E-tourism: charging demand by electric vehicles on the Isle of Wight

Final Report

for

Scottish and Southern Electricity Networks

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elementenergy

an ERM Group company

Element Energy Limited, Suite 1, Bishop Bateman Court, Thompson's Lane, Cambridge, CB5 8AQ UK

Tel: +44 (0)1223 852499

Executive Summary

The Isle of Wight E tourism project is a Network Innovation Allowance project that aims to understand how electric vehicle (EV) charging demand at popular tourist sites on the Isle of Wight will increase. The projected impact of tourist and residential EV charging demand on the electricity distribution network in 2030 has been assessed for four case studies. Table 1 lists the four case studies and they are shown on a map in Figure 1. Charging demand has been distributed to relevant primary substations, which convert 33kV electricity into 11kV electricity for local distribution via high voltage (HV) feeders. Projected tourist and residential charging demand from the use cases studied at primary substation level is typically on the order of hundreds of kW, while current electricity demand on primary substations is in the order of MW, so constraints are not expected to occur on primary substations due to additional demand from tourist EV charging.

Table 1: A table listing the case studies considered in this e-tourism project.

Number on map	Case study name	Case study type
1	Southampton ferry terminal	Ferry terminal
2	East Cowes ferry terminal	Ferry terminal
3	Woodland resort	Overnight tourist attraction
4	Shanklin	Overnight tourist attraction

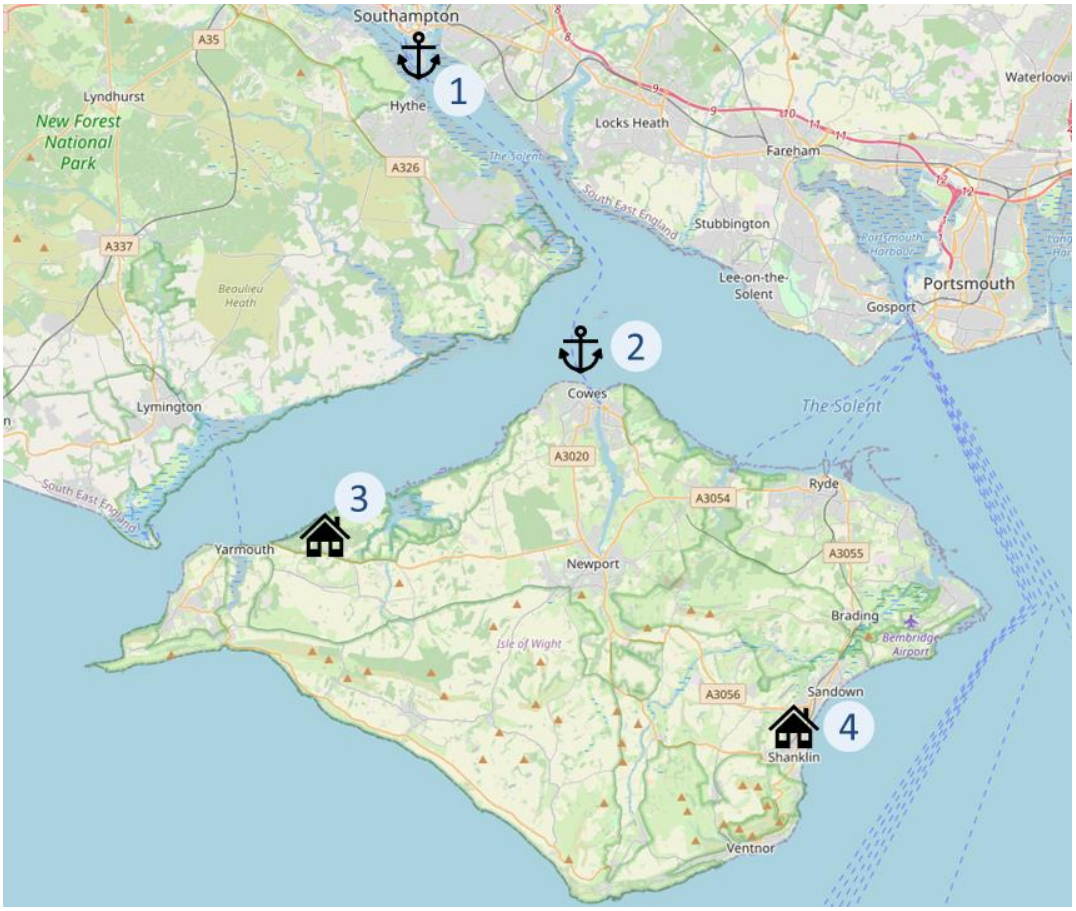

Figure 1: Map of the Isle of Wight and southern England indicating the location of the four tourist sites selected as case studies. © OpenStreetMap contributors

Charging demand has also been distributed to secondary substations. Secondary substations convert 11kV electricity from HV feeders to 400V or 240V for supplying households and small businesses by low voltage (LV) feeders. Table 2 shows the high-level findings of the network analysis at secondary substations, showing the status of the local distribution network in 2030. Currently all the secondary substations of interest are not experiencing demand constraints, i.e. peak demand is below the transformer rating. The EHV network on the Isle of Wight has generation constraints and is under active network management, however these constraints are not visible at the voltage levels being considered in this study.

The default assumption on EV charging behaviour was that all vehicles would follow unmanaged charging profiles, as this gives a large increase in evening peak demand and gives an idea of maximum expected impact on the distribution network. For sites where constraints are expected, the potential of smart charging to mitigate constraints has been assessed, by assuming EV charging behaviour follows a smart charging demand profile where appropriate rather than a standard unmanaged charging profile.

Table 2: A summary of the findings from the network analysis of secondary substations. Green: no demand constraints expected; amber: demand constraints expected, however capacity breaches are small and short; red: large, long duration demand constraints expected, network upgrade required to mitigate. Note generation constraints are not considered in this table.

Case study	Secondary substation	Current network status	Days of constraint expected in 2030	Days of constraint expected in 2030 with smart charging
Southampton Ferry Terminal	French Quarter		0	0
East Cowes Ferry Terminal	Waitrose		0	0
Woodland Resort	Lucketts		161	52
Shanklin[1]	Regent Street		0	0

Both ferry terminals are served by secondary substations with a high level of spare capacity, so are expected to be able to accommodate increased electricity demand from EV charging. The combination of high residential and EV charging demand on secondary substations in Shanklin is expected to cause peak demand to approach transformer ratings, but no thermal constraints are predicted in 2030. Of the sites analysed, only the Woodland Resort is expected to experience large capacity breaches, due to the small secondary substation currently installed here. The Woodland Resort is currently still in development, due to open to the public in 2023. Therefore, their connection to the grid is a new request on a substation (Lucketts) that currently has very little demand. Hence, the capacity of the small secondary substation is quickly exceeded when the addition of EV charging is accounted for.

Table 3 shows how tourist visit numbers are expected to vary throughout the year, as well as the average daily distance travelled by tourists visiting each of the four case studies. For

[1] Note that Shanklin is served by several secondary substations. Results have been shown here for the secondary substation with the least spare capacity on the distribution network and a high level of expected EV charging demand, therefore this is the secondary substation in Shanklin at highest risk of experiencing thermal constraints.

the purposes of this study, a tourist is defined as any individual taking a day trip or overnight stay for a holiday or to visit friends or relatives. Car visit number estimates were based on site visit statistics, and daily ferry crossing data was used to estimate how visit numbers varied throughout the year for sites where daily visit data was not available. The average daily distance travelled was calculated from location of ferry bookings for the Southampton ferry terminal. For sites on the island, daily distance travelled was assumed to be in line with the average daily distance travelled by cars in the UK. Visit numbers are highly seasonal, showing a much larger peak in the summer than winter for all sites.

Table 3: A summary of tourist visit estimated for the selected use cases.

Case study	Daily average tourist cars visiting	Winter peak daily cars visiting	Summer peak daily cars visiting	Average daily distance travelled / km
Southampton Ferry Terminal	253	343	761	160
East Cowes Ferry Terminal	245	325	702	33
Woodland Resort	53	76	127	33
Shanklin	754	347	3,071	33

These visit numbers are based on data from 2019 and have been applied to 2030 assuming no change from levels before the Covid-19 pandemic. There is large uncertainty in how tourist visit numbers will vary from one year to the next, as tourism is affected by many social and economic factors. Given these uncertainties, it was agreed that the most reasonable assumption was that tourist numbers would not change from the statistics that had been collected for 2019.

With regards to the Covid-19 pandemic specifically, very little is understood about the long-term effects this will have on tourism. Therefore, this study does not speculate on what these effects could be. In the short term, a fall in international tourism has been observed as lockdowns and travel bans have prevented travel to and from some countries; however, an increase in domestic tourism may have compensated for fewer international visits. By 2030 it is considered unlikely that these short-term effects will still be visible. It may be worth reviewing the effects of Covid-19 on the tourism sector at a later date, for example in two years' time, to see if any long-term effects are expected, and to determine if these effects need to be accounted for in any future updates of the study.

Contents

Authors

For comments or queries please contact:

alessandro.zanre@element-energy.co.uk

freddie.barnes@element-energy.co.uk

Reviewers

Celine Cluzel, Partner, Element Energy

Ian Walker, Partner, Element Energy

Georgios Simopoulos, Innovation Project Manager, SSEN

Richard Hartshorn, EV Readiness Manager, SSEN

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Acronyms

BEV	Battery electric vehicle
DNO	Distribution network operator
EHV	Extra high voltage
EV	Electric vehicle
EVCP	Electric vehicle charging point
HV	High voltage
ICE	Internal combustion engine
LV	Low voltage
MDI	Maximum demand indicator
PHEV	Plug-in hybrid electric vehicle
SSEN	Scottish and Southern Energy Networks

1 Introduction

1.1 Objectives of this study

The e-tourism project is a three-year Network Innovation Allowance project being undertaken by Scottish and Southern Electricity Networks (SSEN) and funded by Ofgem. The project aims to understand how electric vehicle (EV) charging demand from tourist travel to popular sites in SSEN's operating area will increase and the effect this demand could have on the local electricity distribution network. EVs are a highly disruptive technology and are expected to increase electricity demand at all voltage levels of the network. It is therefore important that distribution network operators (DNOs) forecast EV uptake and charging demand. Anticipation of future electricity demand and management of the distribution network allows DNOs to keep costs down for all bill payers. Following a previous study completed by Element Energy for SSEN in 2020, which investigated the impacts of e-tourism in Scottish tourist hotspots, this study focuses on e-tourism on the Isle of Wight. Several factors make the Isle of Wight sensitive to the future increase in E-tourism:

- Tourism on the Isle of Wight is highly seasonal, over double the number of tourists visited the island in Q3 (summer peak) than in Q1 or Q4 (winter)[2].
- The main access to the island is via ferry, and 66% of visitors are expected to travel to the island by car[2].
- Many of the tourist attractions and resorts are situated in sparsely populated areas. In these areas the existing electricity network may not have sufficient capacity to accommodate additional demand from tourist EV charging, which represents a challenge for SSEN.

The electricity network on the Isle of Wight is currently heavily constrained and under active network management due to excess solar generation. Increasing EV charging demand presents a challenge at the low voltage level of the distribution network, where electricity load exceeding transformer ratings could lead to thermal constraints. However, as EV charging demand is an inherently flexible load in terms of where and when it is placed on the electricity network, EV charging demand could be made to coincide with times of high generation, to reduce the risk of reverse power flows. The potential for flexibility services to facilitate the balancing of electricity demand with generation and delay or avoid network upgrades is very valuable for both SSEN and local stakeholders. There is also interest from the tourism sector in promoting the island as an eco-tourism destination and a key component of this change is increasing EV availability for tourists, and providing sufficient EV charging infrastructure and network capacity for EVs to charge.

The e-tourism study considers not only the additional demand on the distribution network as a result of tourist EV charging, but also the expected increase in demand from residential EV charging on the island. Both additional demands are applied to the expected baseline demand on the distribution network to give a complete picture of the additional load placed on the distribution network by EV charging[3]. This approach has been taken to directly identify and compare the impact that tourist EV charging and residential EV charging has on the distribution network, specifically in the smaller communities found on the Isle of Wight.

[2]Visit Isle of Wight tourism data, 2019.
[3] The impact of heat pumps on the distribution network has not been considered in this study as current policy suggests that the role out of heat pumps will be largely after the scope of this study, and in the next 10 years increases in electricity demand will be dominated by increased EV charging.

Key objectives of this study are to:

- Understand tourist visitor numbers and travel behaviour on the Isle of Wight.
- Predict how tourist EV charging demand will change over the study period and where/when it will be highest.
- Predict how residential EV charging demand will be different in the study year of 2030 and where/when it will be highest.
- Distribute both projected tourist and residential charging demand among primary and secondary substations to determine the need for reinforcement or potential for flexible charging solutions or local solutions to manage the network.
- Model and identify the benefits of smart charging at sites where EV charging demand causes constraints on the distribution network.

The key year for this study is 2030, the year that the UK government plans to end the sale of new internal combustion engine (ICE) cars.

It is worth noting that this study does not consider the effects of the Covid-19 pandemic on tourist demand or EV uptake. While the pandemic has undoubtedly had significant short-term effects on these and many other related factors, the study is concerned with predicting tourist EV charging demand in 2030. At the time of writing, it is considered unlikely that the pandemic will cause large long-term effects on tourist demand on the Isle of Wight or EV uptake in 2030. Therefore, we have deemed that the most justifiable approach was to use pre-COVID tourist data for the analysis.

1.2 Overview of case studies

The use cases for the study were selected to cover different tourist contexts across the island. Therefore, a variety of tourist sites were chosen to capture the variation in tourist and charging demand between different sites. The use cases can be split into three categories:

- Ferry terminals:
  - Terminals on the mainland and island have been included to capture EV charging demand from tourists entering and leaving the island.
  - Tourists are expected to use rapid charging while waiting or after having completed a ferry journey.
- Daytime tourist attractions:
  - Popular attractions are expected to show much higher demand for EV charging from tourist cars than resident vehicles, due to the high numbers of tourist visits during the day compared to the resident car population.
  - These sites may flag areas where current load modelling does not predict constraints but tourist EVs could lead to higher peak load than anticipated.
- Overnight tourist attractions:
  - Most tourist EV charging is expected to occur overnight, rather than during the day at daytime tourist sites.
  - There is potential for charging to be managed (i.e. smart charging) as vehicles will be plugged in for a long time overnight.

Engagement with local stakeholders was undertaken to understand which tourist sites are particularly popular and where good quality visit and tourist behaviour data could be obtained. Based on this engagement, four use cases were selected, four on the island and one on the mainland. These sites include two ferry terminals and two tourist attractions where visitors are expected to stay overnight. The use cases are highlighted on the map of the island in Figure 2 below.

Figure 2: Map of the Isle of Wight and southern England indicating the location of the four tourist sites selected as case studies. © OpenStreetMap contributors

The four sites are listed in Table 4 (corresponding to the numbers in Figure 2):

Table 4: A table listing the case studies considered in this e-tourism project.

Number on map	Case study name	Case study type	Relevant report section
1	Southampton ferry terminal	Ferry terminal	3
2	East Cowes ferry terminal	Ferry terminal	4
3	Woodland Resort	Overnight tourist attraction	5
4	Shanklin	Overnight tourist attraction	6

1.3 About this report

The purpose of this report is to describe the work undertaken in the Isle of Wight e-tourism study and present the conclusions from our analysis. This includes the analysis of tourist travel behaviour, predicted tourist EV charging demand, predicted residential EV charging demand, and the impact of EV charging demand on the electricity distribution network. The conclusions of this analysis are presented for use in identifying where there are opportunities for flexibility services, where smart charging could help delay upgrades to the network, and where network upgrades may be required.

An overview of the approach taken in the study is given in section 2, followed by specific analysis for each of the 4 case studies sites (sections 3-6). Each of the case study sections is structured as follows:

- Subsection X.1 gives an overview of the tourist site and estimated visitor numbers.
- Subsection X.2 presents the projected tourist EV charging demand at each of the case studies.
- Subsection X.3 presents the projected residential EV charging demand at each of the case studies.
- Subsection X.4 gives key findings from the network analysis performed.

Overall conclusions and summary tables are provided in section 7.

2 Overview of approach

The Isle of Wight E-tourism study aims to predict the impact of EV charging demand on the distribution network at popular tourist sites.[4] This requires the synthesis of existing data on tourist behaviour and distribution network loading conditions with projections of EV uptake and assumptions on how charging behaviour will evolve in the future. Figure 3 provides a high-level overview of how work in the study has been structured into steps, and the key tasks performed within each step. Each of these steps are described in detail in the following sections of the report.

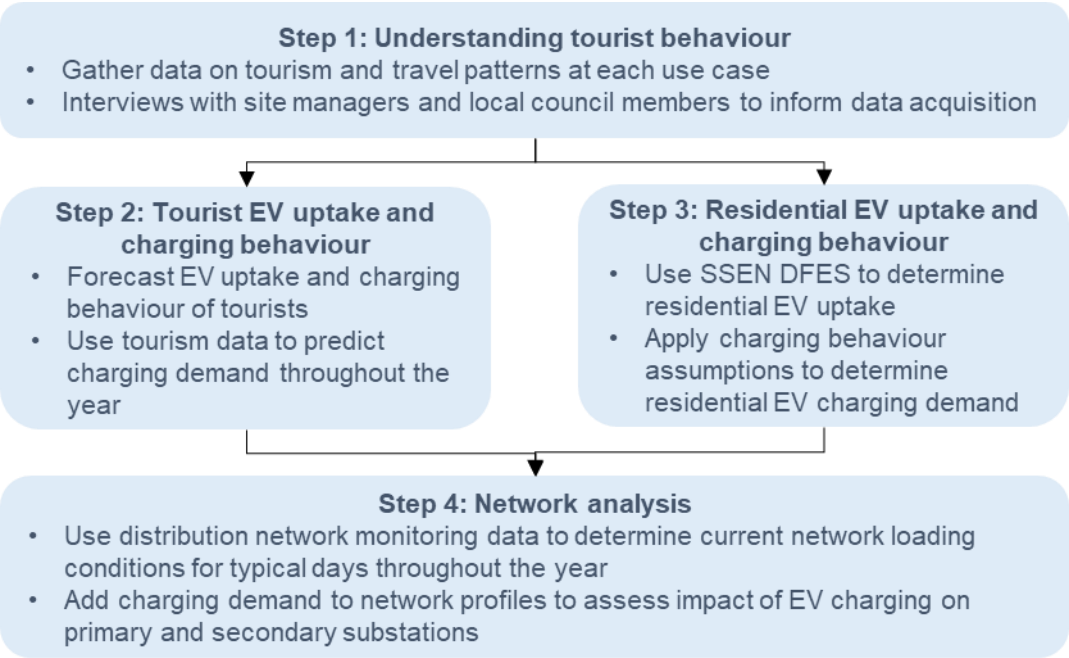

Figure 3: A schematic diagram of work undertaken in the study.

2.1 Step 1: Understanding tourist behaviour

2.1.1 Quantifying number of tourist cars annually

Data on annual tourist visit numbers at each of the use cases were obtained by engagement with relevant stakeholders. In all cases, 2019 data has been used, to provide an understanding of expected tourist demand once travel restrictions from the Covid-19 pandemic have been lifted. Data sources used are outlined below:

- Ferry terminals: data on car crossings was provided by Red Funnel. Visit Isle of Wight survey data was used to determine what share of crossings were attributed to tourists.
- Shanklin: Visit Isle of Wight survey data on tourist visits to Shanklin by quarter was provided. Assumptions on share of tourists travelling by car and number of people in an average car were used to determine the number of cars visiting annually – these assumptions are explained in Section 8 of the report.
- Woodland Resort: as the resort is not yet operational, estimates of peak day visit numbers were provided by the resort. As with Shanklin, these were converted into

[4] Other sources of increased electricity demand, such as heat pumps, have not been included in this study. The study time frame is to 2030, during which time EV charging demand is expected to dominate the growth in electricity demand, while demand from heat pumps and other emerging low carbon technologies is expected to be comparatively small.

car visits by applying assumptions on the share of tourists travelling by car and number of tourists per car.

In total 2.16 million tourists visited the Isle of Wight in 2019[5], an average of 5,900 tourists per day – in comparison the resident population of the Isle of Wight is 142,000[6]. Based on Visit Isle of Wight survey data on the number of visitors who travelled by car and the size of group they travelled in, this equates to approximately 513,000 tourist cars annually. Table 5 gives annual tourist cars visiting each of the use cases in the study, with the exception of the Woodland Resort, which is not yet operational.

Table 5: Annual tourist cars at each of the use cases considered in the study.

Use case	Annual tourist cars
Southampton ferry terminal	92,294
East Cowes ferry terminal	89,389
Woodland resort	Estimate of peak day visits used instead
Shanklin	87,935

2.1.2 Determining tourist visit variation throughout the year

Tourist behaviour on the Isle of Wight is highly seasonal and varies throughout the year. As shown in Table 6, fewer tourists visit the island over the winter months and tourist demand peaks in late summer.

Table 6: tourist visit variation throughout 2019, from Visit Isle of Wight survey data.

Quarter	Share of tourist visits to the island
2019 Q1 (January – March)	15%
2019 Q2 (April – June)	29%
2019 Q3 (July – September)	38%
2019 Q4 (October – December)	18%

It is important to have tourist visit data at as high a resolution as possible, to understand both the range in tourist demand throughout the year and how often large peaks in tourist demand are expected to occur. In this study, tourist demand was assessed for four typical days in each month of the year; average weekdays, average weekend days, peak weekdays, and peak weekends. This allowed for variations in tourist demand throughout the year to be captured, as well as weekends being more common than weekdays for tourist visits. The distinction between average and peak days in each category allowed for occasional events resulting in particularly high tourist demand (e.g. bank holidays, festivals) to be accounted for in the study.

Due to the different data sources available for each of the use cases, this resolution could not be achieved purely from visit data for all use cases, and some assumptions had to be made. The resolution of raw visit data and any further assumptions used to calculate average and peak weekday and weekend day visits for each use case are summarised in Table 7. Crossing data from Southampton to East Cowes ferry terminal was used to scale

[5] Visit Isle of Wight tourism data, 2019
[6] From nomis 2020 population projections at Local Authority level

tourist demand and account for more tourists visiting sites in the peak summer season and on weekends, as more tourists arriving on the island is expected to correlate with more tourists visiting attractions across the island. Further details on the assumptions made to calculate average and peak day visits at each use case can be found in Section 8.1.

Table 7: Visit data resolution and further assumptions needed to calculate typical daily visit demand at each use case.

Use case	Resolution of visit data	Further assumptions needed
Southampton ferry terminal	Daily	None
East Cowes ferry terminal	Daily	None
Woodland resort	Projection for busiest day of year	Southampton ferry terminal profile scaled so busiest day matched Woodland Resort busiest day projection
Shanklin	Quarterly	Southampton ferry terminal profile used to estimate visit variation within each quarter

The above analysis determined the number of tourists arriving each day at each use case on average and peak days, but did not account for tourists who arrive on an earlier day and stay overnight. In order to calculate the number of tourists present at each use case, data on the number of tourists staying overnight and their length of stay is needed. Where tourists only pass through the ferry terminals and do not stay overnight, the number present each day is equal to the number of people arriving each day. However, for Shanklin, which has both day and overnight visitors, a correction had to be applied for tourists staying overnight, as described in Section 8.2.[7]

2.1.3 Understanding tourist travel behaviour

In order to predict the charging demand of vehicles, their distance travelled had to be estimated to determine their daily energy demands. This is a difficult to predict attribute due to individual differences in travel behaviour and the location of the Isle of Wight as an island with all external vehicles entering the island by ferry.

For tourists coming to the island via the Southampton – East Cowes ferry route, data was provided by Red Funnel on the towns where bookings were made from, which were assumed to be the start point of tourist journeys to the island. Therefore for tourists arriving at the Southampton ferry terminal, their daily mileage was assumed to be the average distance travelled based on the number of bookings from each town and the distance from the centre of each town to the Southampton ferry terminal.

For use cases on the island, there were deemed to be too many factors at play to derive a bottom-up estimate of daily mileage. Results from Department for Transport's National Travel Survey were used to determine average daily mileage, by dividing the average total annual mileage for cars by 365. The resulting figure of 33 km per day was assumed to be the average daily mileage for tourist and residential cars on the island.

[7] Note there are also both day and overnight visits to the Woodland Resort, however as visits are based off the expected busiest day rather than quarterly visit data

2.2 Step 2: Quantifying tourist EV charging demand

Having identified the number of tourist cars expected at each use case and their visit patterns over the course of a year, EV uptake scenarios and charging behaviour were considered to convert estimates of tourist cars into charging demand projections.

2.2.1 EV uptake scenarios

As most of the tourism on the Isle of Wight originates from the mainland, the EV uptake scenario used in this study is an average uptake for cars from GB. The scenario selected was the 'Consumer Acceptance' uptake scenario from the Element Energy Consumer Choice Model (ECCo). Further information on this model is provided in Section 9. This study considers both the uptake of battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs), modelling their behaviour separately. In total the 'Consumer Acceptance' uptake scenario projects 55% of car stock to be EVs in 2030, of this 45% are BEVs and 10% PHEVs. EV uptake projections for GB in 2030 are illustrated in Figure 4.

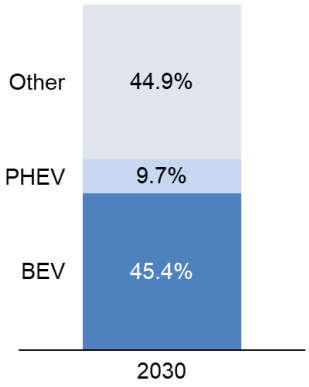

Figure 4: A graph showing the projected EV stock for GB in 2030.

2.2.2 Charging behaviour assumptions

Daily energy requirements for each vehicle were calculated by multiplying daily mileage by electricity consumption of an EV car (i.e. the energy required by an EV car to travel a unit of distance). Element Energy's Cost and Performance Model was used to determine electricity consumption in 2030 based on expected improvements in vehicle technology. A value of 0.186 kWh/km was calculated as the electricity consumption for EV cars in 2030 and was used for calculations of daily energy requirements in this study.[8]

Site-specific assumptions were made on the types of electric vehicle charging points (EVCPs) available at each site, the time spent at an EVCP and the likelihood that a tourist EV would use a specific type of charging at each site. These are assumptions are detailed in the relevant report section. For each use case EVCPs have been assumed to either be slow/fast public (7 kW) or rapid (50-350 kW). The time spent at an EVCP is a site-specific assumption generally chosen through stakeholder engagement as the time site operators expect visitors to spend at their site. The time spent at an EVCP creates an approximation of the maximum amount of energy an EVCP can give a car by multiplying the power of the EVCP by the time spent at the EVCP. The likelihood that a tourist EV uses a type of EVCP

[8] Note that as plug-in hybrid electric vehicles (PHEVs) use an internal combustion engine rather than electric energy for a significant proportion of their driving, overall electricity consumption is typically lower for these vehicles. The figure provided represents the electricity consumption of PHEVs when driving under fully electric power.

is quantified by scaling the number of tourist EVs by a percentage for each type of EVCP. This also captures the fact that not all tourist EVs will choose to charge at a site. The percentage of tourists charging is increased on a peak day to capture the maximum expected tourist EV charging demand on that day.

These factors have been used to determine the charging demand required per EV, which gives the total charging demand expected at the site per day when multiplied by the number of EVs visiting the site per day.

2.2.3 EV charging demand profiles

Three distinct charging categories have been used to distribute tourist EV charging demand throughout the day in order to quantify the impact that the power demand from tourist EV charging will have on the distribution network. Each charging category has its own representative demand profile. These profiles are shown in Figure 5, and have been normalised to represent a daily charging demand on 1 kWh / day. The charging categories correspond to the type of EVCP used by tourist EVs, which are:

- Slow/fast public charging (7kW): charging during the day while at a tourist site, all charging is assumed to be performed during site opening hours,
- Overnight charging (7kW): charging overnight at a tourist site or settlement, profile matches observed behaviour of EVs charging overnight.[9]
- Rapid charging (50-350 kW): rapid charging for a short period of time, before continuing on route/journey.

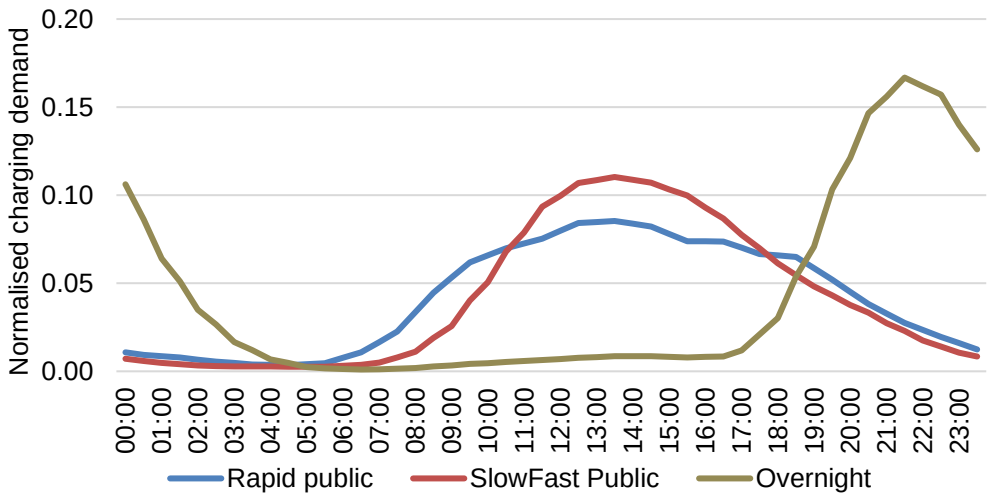

Figure 5: A graph showing the normalised tourist EV charging demand for each charging demand type.

The demand profiles are diversified based on the assumption that sufficient EVs are charging throughout the day to give a smooth variation in charging demand. In the case where few EVs are charging this assumption is no longer valid – a more detailed discussion of the effects of charging diversity is provided in Section 8.3. The demand profiles describe the power demand from tourist EVs at each site at a 30-minute resolution, to match the frequency of network monitoring data provided by SSEN. The charging profile for each charging category was normalised to a total energy demand of 1 kWh / day. For each use case, the charging profile for each charging category was multiplied by the total daily EV charging demand in kWh to calculate the expected charging demand profile for each

[9] Electric Vehicle Charging Behaviour Study, 2019. Link

charging category. Profiles for each of the three categories were summed to produce an overall charging demand profile, representing how charging power demand is expected to vary throughout the day at that site at half-hourly resolution.[10]

2.3 Step 3: Quantifying residential EV charging demand

This study also considered the charging demand from residential EVs on the Isle of Wight. As with tourist EV charging demand, to achieve this the number of residential EVs, their charging behaviour and demand profiles must be accounted for.

Two levels of residential EV charging demand have been modelled in this study:

- Residential charging demand at **secondary** substation level, calculated from the number of EVs assigned to the secondary substation being studied.
- Residential charging demand at the **primary** substation level, calculated from the number of EVs assigned to the primary substation being studied.

This modelling has been performed for each of the secondary and primary substations that serve the use cases.

2.3.1 EV uptake scenarios

As the residential EV charging demand is only concerned with EVs local to the Isle of Wight, the EV uptake scenario used was selected to represent the projected uptake of EVs specifically on the island. The EV uptake scenario is the 'Consumer Transformation' scenario from SSEN's DFES.[11] This provides detailed projections of the expected EVs at each primary and secondary substation. The number of EVs projected at each primary substation was calculated by summing the projected EVs at each of the secondary substations serving the primary.

In some cases fractional EV numbers (i.e. a number between 0 and 1) were projected at secondary substation level. In these cases EV uptake was rounded up for the secondary substation to ensure that at least 1 EV was allocated, to better represent the charging behaviour of a residential EV on that secondary substation.

SSEN's DFES provides uptake projections for both EV passenger cars and EV vans. As the passenger cars and vans have different charging and travel behaviour, EV uptake of the two vehicle types have been treated separately in this study.

SSEN's DFES projections do not split EVs into BEVs and PHEVs, however BEVs and PHEVs were modelled separately in this study to account for their different battery sizes and charging behaviour. Therefore, the number of EVs projected at each substation by SSEN were split into BEVs and PHEVs using the expected national split of EVs based on the results of the ECCo model; in 2030, 82% of EV cars were assumed to be BEVs and 18 % to be PHEVs, and 90% of EV vans were assumed to be BEVs and 10% to be PHEVs. The resulting uptake of EVs on the Isle of Wight is displayed in Figure 6.

[10] Note that these profiles have been calculated assuming there are no constraints to the supply of charging demand. In reality, maximum network demand from EV charging will be limited by the number of EVCPs available and the power rating of these EVCPs. While this is not always a realistic situation, it gives DNOs visibility over how demand on the distribution network would be expected to increase if further EVCPs were installed.

[11] The Consumer Transformation scenario was used as it represents a high electrification world with low levels of modal shift away from private car use, so gives an idea of the maximum level of residential EV charging demand expected across the island.

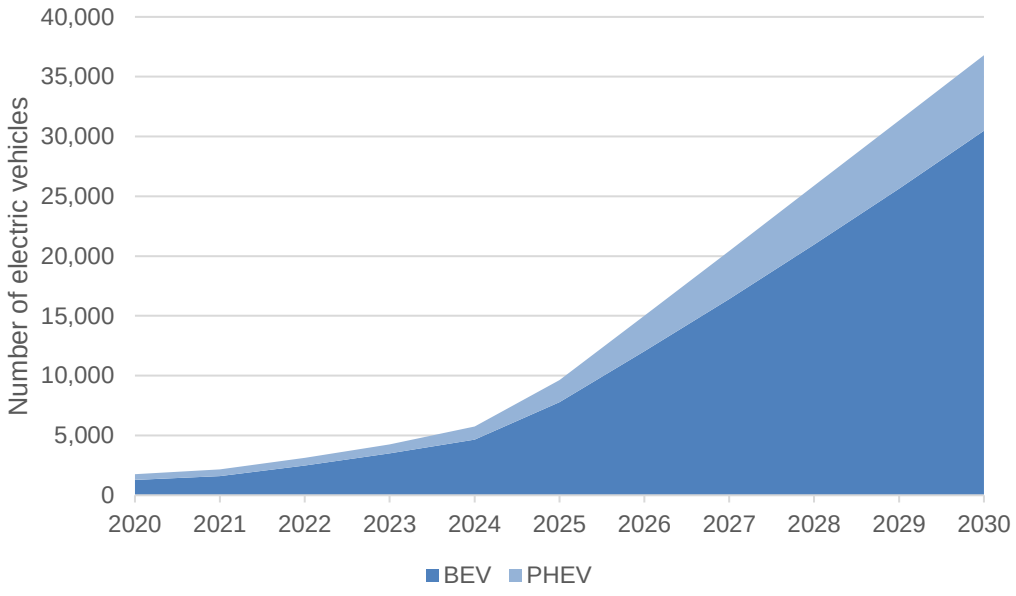

Figure 6: A graph showing the projected total number of residential EVs on the Isle of Wight based on SSEN's DFES 'Consumer Transformation' scenario.

2.3.2 Charging behaviour assumptions

Assumptions were made based on the expected energy consumption and distance travelled by BEVs and PHEVs on the Isle of Wight. It was assumed that passenger cars travel the average distance for a passenger car in the UK. The distance travelled by EV vans is taken from the projected average distance travelled by EV vans by ECCo in 2030. All energy consumption assumptions are based on the 2030 values from Element Energy's Cost and Performance model. These values are summarised in Table 8 below.

Table 8: summary of the charging behaviour assumptions made in the approach to quantifying the residential EV charging demand.

Assumption	Unit	Passenger car		Van	
		BEV	PHEV	BEV	PHEV
Energy consumption	kWh/km	0.186	0.135	0.196	0.178
Average daily distance travelled	km	32.6	32.6	62.4	62.4
Expected daily energy demand	kWh	6.07	4.40	12.2	11.1

It was assumed that residential EVs charge once per day and do all of their charging on the secondary substation they are assigned to in SSEN's DFES. These assumptions allowed the expected daily energy demand from residential EVs to be calculated on each substation, by multiplying daily demand per EV by the projected number of EVs assigned to the substation. The total annual projected demand of residential EVs on the Isle of Wight is shown in Figure 7.

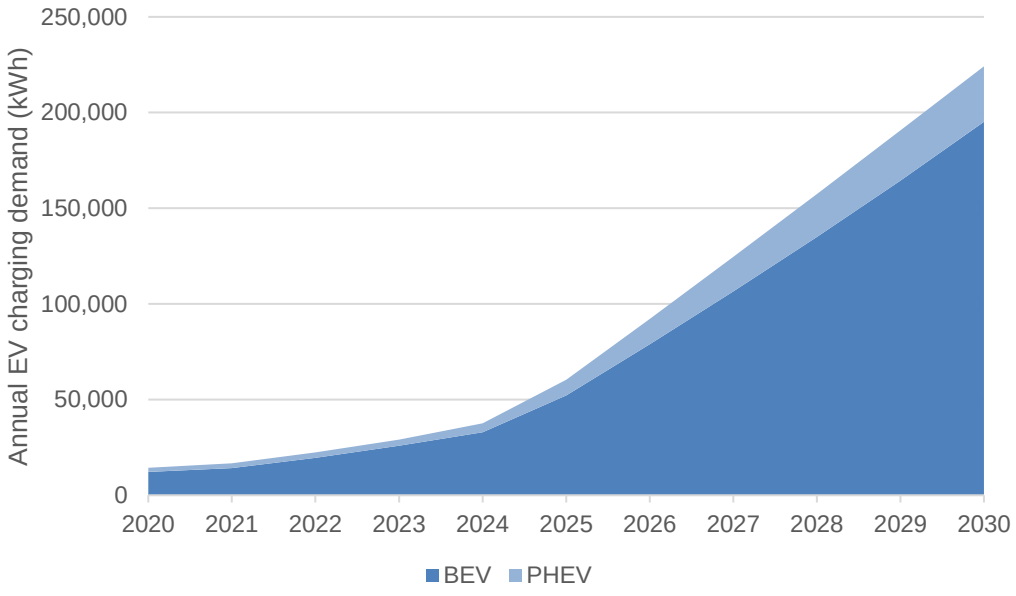

Figure 7: A graph showing the projected total residential EV charging demand for the Isle of Wight based on SSEN's 'Consumer Transformation' scenario.

2.3.3 EV charging demand profiles

In line with standard residential charging behaviour, an overnight charging profile has been adopted to distribute the charging demand from residential EVs to show the power demand it places on the distribution network. In order to give a "worst-case" scenario of the impact of residential EV charging on the distribution network, a passive charging profile has been assumed. As in the year of study, 2030, some smart charging is expected, for substations that exceed their firm capacity a smart charging sensitivity is conducted to understand the potential benefits of flexibility on the network. The passive and smart charging profiles used for residential EVs are shown in Figure 8.

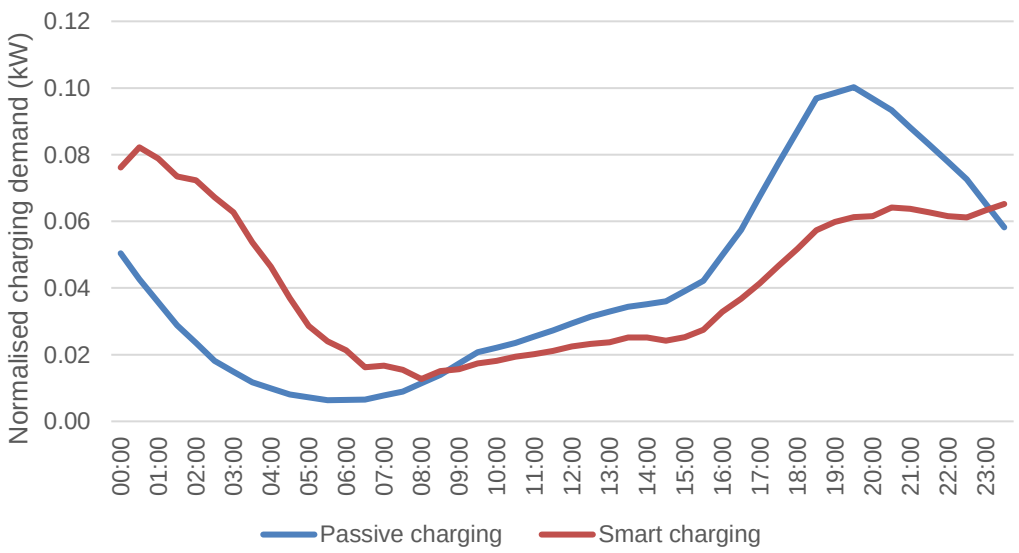

Figure 8: The charging demand profiles used for residential EVs. Both passive and smart charging profiles have been shown.

2.4 Step 4: Network analysis

The final step in the analysis undertaken was to use existing network monitoring data and projected EV charging demand profiles to assess the electricity network impact of increased EV charging demand on primary and secondary substations[12]. Other sources of increased electricity demand other than EV charging (e.g. heat pumps) have not been included. The time scale of this report is to 2030, and electrification of heat in this time period is expected to lead to a much smaller increase in electricity demand than EV charging.

2.4.1 Selection of relevant primary and secondary substations

All of the use cases apart from Shanklin were served by a single secondary substation. The secondary substation that serves the use case and the primary substation the secondary is connected to were included for analysis in the study for each of these use cases.

As Shanklin is a town, it is too large to be served by a single secondary substation. Tourist EV demand was disaggregated from the whole of Shanklin to individual secondary substations based on the share of residential EVs allocated to each of the secondary substations in SSEN's DFES. The spare capacity on each of the secondary substations was also calculated based on maximum demand indicator (MDI) data and transformer ratings provided by SSEN. The results for each of the 10 secondary substations in the Shanklin use case are summarised in Table 9. As the Regent Street secondary substation had the lowest spare capacity and the second highest share of EVs (only 3 percentage points lower than Green Lane secondary substation), this secondary substation was selected for a detailed analysis of network impact.

Table 9: A summary of spare capacity and residential EVs assigned to each of the secondary substations in the Shanklin use case.

Secondary substation name	Spare capacity / kVA	Share of residential EVs
Lower Hyde Touring	350	0%
Atherley Park Way	200	8%
Lidl	165	0%
Lower Hyde Leisure Centre	Not available	0%
Hyde Road	120	16%
Lower Hyde Caravan Site	150	0%
Collingwood Road	140	14%
Regent Street	50	22%
Donnington Drive	100	15%
Green Lane	164	25%

[12] Primary substations convert 33kV electricity into 11kV electricity for local distribution via high voltage (HV) feeders. Secondary substations convert 11kV electricity from HV feeders to 400V or 240V for supplying households and small businesses by low voltage (LV) feeders.

2.4.2 Analysis of network monitoring data

Network monitoring data was provided by SSEN for primary substations that serve each use case. Data was provided for 2019 and 2020 giving load on each primary substation at half-hourly resolution. The data was cleaned to remove data from any days showing anomalous behaviour (e.g. load above maximum for the year, profiles that are suspiciously flat or vary too much between successive half hours). The cleaned data were used to produce typical average and peak weekday and weekend day base load profiles for each month of the year, in line with the day archetypes used to produce profiles of EV charging demand.

Due to the prohibitively large number of secondary substations, detailed load monitoring is not common at this voltage level of the distribution network. Where available, maximum demand indicators (MDIs) were used to scale primary substation load profiles to their downstream secondary substations. This implicitly assumes that network load on secondary substations followed the same profile as their upstream primary substations. In cases where MDIs were not available, load was scaled from primary to secondary substation based on the share of the primary's customers connected to the secondary substation of interest.

2.4.3 Addition of EV charging demand

EV charging demand for each use case was added to corresponding base network load profiles for each use case. As discussed above, network load profiles were produced in the same day archetypes as tourist EV demand profiles, so EV charging demand for each day archetype was added to the base load profile from the same day archetype. Table 10 demonstrates the different datasets used to calculate overall load profiles at primary and secondary substation level. As only tourist EV demand at the 4 use cases in this study has been determined, the full extent of tourist EV demand at primary substation level has not been analysed. This would require an analysis of all tourist sites on each primary substation, which is outside of the scope of this study.

Table 10: Summary of data used for load profiles and EV demand profiles at primary and secondary substation level.

Level	Base load profile	Tourist EV demand	Residential EV demand
Primary substation	Produced from SSEN monitoring data	From modelling of use case	From SSEN DFES at primary level
Secondary substation	Scaled down from primary substation using MDI / customer counts		From SSEN DFES at secondary level

Total network load profiles were compared to firm and rated capacities at primary and secondary substation level respectively. This analysis was performed assuming passive unmanaged charging (i.e. no smart charging). In cases where substation capacities were exceeded, the network impact analysis was repeated with smart charging, to assess how effective smart charging could be as a method for delaying or avoiding thermal constraints. It was assumed that 70% of residential EVs and overnight charging tourists switched to a smart charging profile.[13] For use cases where network constraints are expected, the number of days of constraint has been assessed using the equation shown in Section 8.4.

[13] Early analysis of data from UK Power Networks' Shift Project found that 31% of energy consumed in an EV smart charging trial was consumed during a manual override of the default smart charging mode, while the remaining 69% of energy was consumed under managed smart charging. This suggests a consumer acceptance rate of approximately 70% for smart charging. Link to project report

3 Southampton Ferry Terminal

3.1 Tourist destination overview

3.1.1 Context

The ferry terminal in Southampton (shown in Figure 9) is one of the key ports for visitors to access the island. This ferry terminal is operated by Red Funnel and transports passengers from the mainland to the town of Cowes on the Isle of Wight. Red Funnel operate two ferry terminals in Southampton: a passenger terminal, and a vehicle terminal. As this study aims to assess the impact on excess EV charging demand from tourism, this use case focused on the vehicle terminal operated by Red Funnel in Southampton. Ferries operate in and out of Southampton 24 hours a day, 365 days a year. Each crossing takes approximately 1 hour and approximately 18 crossings take place each day from Southampton. Red Funnel have 3 ferries that operate between Southampton and East Cowes – all 3 ferries run in the summer months, while only 1-2 run in winter with the third in refit. The mean utilisation of Red Funnel's vehicle ferries throughout the year is 50-60%, however, 100% utilisation is not uncommon in the summer months.

Figure 9: A photograph of Southampton ferry terminal during ferry loading. (Source: Red Funnel).

Red Funnel are currently investigating ways to integrate EV charging solutions at the Southampton vehicle ferry terminal. There are two main options available to them, the large marshalling yard and the Triangle car park nearby. For reference these locations are displayed on a map of the Port of Southampton in Figure 10 (the marshalling yard is at the vehicle terminal). The marshalling yard is currently the location where vehicles queue for, embark or disembark their ferry. Triangle car park is owned by Associated British Ports (ABP), but is leased and run by Red Funnel. The car park is available for public use as well as ferry customers. Red Funnel currently plan to install rapid chargers at Triangle car park due to its proximity to the ferry terminal. However, Red Funnel are yet to be convinced about the feasibility and the logistics of installing EVCPs in the marshalling yard without impacting the loading process of the ferries.

3.1.2 Tourism statistics

Red Funnel were able to provide extremely granular data on the number of cars crossing from Southampton each day, with 2019 acting as the reference year. In order to estimate the number of crossings via this route that were completed by tourists, the total number of cars crossing each day was scaled by the ratio of estimated visitors to total crossings to the

island for each month of the year. The percentage of crossings that are believed to be visitors was taken from Visit Isle of Wight's 2019 tourism data. Based on these assumptions, the number of tourists using the Southampton ferry terminal was determined, and their general behaviour is summarised in Table 11 below.

Figure 10: A map of the Port of Southampton, indicating the location of the two ferry terminals and the Triangle car park, operated by Red Funnel.

Table 11: A table summarising the key statistics for the number of tourists visiting Southampton ferry terminal.

Southampton Ferry Terminal overview tourism stats	
Number of tourist cars visiting per year	92,294
Average daily tourist car visits	253
Peak daily tourist car visits	761

Due to the detailed data provided by Red Funnel on the number of crossings from Southampton that take place each day, the monthly variation in tourist demand was estimated to a high level of confidence and analysed for average and peak weekday and weekend days. This is illustrated in Figure 11.

The average tourist demand on both weekdays and weekends generally increased throughout the year, peaking at the end of summer in August and then beginning to decline rapidly to the lower winter levels. While average weekdays are consistently less popular than average weekends, peak weekdays are the busiest time at Southampton ferry terminal, particularly in the summer months. In these months, Friday consistently appears to be the busiest day for tourists crossing from the mainland to the island via Southampton. It is likely that this reflects the behaviour of tourists who begin their visit to the island on Friday.

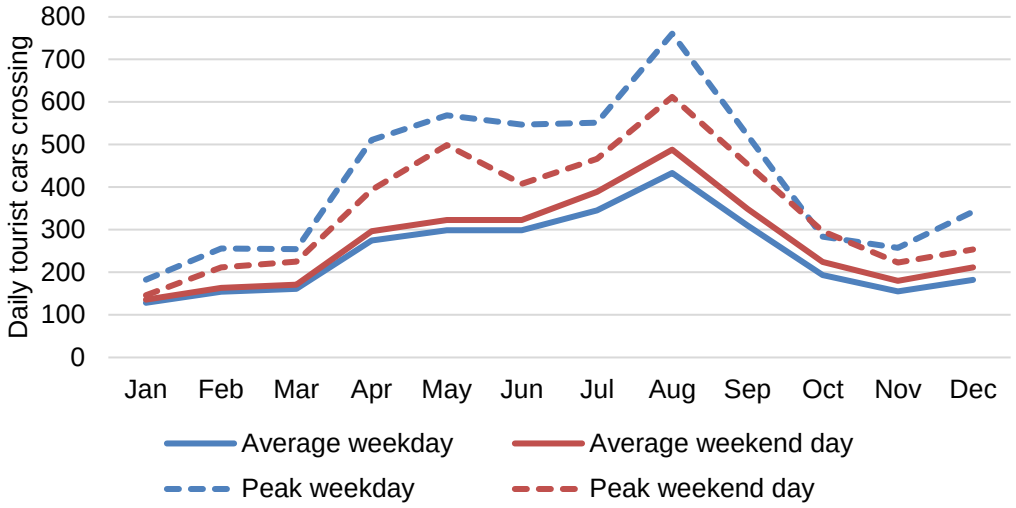

Figure 11: Graph of the daily tourist car visits to Southampton ferry terminal on average and peak weekdays and weekend days.

3.2 Tourist EV charging demand

Assumptions on EV uptake projections and electricity consumption are presented in detail in Sections 2.2.1 and 2.2.2 respectively. However, the assumption on the distance travelled by tourist EVs arriving at the Southampton ferry terminal is not the average distance travelled by a UK passenger car as it is for other sites. The assumption made for Southampton ferry terminal on the distance travelled by tourists arriving at the site is an estimation of the average distance travelled by ferry passengers based on their location of booking. Using booking data provided by Red Funnel, which grouped online ferry bookings by location and number of transactions, it was determined that the average distance a booking was made from in 2019 was 160 km from Southampton. In order to capture the possibility that tourists making long journeys might choose to charge before reaching Southampton, the maximum distance of a booking location from Southampton was capped at 75% of the expected range for a new EV in 2025[14], 260 km[15]. If any journey was further than this distance, it was assumed that the EV driver would choose to stop and charge to allow themselves to reach Southampton with approximately 25% of their capacity remaining. Table 12 summarises these assumptions and any further key assumptions that have been made to estimate the total charging demand of a tourist EV at Southampton ferry terminal.

Table 12: A table summarising the key assumptions made to calculate the expected charging demand from a tourist EV at Southampton ferry terminal in 2030.

	Average day	Peak day
Average daily distance travelled (km)	160	160
Energy expended by distance travelled (kWh)	30	30
Time spent charging at site (hours)	0.5	0.5
Share of EVs using rapid on-site charging per day	20%	40%
Share of EVs using slow/fast on-site charging per day	0%	0%
Share of EVs using overnight charging per day	0%	0%

[14] Assuming the average age of a car is approximately 5 years old.
[15] 347 km * 75% = 260 km. Assumption taken from expected battery sizes from ECCo.

Given the expected number of tourists that use Southampton ferry terminal on an average and peak day listed in Table 11, as well as the assumptions on the percentage of tourists that choose to charge at Southampton ferry terminal, the expected EV charging demand from tourists is 166 kWh on an average August weekday and 480 kWh on a peak August weekend day.

Tourists are only expected to charge for a short period of time at Southampton ferry terminal, either directly before embarking or disembarking a ferry. Therefore, the most suitable type of charging to deploy at the site is rapid EV charging, and it has been assumed that this is the only charging type deployed. As the site operates 24-hours a day, a 24-hour rapid charging profile was selected to model the charging demand from tourists with EVs. As expected, the charging demand through the night is far smaller than in the day, but not negligible. Building throughout the morning, the demand peaks at 283 kW between 13:00-14:00. This is equivalent to six 50 kW chargers, or one 300 kW charger. Figure 12 illustrates the profile of charging demand scaled to reflect the quantity of charging demand created by tourists.

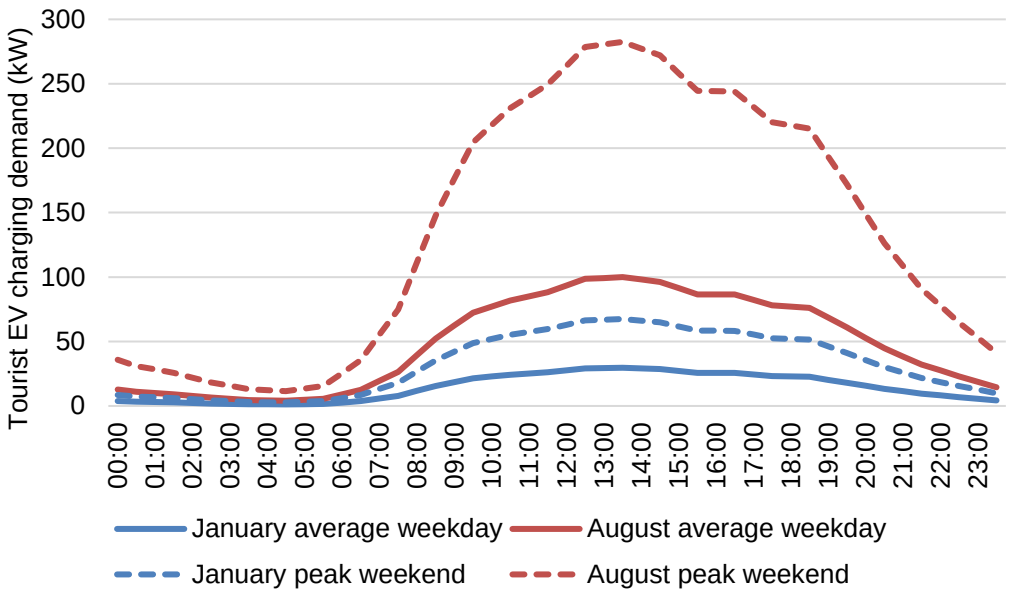

Figure 12: Graph showing the EV charging demand created by tourists at Southampton ferry terminal in 2030.

3.3 Residential EV charging demand

The secondary substation that serves the Southampton ferry terminal is also expected to serve some residential EVs in 2030. Table 13 summarises the projected number of residential EVs and daily charging demand resulting from these EVs in 2030, for the primary and secondary substation that serve the Southampton ferry terminal use case. The resulting profile of expected residential EV charging demand on the secondary substation serving Southampton ferry terminal is displayed in Figure 13. Based on an average total demand of 85 kWh per day, the peak demand of overnight residential charging is 8.6 kW, occurring

between 19:00-20:00. Further details on the assumptions and approach of forecasting residential EV charging demand can be found in Section 2.3.

Table 13: Projected residential EV uptake and daily charging demand at primary and secondary substation level for the Southampton ferry terminal use case in 2030.

Level	Projected residential EVs in 2030	Average daily residential charging demand (kWh)
Primary substation	1,533	9,495
Secondary substation	14	85

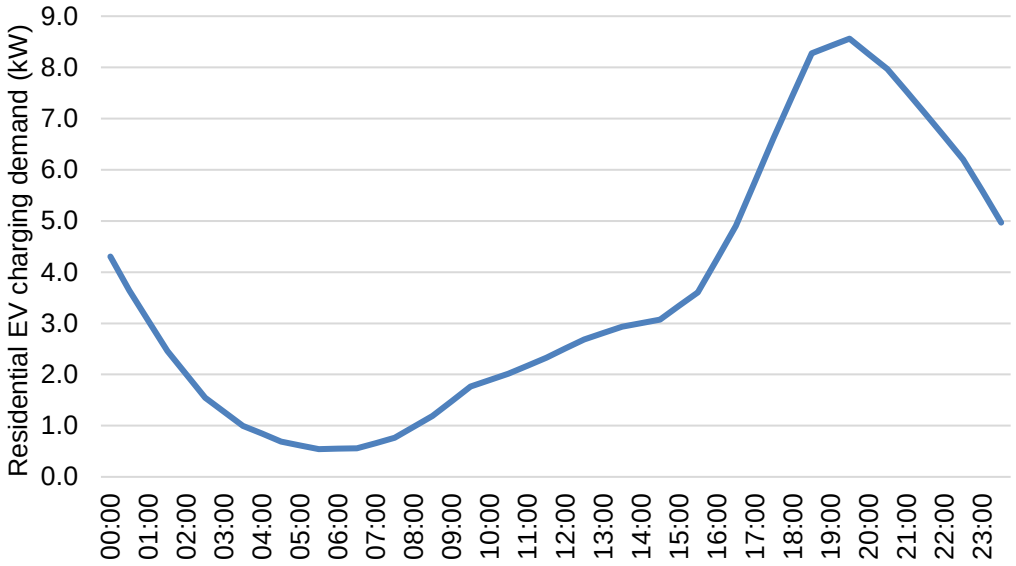

Figure 13: A graph of the total residential EV charging demand at the secondary substation serving Southampton ferry terminal in 2030.

3.4 Network impact findings

Relevant information for the distribution network at the Southampton ferry terminal is provided in Table 14, and base network load profiles for the secondary substation that serves the ferry terminal are shown in Figure 14. The secondary substation has a relatively high rating of 1,000 kW and the 375 kW MDI suggests there is at least 625 kW of spare capacity for EV charging. Based on this assessment it may be feasible to install 4 x 150 kW chargers or 2 x 350 kW chargers, although some load management may be required in the latter case to avoid breaching constraints.

Table 14: Summary of distribution network information for the Southampton ferry terminal use case.

Primary substation name	Central Bridge
Maximum demand (MW)	14.5
Firm capacity (MW)	40.0
Secondary substation name	French Quarter
Maximum demand indicator (kW)	375
Share of primary's customers	N/A
Transformer rating (kW)	1,000

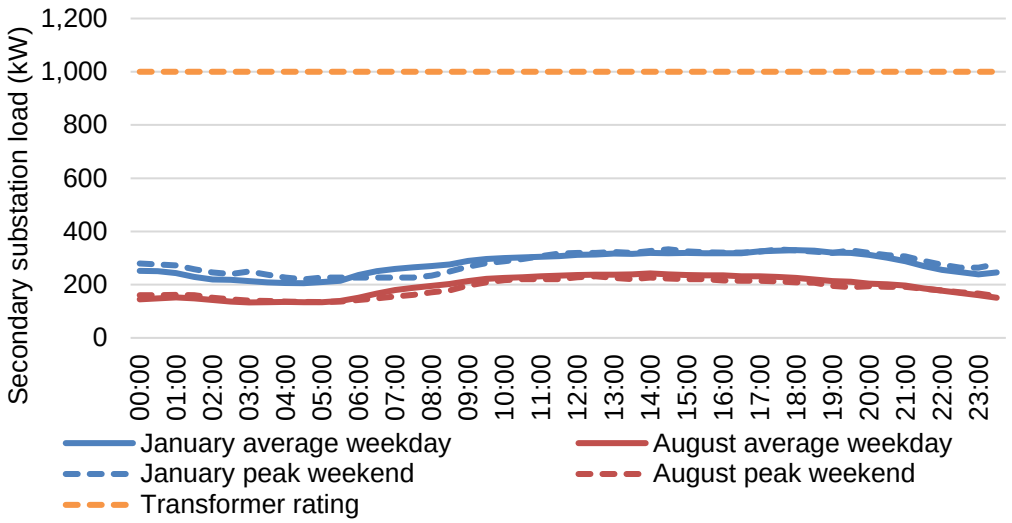

Figure 14: A graph showing base network load on the Southampton ferry terminal secondary substation.

Predicted network load with added tourist and residential EV charging in 2030 is shown in Figure 15. This suggests that there is more than enough network capacity to accommodate increased EV charging from both tourists and residents. It is however worth noting that EV charging demand has been calculated using fully diversified charging profiles. If rapid chargers installed at the site are 50 kW, the diversity assumption is likely to be reasonable. As shown in Figure 12, peak EV charging load is predicted to be 283 kW, which would correspond to 6 x 50 kW chargers being used simultaneously; in this case, there would be sufficient chargers for a smooth variation in EV charging demand throughout the day. However, if higher power chargers were to be installed, the actual charging profile would likely be peakier than is suggested by this diversified charging profile, corresponding to higher peak loads. For a detailed explanation of the effect of diversity on EV charging demand, see Section 8.3.

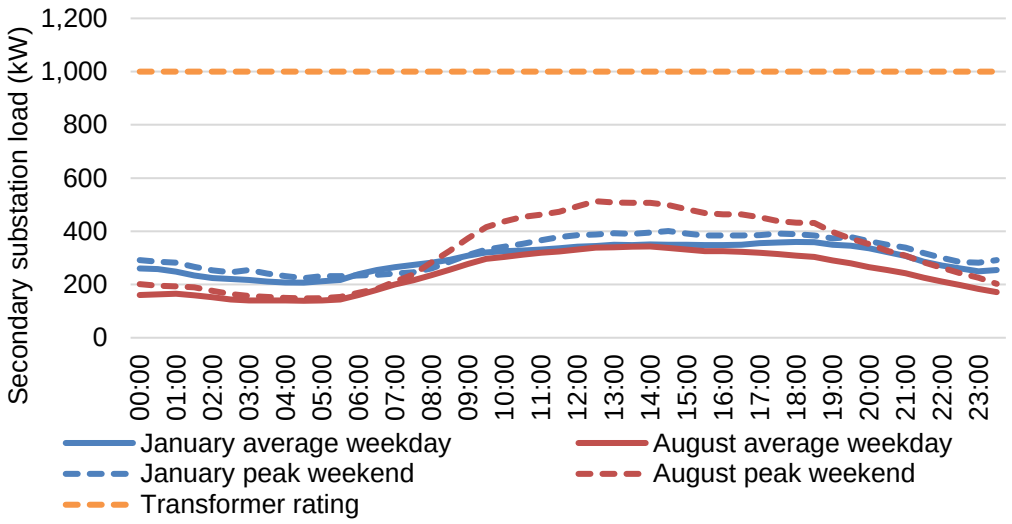

Figure 15: A graph showing predicted load on the Southampton ferry terminal secondary substation in 2030, accounting for tourist and residential EV charging.

4 East Cowes Ferry Terminal

4.1 Tourist destination overview

4.1.1 Context

As the reciprocal ferry terminals to Southampton, the Red Funnel operated ferry terminals in Cowes are responsible for transporting 40% of visitors back from the island to the mainland. There are two terminals in Cowes: a terminal in West Cowes that serves pedestrian ferry arrivals, and a terminal in East Cowes that serves arrivals by vehicles, as shown in Figure 16, the focus of this study.

Figure 16: A photograph of East Cowes ferry terminal as a ferry enters Cowes harbour. (Source: Red Funnel).

East Cowes ferry terminal has two large waiting areas on site and a car park on Well Road. This car park is owned and operated by Red Funnel, which is open to both ferry passengers and the public. They are currently planning the installation of rapid chargers at Well Road car park, expecting the car park to serve the rising demand from ferry passengers, charging immediately prior to loading or after disembarking. They also expect some residents not using the ferry service to charge at Well Road car park. The location of the ferry terminals and Well Road car park are highlighted in Figure 17. As with Southampton ferry terminal, Red Funnel have considered but doubt the feasibility of installing EVCPs in the marshalling yard without impacting the queuing logistics. Red Funnel have also expressed their interest in installing EVCPs in the vicinity of the West Cowes ferry terminal. While this terminal is passenger only, and therefore is not considered in this study, they believe it to still be in the best interests of the island's charging demands. This use case considers installation of charge points in the waiting areas at East Cowes ferry terminal.

Figure 17: A map of Cowes, indicating the location of the two ferry terminals and Well Road car park, operated by Red Funnel.

4.1.2 Tourism statistics

As for Southampton ferry terminal, Red Funnel were able to provide extremely detailed information on the number of cars crossing from East Cowes each day in 2019. In order to estimate the number of crossings via this route that were completed by tourists, the total number of cars crossing each day was scaled by the ratio of estimated visitors to total crossings to the island for each month of the year. The monthly percentages of crossings that are believed to be visitors were taken from Visit Isle of Wight's 2019 tourism data. Based on these assumptions, the number of tourists using the East Cowes ferry terminal was determined, and their general behaviour is summarised in Table 15 below.

Table 15: A table summarising the key statistics for the number of tourists visiting East Cowes ferry terminal.

East Cowes Ferry Terminal overview tourism stats	
Number of tourist cars visiting per year	89,389
Average daily tourist car visits	245
Peak daily tourist car visits	702

Due to the detailed data provided by Red Funnel on the number of crossings at East Cowes that take place each day, the monthly variation in tourist demand was estimated to a high level of confidence and disaggregated into the average and peak weekday and weekend days. This is illustrated in Figure 18.

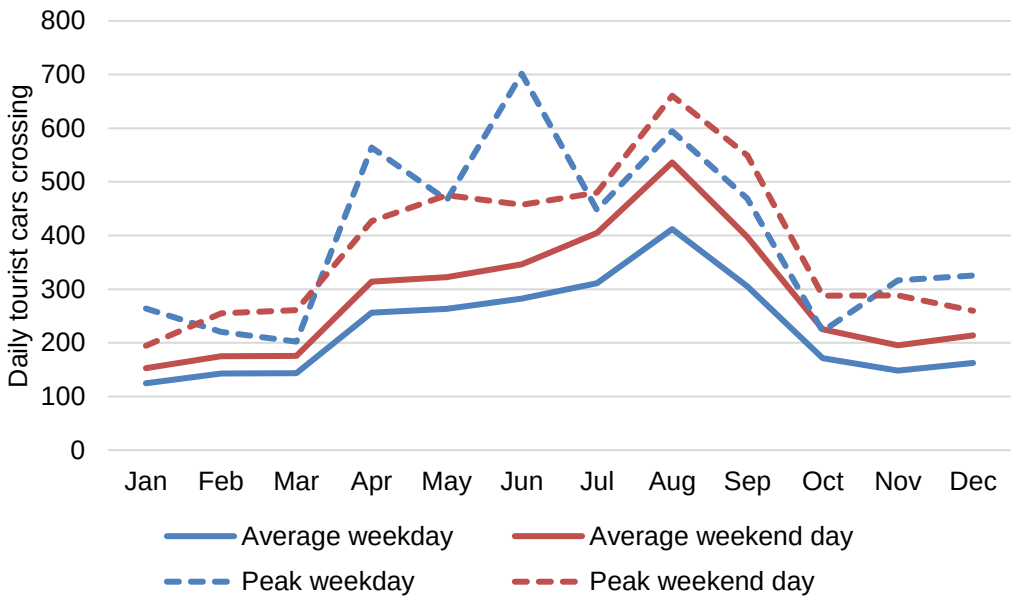

Figure 18: Graph of the daily tourist car visits to East Cowes ferry terminal on average and peak weekdays and weekend days

The average tourist demand on both weekdays and weekend days increases throughout the summer up until the end of the school summer holidays in August when it begins to decline again. Average weekend days consistently experience more crossings from visitors than average weekdays, however peak days show significantly different behaviour. Weekday crossings peak in June, while weekend day crossings peak in August. While Sunday is the busiest day for crossings on average, Mondays in April, May, and June are responsible for the high peak weekday crossings in these months. It is likely that this is reflecting activity on bank holidays as well as tourists choosing to use Monday as their "changeover" day to travel back from their trip to the island. Similar reasoning can be used to explain why Sunday is the busiest day on average.

4.2 Tourist EV charging demand

Table 16 summarises key assumptions that have been made to estimate the total charging demand of a tourist EV at East Cowes ferry terminal. Assumptions on EV uptake projections and electricity consumption are presented in detail in Sections 2.2.1 and 2.2.2 respectively.

Table 16: 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)	33	33
Energy expended by distance travelled (kWh)	6	6
Time spent charging at site (hours)	0.5	0.5
Share of EVs using rapid on-site charging per day	20%	40%
Share of EVs using slow/fast on-site charging per day	0%	0%
Share of EVs using overnight charging per day	0%	0%

Given the expected number of tourists that use East Cowes ferry terminal on an average and peak day listed in Table 15, as well as the assumptions on the percentage of tourists that chose to charge at East Cowes ferry terminal, the expected EV charging demand from tourists is 166 kWh on an average August weekday and 480 kWh on a peak August weekend day.

Tourists are expected to charge for a short period of time at East Cowes ferry terminal, either directly before embarking or disembarking a ferry. Therefore, the most suitable type of charging to deploy at the site is rapid EV charging, and it has been assumed that this is the only charging type deployed. As the site operates 24-hours a day, a 24-hour rapid charging profile was selected to model the charging demand from tourists with EVs. As expected, the charging demand through the night is far smaller than in the day, but not negligible. Building throughout the morning, the demand peaks between 13:00-14:00. Figure 19 illustrates the profile of charging demand scaled to reflect the quantity of charging demand created by tourists.

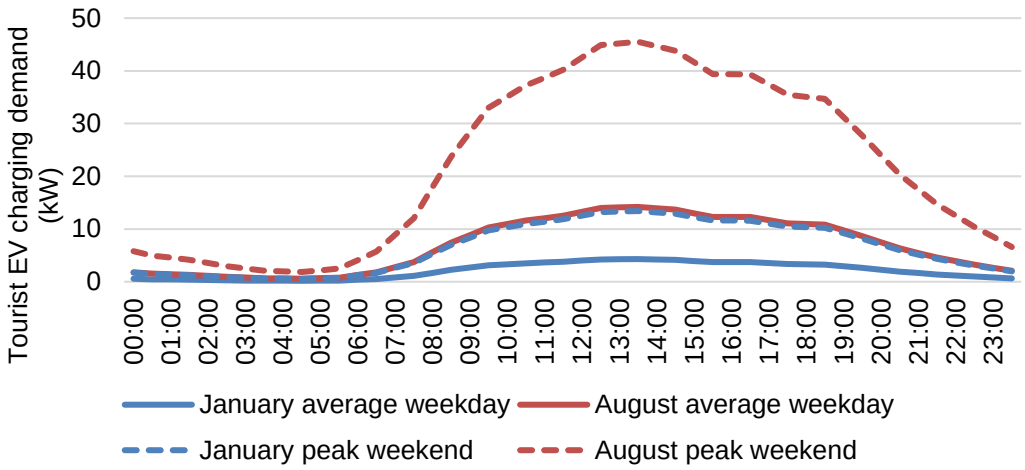

Figure 19: Graph showing the EV charging demand created by tourists at East Cowes ferry terminal in 2030.

Evidently, the demand at East Cowes ferry terminal is significantly smaller than at Southampton ferry terminal at the other end of the ferry route (approximately 6 times smaller). This is because it is assumed that tourists choose to recharge their EVs before their crossing rather than after their crossing. The analysis of booking data suggests that the average distance travelled to reach Southampton ferry terminal is 160 km (see section 3.2 for details). Whereas the average distance travelled by tourists arriving at East Cowes for their return trip back to the island is assumed to be 33 km (as detailed in section 2.2.2). This disparity in distance travelled is the driving factor in the difference between the EV charging demand at the two ferry terminals.

4.3 Residential EV charging demand

Table 17 summarises the projected number of residential EVs and daily charging demand resulting from these EVs in 2030, for the primary and secondary substation that serve the East Cowes use case. The resulting profile of expected residential EV charging demand on the secondary substation serving East Cowes ferry terminal is displayed in Figure 20. Based on an average total demand of 72 kWh per day, the peak demand of overnight residential charging is 7.2 kW, occurring between 19:00-20:00. Further details on the assumptions and approach of forecasting residential EV charging demand can be found in Section 2.3.

Table 17: Projected residential EV uptake and daily charging demand at primary and secondary substation level for the East Cowes ferry terminal use case.

Level	Projected residential EVs in 2030	Average daily residential charging demand (kWh)
Primary substation	6,219	37,701
Secondary substation	11	72

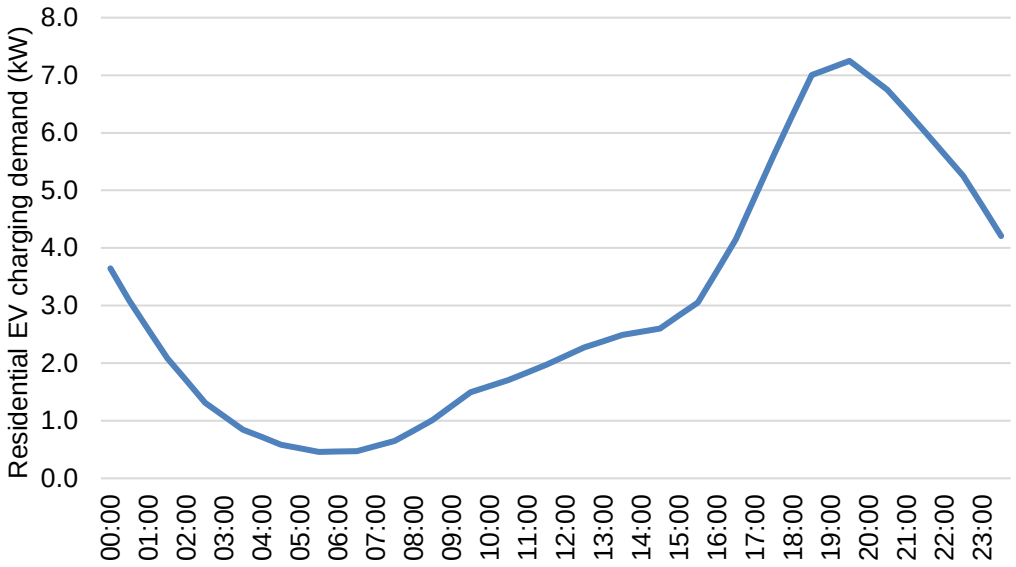

Figure 20: A graph of the total residential EV charging demand at the secondary substation serving East Cowes ferry terminal in 2030.

4.4 Network impact findings

Relevant information for the distribution network at the East Cowes ferry terminal is provided in Table 18, and base network load profiles for the secondary substation that serves the ferry terminal are shown in Figure 21. The secondary substation serving the East Cowes ferry terminal, referred to as Waitrose by SSEN, has a relatively high rating of 1,000 kW. Maximum load on this secondary substation is estimated to be 258 kW, suggesting there is approximately 742 kW of spare capacity for EV charging. Based on this assessment it is feasible to install 5 x 150 kW chargers or 2 x 350 kW chargers without exceeding the transformer rating. Although some load management may be required in the former case to avoid breaching constraints.

Table 18: Summary of distribution network information for the East Cowes ferry terminal use case.

Primary substation name	Cowes PS
Maximum demand (MW)	16.8
Firm capacity (MW)	30.0
Secondary substation name	Waitrose
Maximum demand indicator (kW)	258
Share of primary's customers	N/A
Transformer rating (kW)	1,000

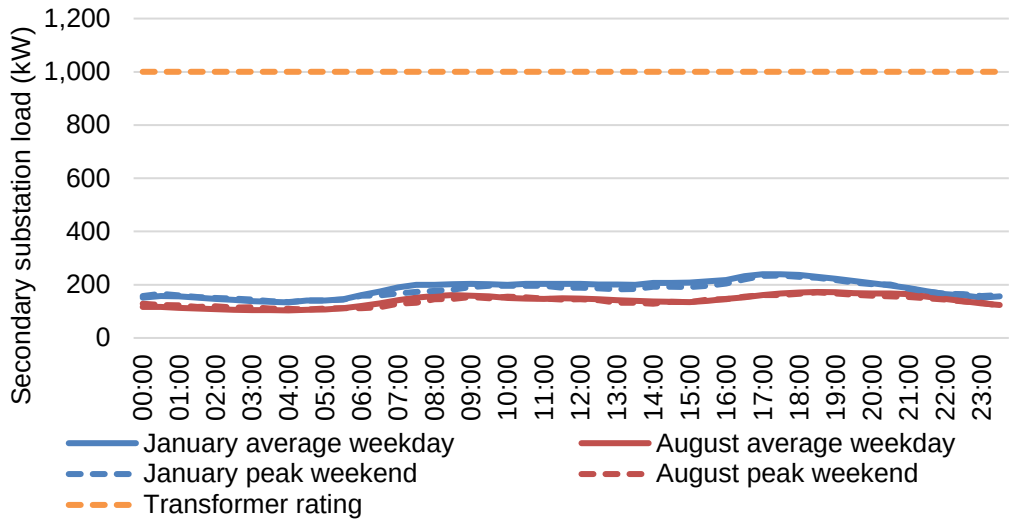

Figure 21: A graph showing base network load on the East Cowes ferry terminal secondary substation.

The predicted network load with added tourist and residential EV charging in 2030 is shown in Figure 22. It is clear that there is more than enough network capacity to accommodate increased EV charging from both tourists and residents. However, as with Southampton ferry terminal, the profiles used to distribute the charging demand from tourists and residents are fully diversified. As the use of this profile produces a peak of < 50 kW based on the EV charging demand modelling assumptions for this site, this profile does not accurately represent the impact of installing rapid charging at East Cowes ferry terminal. For a detailed explanation of the effect of diversity on EV charging demand, see Section 8.

The available data on current network loading suggests that there is sufficient capacity for 14 x 50 kW chargers to run simultaneously or a smaller number of ultra-rapid (150 kW and 350 kW) chargers, as discussed above.

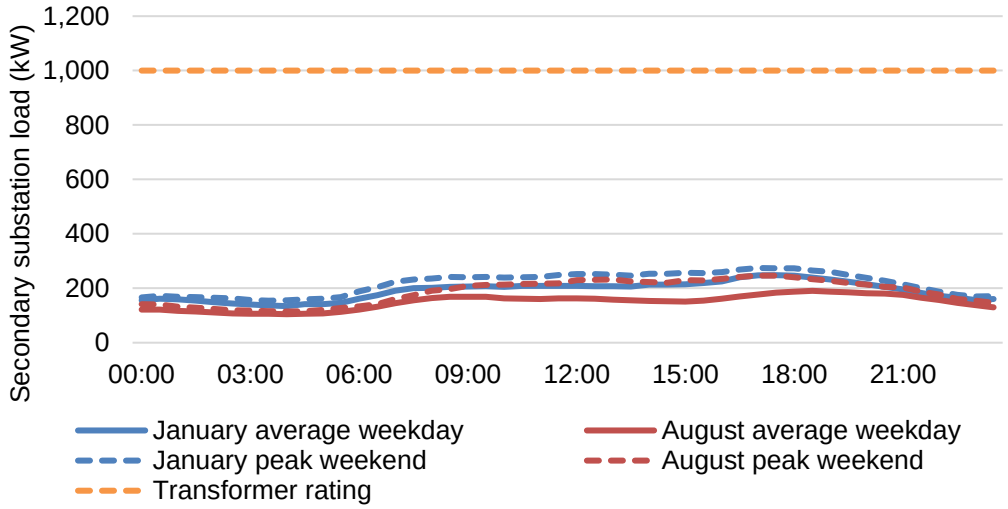

Figure 22: A graph showing predicted load on the East Cowes ferry terminal secondary substation in 2030, accounting for tourist and residential EV charging.

5 Woodland Resort

5.1 Tourist destination overview

5.1.1 Context

The Woodland Resort is a new attraction that is currently under development in the northwest of the island, approximately a 1.5-mile drive from Yarmouth ferry terminal. Aiming to open in April 2023, the eco-wellness resort plans to place sustainability at the centre of all its activities. The Woodland Resort will accommodate overnight guests in various accommodation types, including tree houses (illustrated in Figure 23) and mini houses. In addition, the resort is set to have an on-site café, restaurant and spa and wellness centre to attract day as well as overnight visitors. In high season, the resort expects to attract approximately 500 visitors per day, which includes 150-200 visitors staying overnight.

Figure 23: 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 currently will be installed with at least 10 EVCPs[16]. Furthermore, the Woodland Resort plans to make EVs available for guests. They are currently considering placing 5 EVs in Yarmouth so tourists can utilise EVs across the island, charging them at the Woodland Resort. In addition, Wightlink, operators of the ferry terminal in Yarmouth, have plans to provide substantial incentives for tourists to use EVs on the island, encouraging tourists to bring their EVs to the Woodland Resort. Finally, the Woodland Resort plan to have approximately 50 e-bikes and 50 e-scooters available at the resort, all contributing to the tourist EV charging demand at the site.

5.1.2 Tourism statistics

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. The visitor numbers are then scaled based on the percentage of tourists that travel to the Isle of Wight in a car and the average group size in a car[17] to give the number of cars expected to visit the site on a peak day. This equates to 119 cars arriving at the site each day.

In addition to the tourists arriving at the Woodland Resort each day, the cars that are staying overnight also must be accounted for. This is done by multiplying the estimated number of cars arriving at the site each day by the average stay of visitors on the island. This information is available by quarter[18], over the course of 2019, the average length of stay on the island was 2.85 days, however this rose to 3.48 days in the 3rd quarter of the year, during

[16] The power of the EVCPs is yet to be decided.
[17] See appendix for details on assumption, based on figures from Visit Isle of Wight tourism data, 2019.
[18] Isle of Wight tourism data, see appendix for more detail.

peak season. The resulting statistics for the number of tourist cars expected at the Woodland Resort are detailed in Table 19 below.

Table 19: A table summarising the key statistics for the number of tourists visiting the Woodland Resort.

East Cowes Ferry Terminal overview tourism stats	
Number of tourist cars visiting per year	19,236
Average daily tourist car visits	53
Peak daily tourist car visits	127

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. Red Funnel data for ferry crossings from Southampton to East Cowes was used to capture the monthly variation in tourist demand. The profile of tourist crossings was normalised and scaled based on the assumption that the maximum tourist demand for the Woodland Resort will occur during the islands peak season in August. Given that the busiest average day of the week for the Southampton to East Cowes ferry terminal is Friday, the profile was shifted by one day so that the busiest average day would occur on a Saturday to reflect that the Woodland Resort will likely be busiest at the weekend. The final profile for the expected tourist demand at the Woodland Resort is presented in Figure 24.

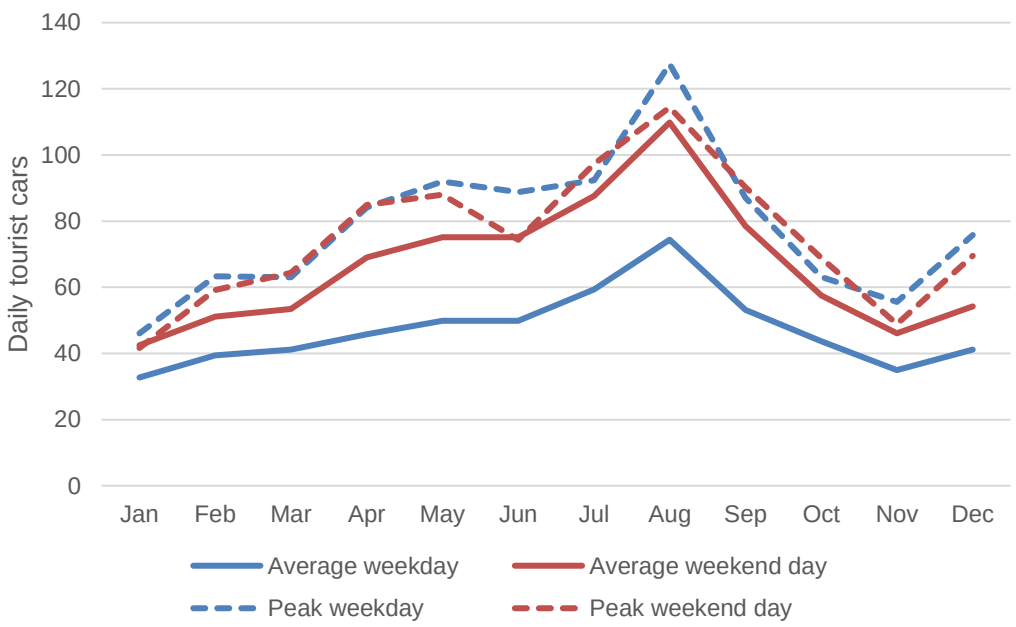

Figure 24: A graph of the daily tourist car visits to the Woodland Resort on average and peak weekdays and weekends.

5.2 Tourist EV charging demand

Table 20 summarises these assumptions and any further key assumptions that have been made to estimate the total charging demand of a tourist EV at the Woodland Resort. Assumptions on EV uptake projections and electricity consumption are presented in detail in Sections 2.2.1 and 2.2.2 respectively.

Table 20: 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)	33	33
Energy expended by distance travelled (kWh)	6	6
Time spent charging at site during day (hours)	2.5	2.5
Share of EVs using slow/fast on-site charging per day	20%	40%
Time spent charging at site during overnight (hours)	8	8
Share of EVs using overnight charging per day	50%	50%

Given the expected number of tourists that are expected to visit the Woodland Resort on an average and peak day, listed in Table 19, as well as the assumptions on the percentage of tourists that choose to charge at the Woodland Resort, 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 tackled separately and appropriate charge profiles applied to reflect each behaviour type. The two profiles are aggregated in Figure 25 to produce the total expected tourist EV charging demand profile at the Woodland Resort.

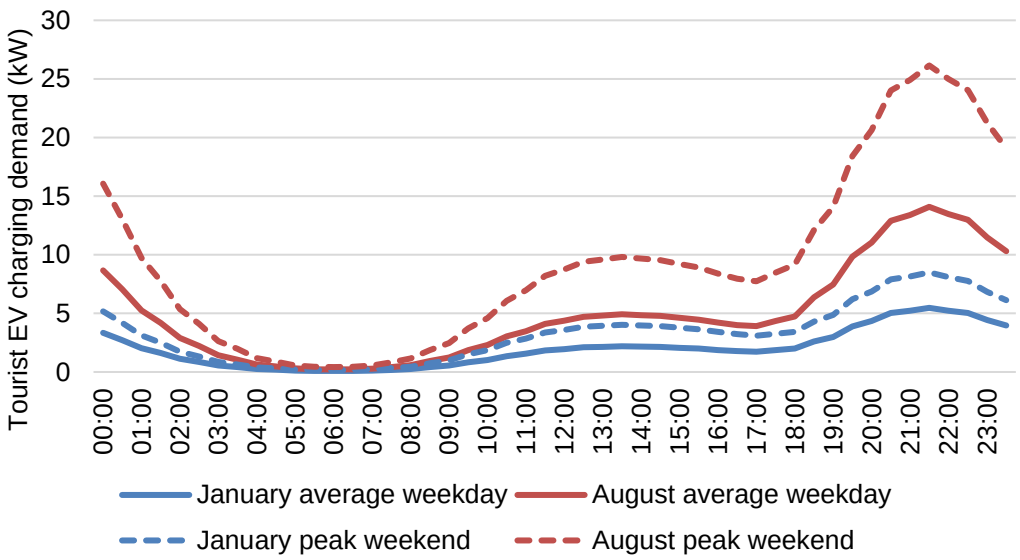

Figure 25: A graph showing the expected EV charging demand created by tourists at the Woodland Resort in 2030.

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. As a baseline, it is assumed that all charging at the site is passive to capture the worst-case scenario on the primary and secondary substations that serve the Woodland Resort.

5.3 Residential EV charging demand

Table 21 summarises the projected number of residential EVs and daily charging demand resulting from these EVs in 2030, for the primary and secondary substation that serve the Woodland Resort use case. The resulting profile of expected residential EV charging demand on the secondary substation serving the Woodland Resort is displayed in Figure 26. Based on an average total demand of only 12 kWh per day, the peak demand of overnight residential charging is 1.2 kW, occurring between 19:00-20:00.

The residential overnight charging profile used for all residential EV charging demands is fully diversified. Clearly on its own this does not represent the behaviour of one BEV car present on the secondary substation, however, when combined with the tourist overnight charging profile, the resulting distribution represents the expected behaviour of all the EVs served by the secondary substation, both tourist and residential. Therefore, no further impact analysis on installation of a single charge point was conducted for the Woodland Resort.

Further details on the assumptions and approach of forecasting residential EV charging demand can be found in Section 2.3.

Table 21: Projected residential EV uptake and daily charging demand at primary and secondary substation level for the Woodland Resort use case in 2030.

Level	Projected residential EVs in 2030	Average daily residential charging demand (kWh)
Primary substation	1,985	12,441
Secondary substation	1	12

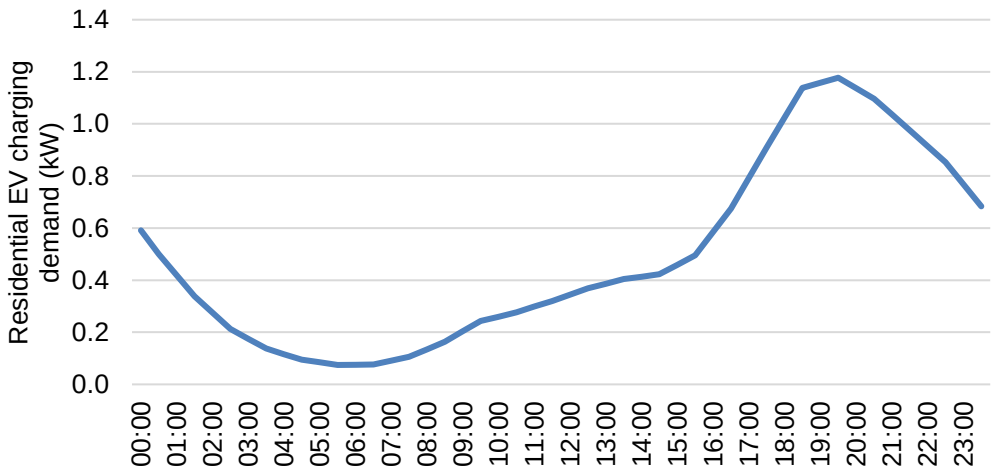

Figure 26: A graph of the total residential EV charging demand at the secondary substation serving the Woodland Resort in 2030.

5.4 Network impact findings

A summary of the key distribution network information for the Woodland Resort is given in Table 22, and base network load profiles for the secondary substation that serves the resort are shown in Figure 27. Situated in a rural area, the secondary substation is a small pole mounted transformer, with a rating of only 15 kW. Because the substation serving the Woodland Resort is a pole mounted transformer, there is no MDI at this substation. Therefore, the demand profile has been calculated by scaling the demand on the primary

substation, Shalfleet, by the number of customers on the Lucketts substation, the secondary substation serving the resort (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.

Table 22: Summary of distribution network information for the Woodland Resort use case.

Primary substation name	Shalfleet
Maximum demand (MW)	5.5
Firm capacity (MW)	15.0
Secondary substation name	Lucketts
Maximum demand indicator (kW)	N/A
Share of primary's customers	0.1%
Transformer rating (kW)	15

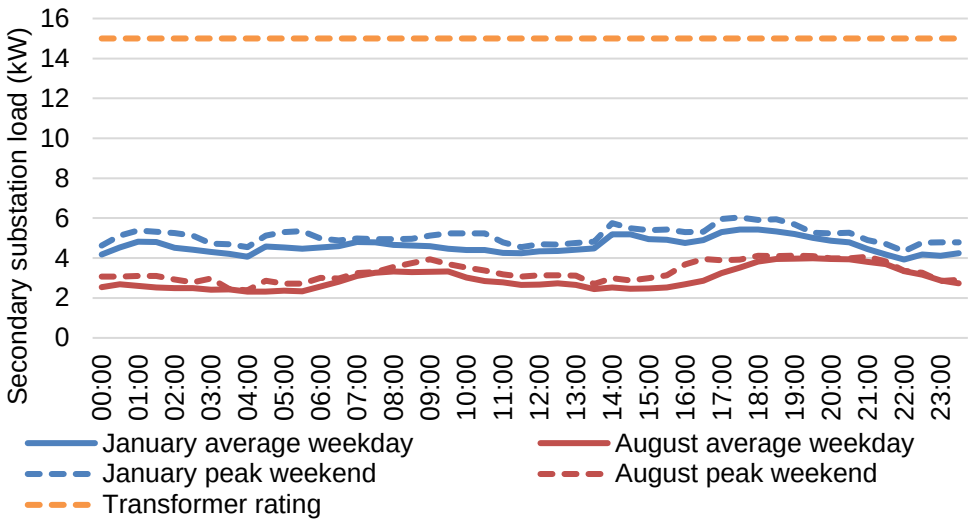

Figure 27: A graph showing base network load on the Woodland Resort secondary substation.

Predicted network load with added tourist and residential EV charging in 2030 is shown in Figure 28. It suggests that the load on the distribution network exceeds the firm capacity marginally on an average August weekend and exceeds the firm capacity substantially on a peak August weekend. Over a calendar year in 2030, it is expected that as a result of tourist and residential EV charging demand, the thermal constraints of Lucketts substation will be exceeded 161 times.

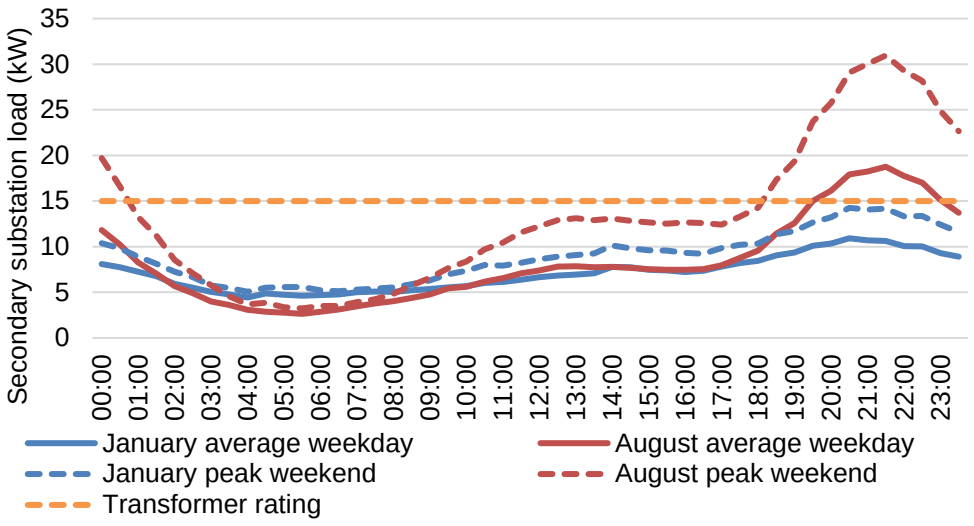

Figure 28: A graph showing predicted load on the Woodland Resort secondary substation in 2030, accounting for tourist and residential EV charging.

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 this study a sensitivity analysis was conducted for the Woodland Resort to investigate the effect smart charging could have on the impact on the distribution network.

The result that smart charging can have on reducing the impact on the distribution network is illustrated in Figure 29. It demonstrates that while smart charging is unlikely to completely avoid the need to reinforce the distribution network by 2030 to cope with the charging demand from tourist EVs, it can help reduce the magnitude of the upgrade required. With the implementation of managed smart charging, average weekdays throughout the year no longer exceed the rating of the transformer. It is only on peak summer weekends that the charging demand is expected to lead to the transformer exceeding its rating. This decreases the number of days in which the thermal constraints of the transformer are exceeded to 52. Smart charging also successfully reduces the minimum size of reinforcement required from installing a second 15 kW transformer to upgrading the current transformer by 5 kW. Hence the use of managed smart charging reduces the need to reinforce Lucketts substation, although does not mitigate it entirely. For more detail on the approach to generating a smart charging profile, refer to section 2.4.

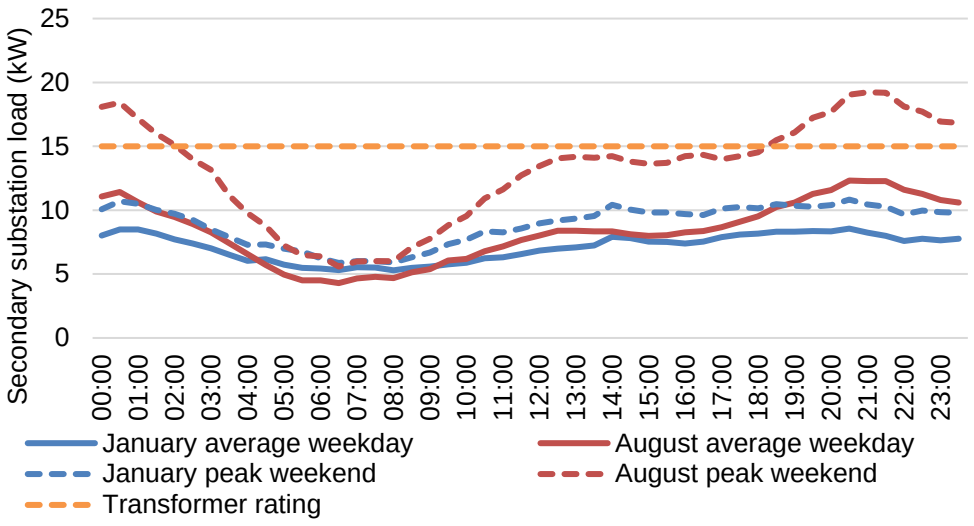

Figure 29: A graph showing predicted load on the Woodland Resort secondary substation in 2030, given tourist and residential EV charging using a smart charging profile.

The Woodland Resort use case is currently served by a small pole mounted transformer and load is expected to greatly increase once the resort is operational and tourist EVs are charging at the site. Constraints are expected to be only partially mitigated by installation of smart charging, so it is likely that network reinforcement will be necessary. However, this could provide an ideal opportunity to test the potential for smart charging to lower peak load at tourist sites. The feasibility of installing an additional pole mounted transformer and managing EV charging to prevent thermal constraints could be assessed. The cost of this solution could then be compared to the cost of installing a ground mounted transformer. The latter option would guarantee constraints would not be breached, however is likely to be significantly more expensive than installing a pole mounted transformer. Therefore, the decision of whether reinforcing with an additional pole mounted transformer or installing a ground mounted transformer would be decided by the extent of demand growth expected once the Woodland Resort is operational, including electricity demand of the site and external factors such as EV charging.

6 Shanklin

6.1 Tourist destination overview

6.1.1 Context

Figure 30: A photograph of Shanklin. (Source: Pixbay).

Shanklin, pictured in Figure 30, is a town that sits on the east coast of the island. It was selected as a use case because it was the most visited settlement on the island in 2019. Shanklin is a seaside town, located on Sandown Bay. Many tourist attractions situated in Shanklin also attract both day and overnight visitors to the town. These attractions include Shanklin Chine – the historic gorge and nature trail, Shanklin Theatre, Rylstone Gardens, the Old Village and Shanklin Esplanade. Most tourists staying in Shanklin choose to stay either in a hotel or guest house (61%), whilst approximately 19% stayed in a form of rented accommodation, either a house or a static caravan. The remaining 20% stay in other accommodation including second homes or with relatives.

There are currently two public EVCPs in Shanklin, both located at Landguard Holiday Park with a power of 22 kW[19]. There are several car parks in Shanklin that could be investigated on their suitability for the deployment of EVCPs. These sites include Hope Road car park, Spa car park, the Pay & Park and Landguard Road car park amongst others.

6.1.2 Tourism statistics

According to Visit Isle of Wight data, in 2018, 370,000 tourists visited Shanklin, with 63% choosing to stay overnight. This data can be broken down to the quarterly influx of tourists to the town. The third quarter, spanning the peak summer season, is the busiest for tourism, with over 150,000 tourists visiting the town during the summer months, 100,000 of them choosing to stay overnight in Shanklin for an average of 5.3 nights. Over the course of the year the average number of visitors per day is estimated to be 1,015, this increases to 1,645 in peak season. As Shanklin is predominantly an overnight destination for tourists, to calculate the number of tourists in the town at any given time, the length of tourists' stay must be taken into account. Having scaled the number of tourists by the average length of stay, the number of cars visitors bring is estimated using the Visit Isle of Wight tourism data detailed in the appendix. The results are summarised in Table 23.

Table 23: A table summarising the key statistics for the number of tourists visiting Shanklin.

East Cowes Ferry Terminal overview tourism stats	
Number of tourist cars visiting per year	87,935
Average daily tourist car visits	754
Peak daily tourist car visits	3,017

[19] Source: Zap-map.com

The expected number of tourist cars per day was applied to a profile of visitors arriving on the island to capture the daily and monthly fluctuations that occurs within the seasonal variation in the tourist demand. Red Funnel data for ferry crossings from Southampton to East Cowes was used to capture the monthly variation in tourist demand. The profile of tourist crossings was normalised and scaled based on an average day in Shanklin for each quarter. Figure 31 displays the final profile for the number of tourist cars that are present in Shanklin based on these assumptions.

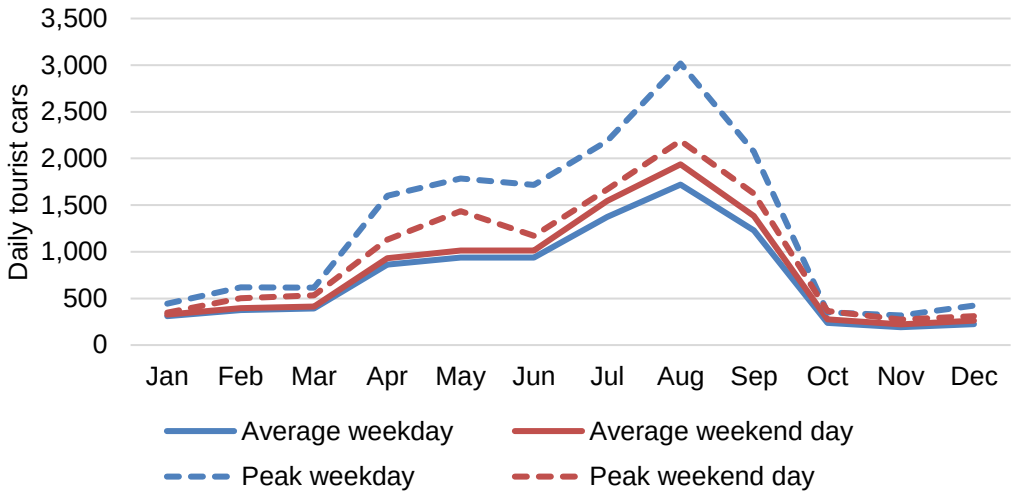

Figure 31: A graph of the daily tourist car visits to Shanklin on average and peak weekdays and weekends.

The average tourist demand increases throughout the peak season from March to the end of August. The peak days follow a similar trend; however, their increases are clearly more pronounced during school holiday periods, specifically the Easter and summer holidays. Although an average weekend sees more tourist cars in Shanklin than the average weekday, the peak weekdays are substantially busier than the peak weekends, with the busiest peak day falling on a Friday in August.

6.2 Tourist EV charging demand

Table 24 summarises these assumptions and any further key assumptions that have been made to estimate the total charging demand of a tourist EV at Shanklin. This includes the estimated time spent charging at the site and the share of tourist EVs charging on an average or peak day. Assumptions on EV uptake projections and electricity consumption are presented in detail in Sections 2.2.1 and 2.2.2 respectively.

Table 24: 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)	33	33
Energy expended by distance travelled (kWh)	6	6
Time spent charging at site during day (hours)	2.5	2.5
Share of EVs using slow/fast on-site charging per day	20%	40%
Time spent charging at site during overnight (hours)	8	8
Share of EVs using overnight charging per day	50%	50%

Given the expected number of tourists cars expected to be in Shanklin on a given average and peak day, listed in Table 23, as well as the assumptions on the percentage of tourists that choose to charge while staying in Shanklin, the expected EV charging demand from tourists is 2,719 kWh on an average August weekday and 5,871 kWh on a peak August weekday.

It is expected that tourists that visit Shanklin only for the day will charge using slow/fast daytime charging, whereas tourists staying overnight in Shanklin will likely make daytime excursions to other attractions on the island, returning to charge their car overnight. Therefore, the two different behaviours have been tackled separately and appropriate charging profiles applied to reflect each behaviour type. The two profiles are aggregated in Figure 32 to produce the total expected tourist EV charging demand profile in Shanklin.

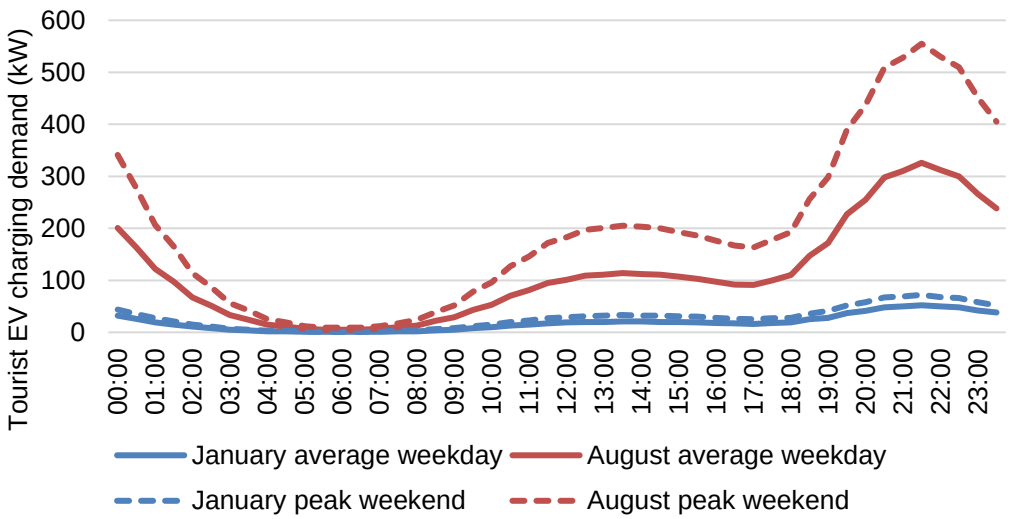

Figure 32: A graph showing the expected EV charging demand created by tourists in Shanklin in 2030.

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 555 kW occurring between 21:00-22:00. As a baseline, it is assumed that all charging at the site is passive to capture the worst-case scenario on the primary and secondary substations that serve the Shanklin.

6.3 Residential EV charging demand

SSEN have highlighted 10 secondary substations and one primary substation in Shanklin for analysis of the impact of tourist EV charging. The residential EV charging demand has been projected for each of 10 secondary substations. In 2030 the modelling suggests that the average demand from residential EV charging on the secondary substations in Shanklin is 243 kWh per day while the greatest demand on a single secondary substation in Shanklin is 618 kWh per day. The daily residential EV charging demand on the primary substation that serves the entirety of Shanklin is expected to be 25,547 kWh in 2030. The total residential EV charging demand on the 10 SSEN selected secondary substations in Shanklin combined is 2,427 kWh. The resulting profile of expected residential EV charging demand on these 10 secondary substations combined is displayed in Figure 33. The total peak demand on the secondary substations in Shanklin combined is 243 kW, occurring between 19:00-20:00. Table 25 summarises the projected number of residential EVs and daily charging demand resulting from these EVs in 2030, for the primary and secondary

substation that is analysed for the Shanklin use case (see section 2.4.1 for details). The secondary substation selected for analysis and shown in Table 25 was Regent Street. The justification for this is provided in section 2.4.1. Further details on the assumptions and approach of forecasting residential EV charging demand can be found in Section 2.3.

Table 25: Projected residential EV uptake and daily charging demand at primary and secondary substation level for the Shanklin use case in 2030.

Level	Projected residential EVs in 2030	Average daily residential charging demand (kWh)
Primary substation	4,190	25,547
Secondary substation	79	479

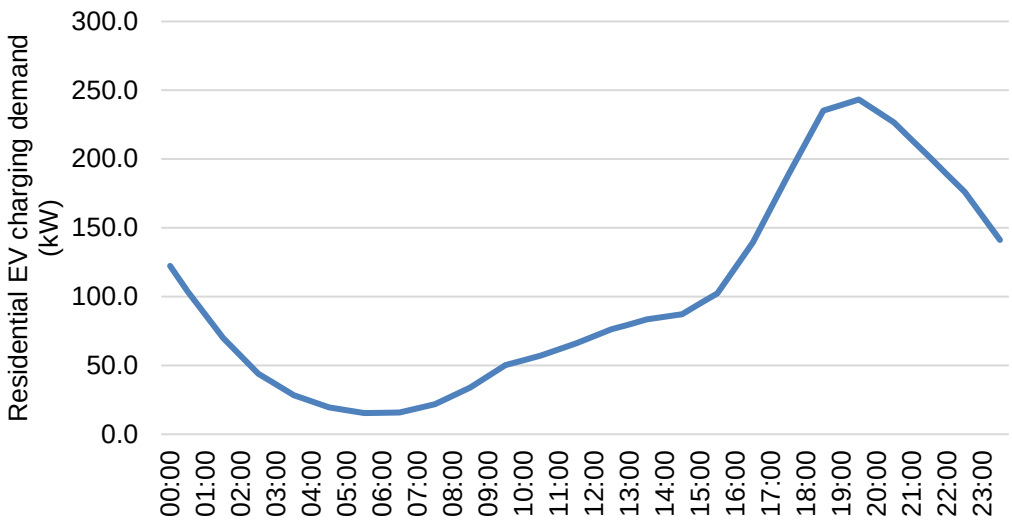

Figure 33: A graph of the total residential EV charging demand at the 10 secondary substations analysed in Shanklin in 2030.

6.4 Network impact findings

The key distribution network information for Shanklin is summarised in Table 26. In total, 10 secondary substations serve Shanklin. However, as detailed in section 2.4.1, thermal constraints on the secondary substations in Shanklin can be identified with confidence by analysing only Regent Street substation. The base network load profiles for Regent Street are shown in Figure 34. The rating of the Regent Street Transformer is 500 kW and the 450 kW reading from the MDI suggest that there is 50 kW of spare capacity for EV charging demand at the Regent Street substation in Shanklin.

Table 26: Summary of distribution network information for the Shanklin use case.

Primary substation name	Shanklin
Maximum demand (MW)	10.3
Firm capacity (MW)	30.0
Secondary substation name	Regent Street
Maximum demand indicator (kW)	450
Share of primary's customers	N/A
Transformer rating (kW)	500

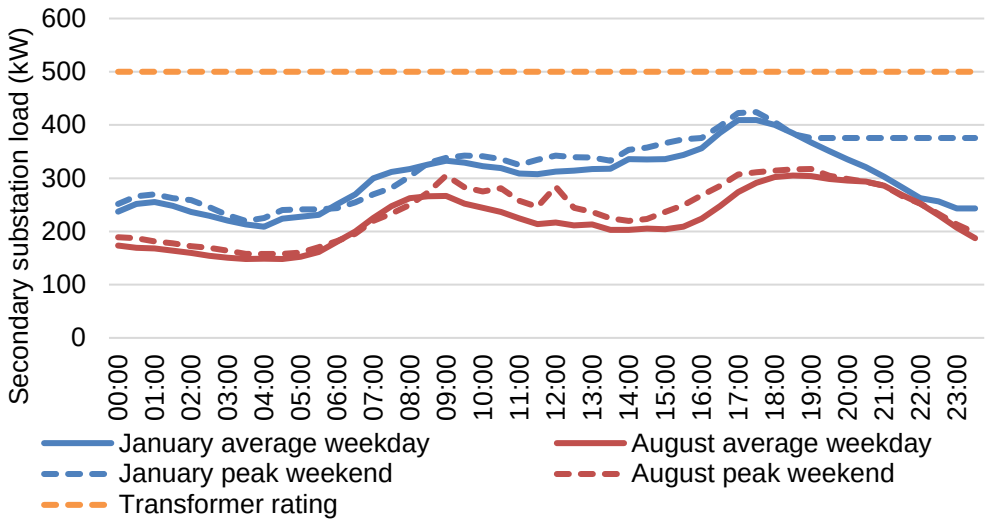

Figure 34: A graph showing base network load on Regent Street secondary substation in Shanklin.

Figure 35 shows the impact on the distribution network from the addition of residential and tourist EV charging demand on top of the base network load. Even in peak season on a peak day, the network analysis suggests that the total demand on the secondary substation does not exceed the rating of the Regent Street transformer. One point of note for Shanklin is that unlike the other use cases investigated in this study, even with the introduction of tourist EV charging, the annual peak of demand on the network occurs during the winter months rather than in August. This is due to the seasonal variation in base network load outweighing the seasonal variation expected in EV charging demand. Although additional EV charging demand is expected to lead to a 10% increase in peak EV charging demand in January and a 40% increase in August, current peak load is significantly lower in summer months, meaning that even with the addition of EV charging demand, peak load is still expected to be highest in the winter for this use case.

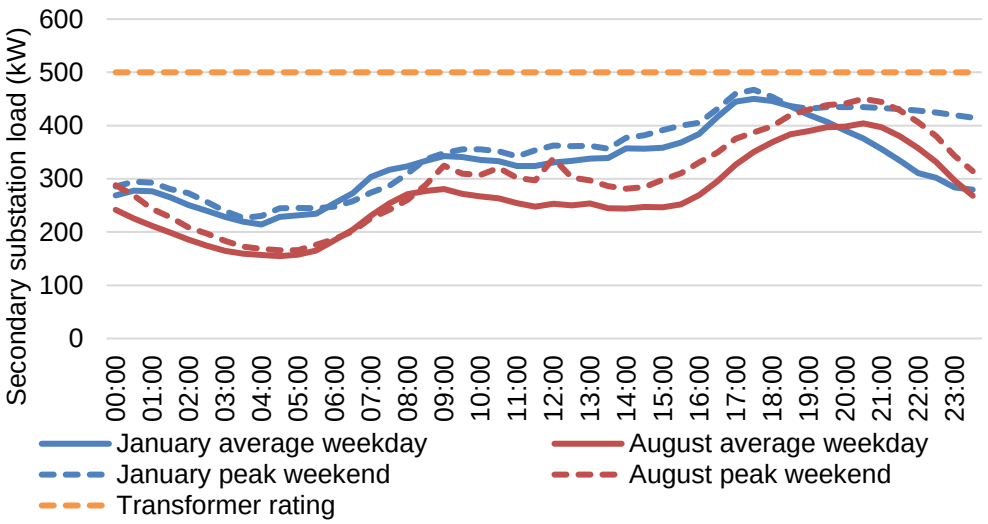

Figure 35: A graph showing predicted load on the Shanklin secondary substation in 2030, accounting for tourist and residential EV charging.

7 Conclusions and next steps

7.1 Key findings from the study

The impact of the charging demand from an increased amount of EVs visiting the Isle of Wight is likely to cause network constraints at tourist resorts and attractions located in rural areas on the island, such as the Woodland Resort. These constraints are projected to only impact on the secondary substations, with the primary substation being mostly unimpacted by the uptake of tourist and residential EVs. Rural secondary substations will be impacted most heavily because, given the small number of customers they serve, their transformer rating is very low and hence cannot cope with the additional load on the network from EV charging points.

Meanwhile, the substations which serve tourist attractions in towns either on the island (East Cowes and Shanklin) and on the mainland (Southampton) are expected to be able to operate in 2030 without any constraints on the substation as a result of tourist or residential EV charging demand. In the case of the ferry terminals, this is because both terminals are served by relatively large secondary substations (both with a transformer rating of 1,000 kW). The secondary substations in Shanklin are also relatively large compared to the transformer serving the Woodland Resort. Five of the ten substations have a transformer rating of 500 kW and the smallest substation is 100 kW, still significantly larger than the pole mounted rural substation at the Woodland Resort. In addition to the sizeable substations capable of dealing with an increase in charging demand, the tourist charging demand for the town was distributed over the substations during the modelling. Therefore, given the ten substations in the settlement, the impact of the charging demand, both tourist and residential, has minimal impact on the substations. The number of days, for which the projected load on the secondary substations serving the selected use cases are expected to exceed the transformer rating, are summarised in Table 27.

Table 27: A summary of the findings from the network analysis of secondary substations. Green: no demand constraints expected; amber: demand constraints expected, however capacity breaches are small and short; red: large, long duration demand constraints expected, network upgrade required to mitigate. Note generation constraints are not considered in this table.

Case study	Secondary substation	Current network status	Days of constraint expected in 2030	Days of constraint expected in 2030 with smart charging
Southampton Ferry Terminal	French Quarter		0	0
East Cowes Ferry Terminal	Waitrose		0	0
Woodland Resort	Lucketts		161	52
Shanklin	Regent Street		0	0

Table 28 summarises the average and peak tourist visits. While it was expected that tourism on the island is busier in the summer months, the finding that visitors stay for longer at overnight attractions (Woodland Resort and Shanklin) during peak season compounds peak in the summer period. Furthermore, when this behaviour is transformed to EV charging demand, summarised in Table 29, this report finds that the profiles of use cases which offer

overnight charging are expected to have far larger peaks when using passive charging behaviour than rapid/day charging.

Table 28: A summary of tourist visit estimated for the selected use cases.

Case study	Daily average tourist cars visiting	Winter peak daily cars visiting	Summer peak daily cars visiting	Average daily distance travelled / km
Southampton Ferry Terminal	253	343	761	160
East Cowes Ferry Terminal	245	325	702	33
Woodland Resort	53	76	127	33
Shanklin	754	347	3,071	33

Table 29: A summary of tourist EV charging demand for winter and summer peak days 2030.

Case study	Winter peak day, 2030		Summer peak day, 2030	
	Total daily charging demand / kWh	Peak charging demand / kW	Total daily charging demand / kWh	Peak charging demand / kW
Southampton Ferry Terminal	1,372	117	3,310	283
East Cowes Ferry Terminal	210	18	544	46
Woodland Resort	133	15	224	26
Shanklin	660	72	4,725	555

As highlighted in Table 27, the introduction of smart charging sees the days of constraints expected on the Woodland Resort largely reduce. When modelled with a passive charging profile, the expected load on the transformer that serves the Woodland Resort exceeds the transformer rating by approximately 106% on a peak day and 25% on an average summer day. If a smart charging profile is used for residential and EV tourists staying overnight at the Woodland Resort, the constraint on a peak day is reduced to 28% over the transformer rating and eliminates any constraint on an average summer day. This demonstrates the importance and benefits smart charging can have on the island, particularly at rural tourist attractions where constraints are likely. While the deployment of smart charging does not completely eliminated the thermal constraints expected at the site, it sufficiently reduces the quantity and size of expected constraints, potentially delaying or decreasing the need to reinforce the grid at the Woodland Resort.

7.2 Limitations

Tourist visit, travel and charging behaviour patterns are very difficult to forecast for several reasons, including uncertainties in economic and weather-related trends. The key limitations encountered in producing this study are detailed below:

- Where only quarterly/daily average visitor data was available, Southampton to East Cowes ferry data was used to determine monthly variation. This cannot account for differences in seasonality of attractions compared to the ferry crossing.
- In cases where specific car data was not available, Visit Isle of Wight data was used to determine the number of cars expected for a given number of tourists[20]. This does not take into account the preferred mode of travel to specific attractions.
- As EV uptake is currently low, there is no data available on the behaviour of tourist EV drivers. Assumptions made on charging behaviour of tourists were based on insights gathered from studies on general drivers, but it is likely that there will be differences in how tourists charge compared with the general driving population.

In addition to modelling tourist visit data, the key limitations to modelling demand on the distribution network are detailed below:

- Fully diversified profiles have been used to model the charging demand of tourist and residential EVs. In cases where tourist or residential EVs are low, this might not be an accurate representative of the charging profile experienced at the site. In the cases where this may occur, it has been flagged.
- Using maximum demand indicators and customer counts to scale load profiles derived for primary substations to their downstream secondary substations does not account for the loss of diversity on moving from primary to secondary substation level. This will only be relevant for secondary substations with few customers.
- In cases where maximum demand indicators were not available, load profiles have been scaled from primary to secondary substation level based on customer counts. This assumes that all customers contribute the same amount of load to the network, which is not the case for large businesses or industrial customers, which will contribute more than a typical residential customer

7.3 Next steps

As thermal constraints are not predicted to be an issue at three of the four use cases analysed, the focus of the next phase of the project will be on how best to ensure EV charging demand can be shifted throughout the day to align with solar generation at higher voltage levels and prevent reverse power flows.

As it is still under development and network reinforcement is expected to be required at the Woodland Resort, this use case would be an ideal location to test findings from this study. This could include assessing the reduction in peak load from implementing smart charging, and testing possible cost savings from smart charging by avoiding more expensive network upgrades where a pole mounted transformer would have to be replaced by a ground mounted transformer. As solar generation is also planned to be installed at the Woodland Resort, this will provide a good opportunity to test how EV charging demand can be shifted to align with times of high solar demand. Learnings from this additional work could be applied to higher voltage levels to assess the feasibility of mitigating generation constraints caused by solar generation by aligning sources of flexible demand to prevent reverse power flows.

[20] See Appendix 8.1 for details.

8 Appendix I: Additional details on project approach

8.1 Converting from tourist visit numbers to number of tourist cars

- 66% of tourists assumed to travel by car (from Visit Isle of Wight statistics)
- 2.78 people per car (from Visit Isle of Wight statistics on average tourist group size)

8.2 Accounting for tourists staying overnight

For the Shanklin use case, where many tourists stay overnight, the number of tourists present at the site on a given day was estimated by multiplying the number of tourists arriving per day by the average length of stay for tourists staying at Shanklin. This correction was only applied to tourists staying overnight, not those performing a day visit. The correction applied is represented in equation form below, and Table 30 summarises the quarterly data on overnight visits and length of stay for tourists visiting Shanklin, provide by Visit Isle of Wight.

$$\begin{aligned} &Tourists\ present\ per\ day \\ &\qquad = tourists\ performing\ day\ visits \\ &\qquad + (overnight\ tourists\ arriving\ per\ day\ \times length\ of\ stay\ in\ days) \end{aligned}$$

Table 30: Summary of statistics on tourists staying overnight and length of stay at Shanklin use case.

Quarter	Share of tourists staying overnight	Length of stay (days)
Q1 (January – March)	54%	3.2
Q2 (April – June)	66%	4.0
Q3 (July – September)	66%	5.3
Q4 (October – December)	61%	3.2

8.3 Charging diversity

Charging profiles used to determine expected EV charging demand at each use case assume that charging demand is fully diversified. This means there are sufficient tourists charging to give a smooth variation in charging demand throughout the day. In reality for low numbers of tourists or chargers the charging profile will show large peaks when tourists are charging and no demand in between.

In this study this effect is most relevant for sites where rapid chargers are planned to be installed. Figure 36 demonstrates this effect for East Cowes ferry terminal. Peak demand using a fully diversified charging profile, represented by the solid blue line, is predicted to be 46 kW, however as rapid EVCPs are planned to be installed at the site, minimum EV charging demand would be at least 50 kW (as rapid charge points have a power of 50 kW or greater). An example profile for installing a single 150 kW ultra-rapid charger is represented by the dashed red line, and in this case the impact of EV charging on the distribution network is likely to be underestimated by using a fully diversified charging profile. For the ferry terminal use cases where peak demand is predicted to be lower than the power of charge points likely to be installed, we have assessed the number of rapid chargers that

could be installed at the site given the spare capacity currently available on the secondary substation that the ferry terminal is connected to.

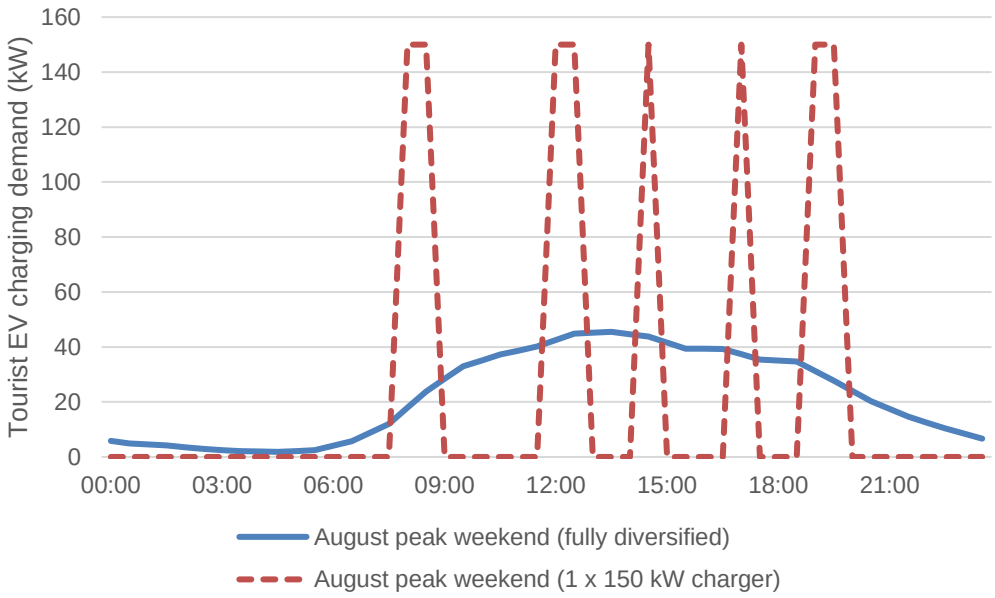

Figure 36: A comparison of charging profiles for East Cowes ferry terminal, assuming a fully diversified charging profile (solid blue line) and an example of actual charging demand if a 150 kW charger were installed (dashed red line).

8.4 Estimating expected days of constraint on distribution network

For sites where transformer ratings are expected to be exceeded, the expected days of constraint per year has been assessed using the following equation:

$$Days\ of\ constraint = 365 \times \left(\underbrace{\frac{1}{7} \times \frac{n_{peak\ weekday}}{12}}_{\text{Peak weekday term}} + \underbrace{\frac{1}{7} \times \frac{n_{peak\ weekend}}{12}}_{\text{Peak weekend term}} + \underbrace{\frac{4}{7} \times \frac{n_{average\ weekday}}{12}}_{\text{Average weekday term}} + \underbrace{\frac{1}{7} \times \frac{n_{average\ weekend}}{12}}_{\text{Average weekend term}}\right)$$

The expression in brackets represents the fraction of days in the year when constraints are exceeded. Peak and average weekdays and weekend days are considered separately for each month:

- Peak weekdays: Friday is assumed to be the peak weekday, meaning that one day in seven in each month on average is a peak weekday. The factor of $\frac{1}{7}$ is multiplied by $\frac{n_{peak\ weekday}}{12}$, the share of months where the peak weekday profile exceeds rated capacity.
- Peak weekends: Saturday is assumed to be the peak weekend day, meaning that one day in seven in each month on average is a peak weekend day. The factor of $\frac{1}{7}$

is multiplied by $\frac{n_{peak\ weekend}}{12}$, the share of months where the peak weekend profile exceeds rated capacity.

- Average weekdays: this is assumed to cover every weekday other than Friday, which accounts for four days in seven for each month on average. The factor of $\frac{4}{7}$ is multiplied by $\frac{n_{average\ weekday}}{12}$, the share of months where the average weekday profile exceeds rated capacity.
- Average weekends: non-peak weekend days (i.e. Sundays) are assumed to fall into this category, which accounts for one day in sever for each month on average. The factor of $\frac{1}{7}$ is multiplied by $\frac{n_{average\ weekend}}{12}$, the share of months where the average weekend profile exceeds rated capacity.

9 Appendix II: Introduction to ECCo

Element Energy's light duty vehicle uptake projections are generated using our bespoke Electric Car Consumer Model (ECCo). This model captures consumer behaviour and calculates the market share of various powertrains to 2050 for given policy and infrastructure landscapes. This covers both conventional petrol and diesel vehicles, as well as full and plug-in hybrids, and range-extended, battery and fuel cell electric vehicles, across all car and van size classes. Figure 37 illustrates the inputs required for ECCo and outputs that the model calculates from these inputs.

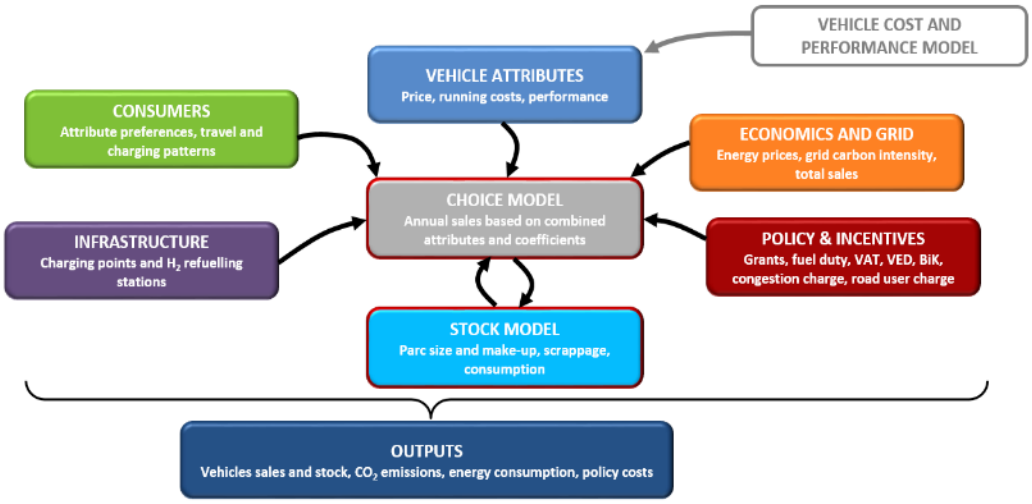

Figure 37. Schematic diagram showing inputs and outputs for ECCo.

Primary research on 2,000 new car buyers was conducted to identify how UK car buyers are influenced by capital and running costs. This research has been used to define model parameters relating to consumer behaviour. Future vehicle attributes are calculated by Element Energy's Car and Van Cost and Performance Model and this allows for a range of technology deployment scenarios to be considered.

ECCo is continuously updated to ensure it reflects the rapid changes occurring in the ultra-low emissions vehicle market, including new vehicle models, policy amendments, and technology trends. It supports the work of multiple clients, for example:

- The UK Department for Transport, to aid in light-duty vehicle policy design.
- Energy Technology Institute's Consumers, Vehicles and Energy Integration project (now hosted by the Energy System Catapult), which simulated pathways to decarbonising the light duty vehicle sector from the perspective the UK's whole energy system.
- Several UK DNOs, to forecast the number of plug-in vehicles charging across their licence areas.

High level policy inputs for a selection of ECCo scenarios are shown in Table 31 below. More information on ECCo can be found on Element Energy's website.[21]

[21] http://www.element-energy.co.uk/sectors/low-carbon-transport/project-case-studies/#project_1

Table 31: High-level summary of policy assumptions for 3 GB ECCo scenarios.

Scenario name	Scenario description	Perceived access to charging for people without access to off-street parking?	ICE/PHEV ban enforced?	Car EV stock in 2030
Limited uptake	The public charging market does not develop sufficiently to be seen as reliable by consumers (especially those parking on-street) and policy to remove conventional vehicles is not put in place.	✗	✗	16.1m
Consumer acceptance	Public charging develops sufficiently for consumer acceptance in 2030, however no government policy is implemented to remove conventional powertrains from the market.	✓	✗	20.5m
ICE ban	In addition to better public charging access, the government bans the sale of ICE vehicles in 2030 and PHEVs in 2035.	✓	✓	20.7m