in August – these profiles are displayed in Figure 17. In the context of Isle of Wight, solar PV represents the best opportunity for local generation because tourist demand on the Isle of Wight maps closely with days of high sunshine. However, as shown in the UKPN data, peak generation on the worst day is less than 10% of peak generation on the best day, so it is very difficult to rely on solar power alone to meet load from EV charging.

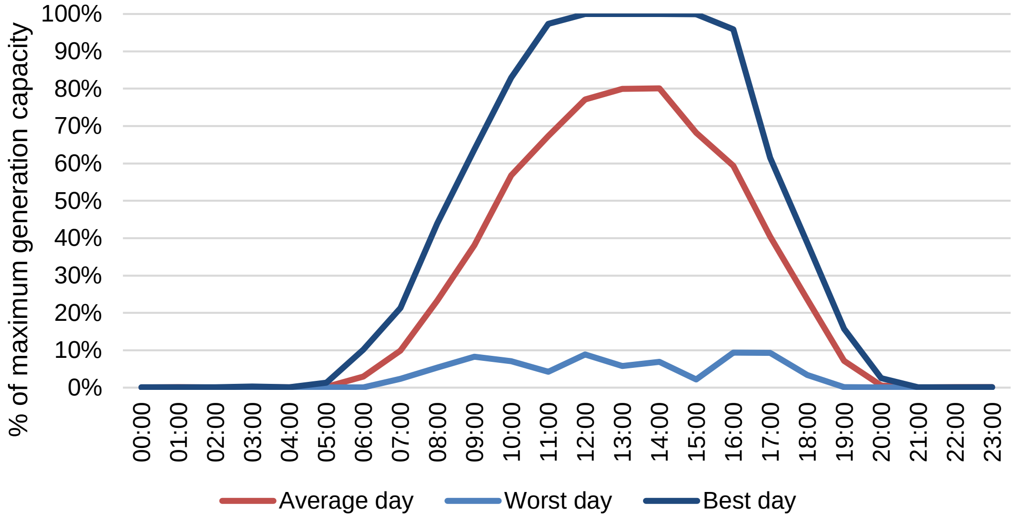

Figure 17: A graph showing the solar generation profiles for representative days in August.

In addition, on days where the output from solar generation exceeds EV charging demand, excess generation can cause reverse power flows on the distribution network. This already represents a significant constraint for SSEN on the Isle of Wight and therefore, any local generation installation may not be permitted to export to the distribution network, without a guaranteed demand to avoid energy imbalance.

When used by itself, solar generation does present an opportunity to directly address EV charging loads which arise during the day and on days with high solar PV output. This aligns well with daytime attractions on the Isle of Wight that attract many visitors on days of fair weather, like the Needles. However, for sites where most of the charging is expected to occur overnight, such as the Woodland Resort, solar generation would not provide a significant benefit. This is because solar PV generates energy during the day, which cannot be used to power charging overnight without additional energy storage measures (which will be investigated in more detail in section 4.4). The drawbacks of relying on local generation alone are further evidenced in our literature review of public EV charging that draws upon local generation; in that the vast majority of examples these sites combine local generation with battery storage to maximise the utilisation of local generation and minimise load on the electricity network.

[26] Data collected as part of UK Power Networks' Validation of Photovoltaic Connection Assessment Tool. Link to report

Ownership models

There are two ownership models that most of the local generation in the UK follows: direct ownership and third-party ownership. Direct ownership simply means the site owns and maintains the generation equipment (most commonly solar PV or wind turbines) outright and finances the purchase using their own capital or a loan. In this ownership model the site uses the savings generated from generating their own electricity, offsetting the need to purchase electricity, to recoup the initial investment or finance loan repayments.

The second option is third-party ownership (TPO), where the local generation is owned by a third-party. In this arrangement, the site has two further options: enter into a power purchasing agreement (PPA) with the third party; or lease the equipment from them directly. In a PPA, the generation is operated at no cost to the site, but the site purchases the electricity produced at a rate agreed in the PPA. This price can follow several models[27]:

- Fixed PPA – locks in a power price for generation at the time of contract signing, providing a guaranteed rate structure for project financing.
- Flexible PPA – offers power to be purchased at a price reflective of the Day Ahead power market, allowing the purchase to capture times of low prices and avoid times of high prices.
- Track & Trade PPA - track the forward market in real time, giving them an increased chance to lock in their pricing at the time of a price drop, rather than in conjunction with their annual renewals cycle.

Each model has differing merits and downsides. While a fixed PPA provides financial certainty, it means the site cannot take advantage of wholesale price fluctuations via energy arbitrage. The opposite is true for flexible and track & trade PPA structures.

Under a leasing agreement through a TPO arrangement, the site would lease the renewable generation equipment for a pre-agreed cost, becoming responsible for the maintenance cost, but also having access to all of the energy produced by the generation.

Both direct ownership and TPO of local generation have merits. While direct ownership enables a site to benefit from the cheapest LCOE by owning the local generation source themselves, it requires large up front capital expenditure or a loan which will be subject to interest rates. Conversely a TPO model is attractive because no upfront cost is required from the site owner; however, purchasing energy via a PPA or leasing the equipment will have to account for the need for the third-party to make a return, increasing the LCOE.

4.3 Energy storage

Applicability of the solution

As the connection agreement between the Woodland Resort and SSEN is yet to be agreed, it is not yet clear how much capacity they will have from the network. Based on electrical plans for the site, a peak load of 1.4 MW is expected. 1.1 MW of this load is from sources other than EV charging and assumed to be inflexible. This could potentially be accommodated by 2 x 500 kW ground mounted transformers, and a 100 kW pole mounted transformer (suitable for 'base' load without EVs). The additional EV charging load could be accommodated using a 1 MWh battery storage system which can discharge at a rate of 0.5C. This power system could accommodate 2 hours of peak load at ~1.5 MW.

[27] Limejump, Power Purchase Agreements.

The network infrastructure at the Needles is able to support current load requirements, but may not be sufficient for additional load from EV charging. Our network impact analysis of the site suggests that on a peak day in 2030, there will be 2.8 MWh of charging demand which the electricity network is unable to provide. This could be provided by a 3 MWh battery system (but this battery would have to be able to sustain a discharge rate of ~0.1C).

Ownership models

There are two primary types of BESS ownership model. Traditional user (site) owned BESS or third-party owned, BaaS (battery-as-a-service), ownership models. In a traditional user ownership model, the user (site) purchases the BESS outright from the BESS developer, taking on the full CAPEX of purchasing the BESS and installation. Within this ownership model there are a range of sub-models through which the BESS developer may retain varying control and responsibility for operating and maintaining the BESS. This includes:

- Guided service – site team operates and maintains BESS. BESS developer offers advisory service, software upgrades and equipment warranties only
- Shared service – In addition to guided service offering, BESS developer is also responsible for BESS maintenance and battery health monitoring, guaranteeing limit performance requirements
- Complete service – BESS developer takes on full asset management responsibility, including all operational and maintenance management

With increasing involvement, the BESS developer would take an increasing share of the BESS revenues (or savings as a result).

The second ownership model, BaaS, is structured so that the BESS developer maintains ownership of the BESS and leases it to the site. Within the BaaS structure, there are similar sublevels to the outright ownership model, with the BESS developer taking on an increasing role in the operation and maintenance management of the BESS. In the BaaS structure, the BESS developer also takes on the financial, contractual, and risk management responsibilities of BESS ownership. While the BaaS ownership model inevitably leads to a greater proportion of the revenues/savings that are generated by a BESS being passed to the BESS developer, it removes the high CAPEX associated with BESS ownership, making it a more accessible option for some use cases.

4.4 Combined generation and storage

Applicability of the solution

At the Woodland Resort, battery storage can be used to provide for EV charging overnight where this exceeds network capacity. Solar could be used in conjunction with battery storage to provide some of the site's electricity needs during the day, however a new secondary substation will still likely be needed to provide security of supply on days when solar power cannot be relied on. If the Woodland Resort aims to be a tourist destination year-round, then they will not be able to rely on solar generation in the winter months.

At the Needles, as tourist visits are strongly influenced by season and weather, there is likely to be a good correlation between available solar generation capacity and tourist EV charging demand. Charging demand is expected predominantly in daylight hours, so this can be matched with solar generation, and battery storage to manage changes in weather conditions which lower solar generation capacity.

Ownership models

The ownership models for combined generation and storage bring together the ownership models for both on-sight generation and stand-alone energy storage. While the generation and storage components can be owned and managed via independent ownership models, part of the benefit of combined generation and storage is the sharing of power components and infrastructure. Therefore, ownership models for combined generation and storage normally tie the two components together, in the form of either direct or third-party ownership. For direct ownership, either the site will manage and co-optimise the battery and generation, or they will involve a battery developer/asset manager, the details of which are discussed in the energy storage ownership models. For third-party ownership, a battery developer/asset manager will most likely co-optimise the storage and generation, providing energy to the site via one of the PPAs described in the local generation section above.

4.5 Novel EV charging solutions

Applicability of the solution

Valet charging: this solution is particularly suited to providing flexibility and reducing peak electricity load during the daytime (overnight charging demand can be more effectively managed by smart charging). This makes it a potentially valuable solution for the Needles, but less so for the Woodland Resort. The ability of this solution to provide utility will depend on finding a suitable place near the resort with sufficient network capacity to install chargers, as well as customer acceptance of the valet charging service.

Ticketed charging: this service would allow sites to limit EV charging load at peak times and give more certainty over where and when there will be load. Given that accommodation will need to be booked by those staying overnight at the Woodland Resort, charging could be booked at the same time. Offering ticketed charging at the Needles would probably require visitors to book their parking ahead of time. Charging and parking slots could be offered for EV drivers to book while allowing drivers who do not wish to charge to park without booking in advance, which would ensure good utilisation of EV chargers and prevent non-EV drivers from blocking spaces with EV chargers.

Overnight charging services: this option would only be suitable for the Woodland Resort as no overnight charging is anticipated at the Needles. This solution is best suited to drivers parking on-street in an area where EV chargers are unavailable, so its applicability to the Woodland Resort may be limited if they have sufficient space and resources to install many EV chargers. However, this solution could also be applied to towns with high tourist demand, where EVs may be parking in areas with no charger availability.

Park and ride: installing charging at park and ride sites is a solution which could be applied to both sites. the Needles already have high levels of parking congestion, particularly in the peak month of August. Park and ride services could help alleviate this congestion, as well as spreading charging load across several locations if EV charging is installed at park and ride sites. The Woodland Resort are already planning on making rental EVs available at Yarmouth Ferry harbour, and could additionally run a coach service from Yarmouth Ferry to the site.

Ownership models

As there are unlikely to be technology purchases specifically for these solutions, ownership models are not relevant and so have not been considered here.

5 Conclusions and recommendations

The analysis of alternative solutions to network reinforcement on the Isle of Wight has shown that there are several viable options. The alternative solutions studied have been summarised in Table 8, with their potential applications. Solutions have been ordered in terms of priority for consideration, which takes into account size of benefits and cost of solutions. Our analysis suggests that smart charging is likely to be the most cost-effective alternative to network upgrades, however this is only true for sites where it can be effectively applied. The applications and benefits of novel EV charging are wide ranging and uncertain due to it being an emerging option, however as it is likely to cost significantly less than installing local generation or battery storage systems, it may be a more cost-effective option for avoiding network upgrades in certain contexts. In areas where neither smart charging or novel EV charging would be sufficient, combined generation and storage is the next most likely option for accommodating EV charging without upgrading the electricity network. Energy storage systems alone are generally less applicable then combined generation and storage but may have some potential applications.

Table 8: Summary table of the short-listed alternative solutions and their potential applications. The priority of the solutions denotes the order in which they should be considered by sites as a potential solution to network capacity issues.

Priority	Alternative solution	Applications
1	Smart charging	• Sites where significant overnight EV charging demand is expected • Sites with limited network capacity but large demand for EV charging during the day
2	Novel EV charging	• Sites which need to be booked in advance where EV charging could be booked at the same time • Sites where a park and ride arrangement could be implemented • Sites with limited space or network capacity available for EV charging • Towns with limited on-street charging availability
3	Combined generation and storage	• Sites which are busiest when the weather is good • Sites where the majority of EV charging demand occurs during the day • Alternatively, sites with evening peaks of short duration and predictable occurrence, so can be reliably managed by energy storage of daily solar generation
4	Energy storage	• Sites where additional transformer capacity can be cost effectively replaced by battery storage • Sites with peaks of short duration and predictable occurrence, so can be reliably managed by energy storage
5	Local generation	• Unlikely to be a solution by itself due to intermittent nature of solar power

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