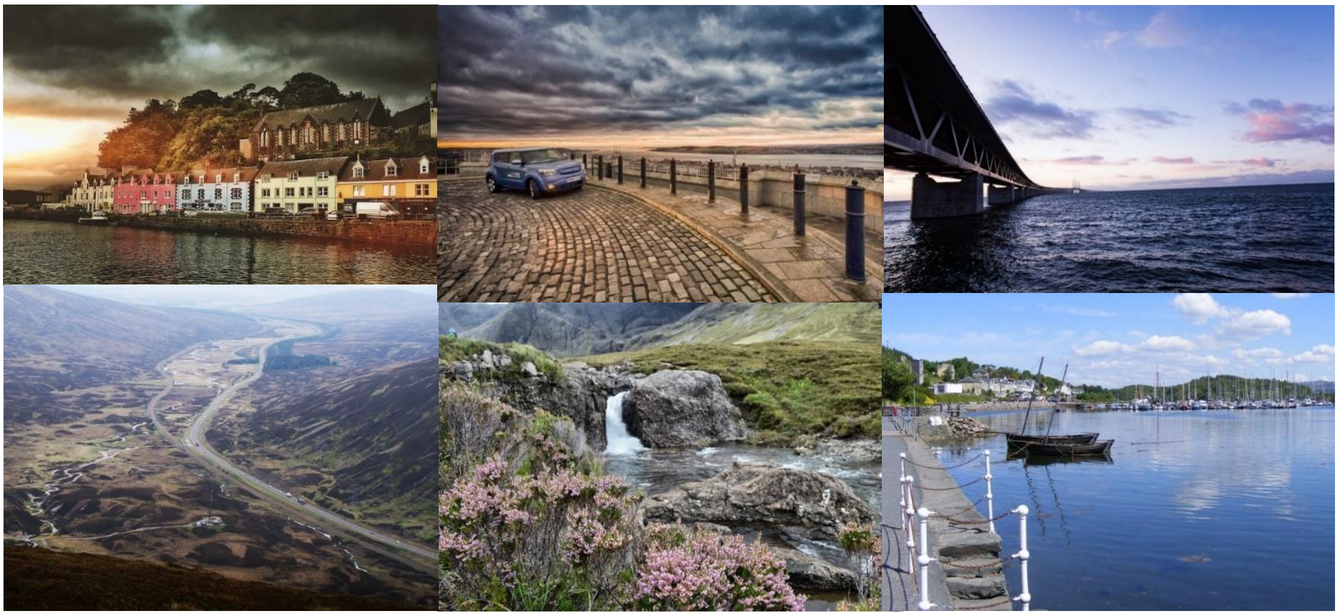
E-tourism: charging demand by electric vehicles in Scottish tourist hotspots

Final report

for

Scottish and Southern Electricity Networks

6th July 2020



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Executive Summary

The E-tourism project is a Network Innovation Allowance project that aims to understand how electric vehicle (EV) charging demand from tourist travel to sites in northern Scotland will increase. The projected impact of tourist EV charging demand on the electricity distribution network has been assessed for eight case studies in northern Scotland for the years 2028 and 2032. Table 1 lists the eight 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 charging demand at each primary substation is typically in 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 summary of the case studies considered in the E tourism project

Number on map	Case study name	Case study type
1	Uig to Tarbert Ferry	Route (ferry)
2	Fairy Pools	Tourist attraction
3	Portree	Settlement (town)
4	Inverness to Skye route (A82, A87)	Route (road)
5	Glasgow to Inverness route (A82)	Route (road)
6	Urquhart Castle	Tourist attraction
7	Perth to Inverness route (A9)	Route (road)
8	Dundee	Settlement (city)

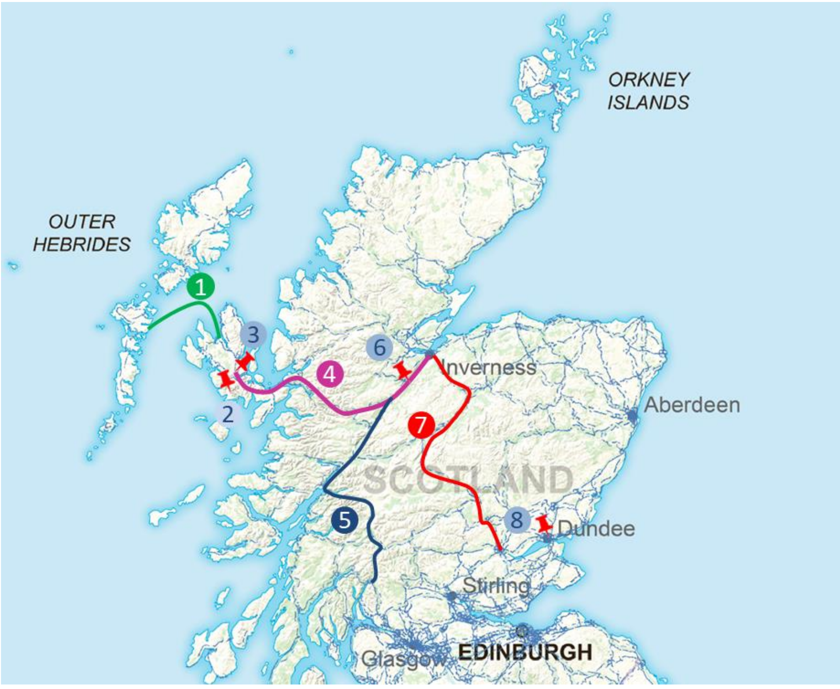

Figure 1: An overview of the 8 case studies being considered in the E-tourism study Contains OS data © Crown copyright and database right 2018

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. For smaller sites that are served by a single secondary substation, these have been included in the analysis. For routes, secondary substations that serve popular stopping points have also been analysed. Table 2 shows the high-level findings of the network analysis at secondary substations, showing the status of the local distribution network in the study years of 2028 and 2032.

Table 2: Summary of findings from network analysis of secondary substations. A key to colour coding is given below

Case study	Secondary substation	Number of days in 2028 in which constraints would be expected	Number of days in 2032 in which constraints would be expected
Uig to Tarbert Ferry	Uig Pier	35	35
	Tarbert Pier	0	0
Fairy Pools	Fairy Pools Car Park	43	191
Portree	-	(analysis conducted at primary station level only)	
Inverness to Skye (A82, A87)	Stoney Lane	0	0
A82 route	Lorn Drive	200	200
	Green Welly Stop	0	0
Urquhart Castle	Urquhart Castle	52	322
A9 route	Dalwhinnie South	169	365
	Grampian Court	56	213
Dundee	-	(analysis conducted at primary station level only)	

Green: no constraints expected

Amber: constraints expected, however capacity breaches are either small or short duration, and may be manageable using flexibility services

Red: constraints expected with large or long duration capacity breaches, which will require network capacity upgrades to mitigate

While the settlements of Portree and Dundee have not been analysed at secondary substation level, the number of local vehicles exceeds the number of tourist vehicles visiting these destinations. Therefore, additional electricity demand will be dominated by domestic EV charging and uptake of other low carbon technologies such as heat pumps. Of the sites where secondary substations have been analysed, Fairy Pools, Urquhart Castle, and the A9 route are expected to show large repeated breaches of capacity, and network reinforcement is likely to be necessary. The first two of these case studies are tourist attractions in remote rural locations, where the electricity distribution network has insufficient spare capacity to accommodate projected tourist EV charging demand. The secondary substations considered on the A9 route are service stations that will be used by both domestic and tourist vehicles, so overall charging demand is expected to be significantly higher than outlined in this study, which only considers charging demand from tourist EVs.

Therefore, network planning that accounts for domestic EV charging demand along the A9 is expected to lead to network capacity upgrades. However, it is important to ensure that tourist EV demand is also accounted for by any upgrade work that is undertaken.

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 eight case studies. For 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 annual site visit statistics and daily traffic counts, as well as assumptions about the share of traffic due to tourists. The average daily distance travelled was calculated from an assumed most likely travel route for tourists travelling to/from the site. Visit numbers are highly seasonal, showing a much larger peak in the summer than winter for most sites.

Table 3: Tourist car visit numbers for the eight case studies being considered

Case study	Daily average tourist cars visiting	Winter peak daily cars visiting	Summer peak daily cars visiting	Average daily distance travelled / km
Uig to Tarbert Ferry	20	15	54	210
Fairy Pools	120	156	264	160
Portree	200	226	440	185
Inverness to Skye (A82, A87)	480	562	975	70
A82 route	1,890	2,187	2,839	82
Urquhart Castle	540	691	1,061	110
A9 route	6,480	8,246	9,268	76
Dundee	9,070[1]	13,057	13,099	100

These visit numbers have been applied to 2028 and 2032 assuming no change from levels before the Covid-19 pandemic. While tourism across northern Scotland has shown an increasing trend over the past years, 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 we had collected.[2]

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, as lockdown rules are eased but international travel remains affected, a fall in international tourism may be expected; however, an increase in domestic tourism may compensate for fewer international visits. By 2028 and 2032, the two key years for this study, 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.

[1] The annual visit statistic used is for Dundee and Angus. While this overestimates tourist cars visiting Dundee, EV drivers are more likely to visit (even if just passing through to charge) due to the provision of EVCPs, so this figure accounts for EV drivers in surrounding areas passing through Dundee.
[2] This assumption was informed by consultation with Visit Scotland

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Front page pictures - credits

From left to right, top to bottom: View of Portree (image from Pixabay); Dundee City as seen from Dundee Law (image from Urban Foresight); Skye bridge (image from Pixabay); Drumochter Pass on the A9 (© Mick Knapton / CC-BY-SA-3.0); Fairy Pools on Skye (image from Pixabay); Harbour at Tarbert (image from Pixabay)

Acronyms

DNO	Distribution network operator
EV	Electric vehicle
EVCP	Electric vehicle charging point
ICE	Internal combustion engine
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 funded by Ofgem that aims to understand how electric vehicle (EV) charging demand from tourist travel to sites in northern Scotland will increase. EVs are a highly disruptive technology and it is important that distribution network operators (DNOs) forecast EV uptake and charging demand as better anticipation of future demand and management of the distribution network allows DNOs to keep costs down for all bill payers. Tourism in northern Scotland is highly seasonal with many tourist attractions situated in remote rural locations where public transport is limited. 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 Scottish and Southern Electricity Networks (SSEN).

This study is the first phase of the E-tourism project and considers additional demand on the distribution network resulting from tourist EV charging. This only represents a fraction of the total expected increase in electricity demand in the coming years, with electrification of domestic transport and heating being the major contributors to this increase. However, the effect of tourist EV charging demand is being considered deliberately in isolation from other causes of increasing electricity demand. This approach has been taken to identify the impact on smaller communities. In these locations, increases in expected electricity demand due to uptake of EVs and electric heating by domestic customers are likely to be small in comparison to increases in demand due to tourist EV charging.

The key objectives of this study are to:

- Understand tourist visitor numbers and travel behaviour in northern Scotland.
- Predict how tourist EV charging demand will change over the study period and where/when it will be highest.
- Distribute projected charging demand among network assets to determine the need for reinforcement or potential for flexible charging solutions or local solutions to manage the network.
- Apply learnings from the sites studied to other sites with similar characteristics.
- Inform investment strategies for network development based on expected impacts of EV uptake and tourist travel patterns.

The key years for this study are 2028 and 2032, with 2032 being the year Scottish government plans to end the sale of new internal combustion engine (ICE) cars and vans.

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 will undoubtedly have significant short-term effects on these and many other related factors, the study is concerned with predicting tourist EV charging demand in 2028 and 2032. At the time of writing very little is understood about what the long-term effects of the pandemic will be, however it is considered unlikely that there will be a large effect on tourist demand or EV uptake in 2028. Therefore, we have deemed that the most justifiable approach is to continue using our projections and assumptions that were made before the pandemic.

1.2 Overview of case studies

Eight locations or routes were selected as case studies to be representative of tourist sites across northern Scotland, leaving aside sites that have been studied before in terms of EV uptake and impact; for example, Mull has not been included as its distribution network is known to be robust, and Orkney has been left out of the study as the impact of EVs has already been researched there.[3]

Figure 2 shows the case studies on a map and Table 4 gives the name and type of each case study, where the type is either a transport route that sees high levels of tourist traffic, a specific attraction, or a town or city that attracts large tourist numbers. The relevant section of the report for each case study is also included in the table.

Table 4: A summary of the case studies considered in the E-tourism project

Number on map	Case study name	Case study type	Relevant report section
1	Uig to Tarbert Ferry	Route (ferry)	3
2	Fairy Pools	Tourist attraction	4
3	Portree	Settlement (town)	5
4	Inverness to Skye route (A82, A87)	Route (road)	6
5	Glasgow to Inverness route (A82)	Route (road)	7
6	Urquhart Castle	Tourist attraction	8
7	Perth to Inverness route (A9)	Route (road)	9
8	Dundee	Settlement (city)	10

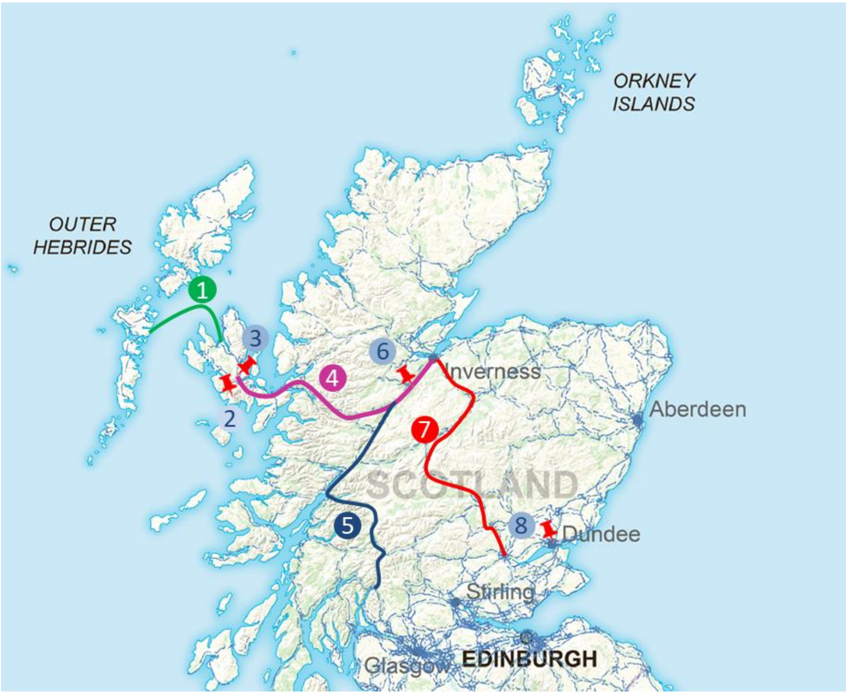

Figure 2: An overview of the 8 case studies being considered in the E-tourism study Contains OS data © Crown copyright and database right 2018

[3] For example, the Orkney Electric Vehicle Strategy 2018 – 2023 can be found here

1.3 About this report

This report aims to describe the analysis of tourist travel behaviour, predicted tourist EV charging demand, and the distribution of this demand across the electricity distribution network. The conclusions of this analysis are presented, for use in identifying where there are opportunities for flexibility services 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 8 case studies sites (Sections 3-10). These sections are structured as follows:

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

Overall conclusions and summary tables are provided in Section 11.

2 Overview of approach

Several stages were required to determine the additional charging demand due to tourism. Firstly, the number of tourist cars visiting sites and how this varied throughout the year had to be considered.[4] Once this was determined, assumptions were made on expected EV uptake and how and where tourists are likely to charge to determine the total electricity demand for tourist EVs at each case study. This charging demand was then distributed across the distribution network to determine where and when constraints would be likely to occur. The contributions of each section of the approach to the study are shown in Figure 3.

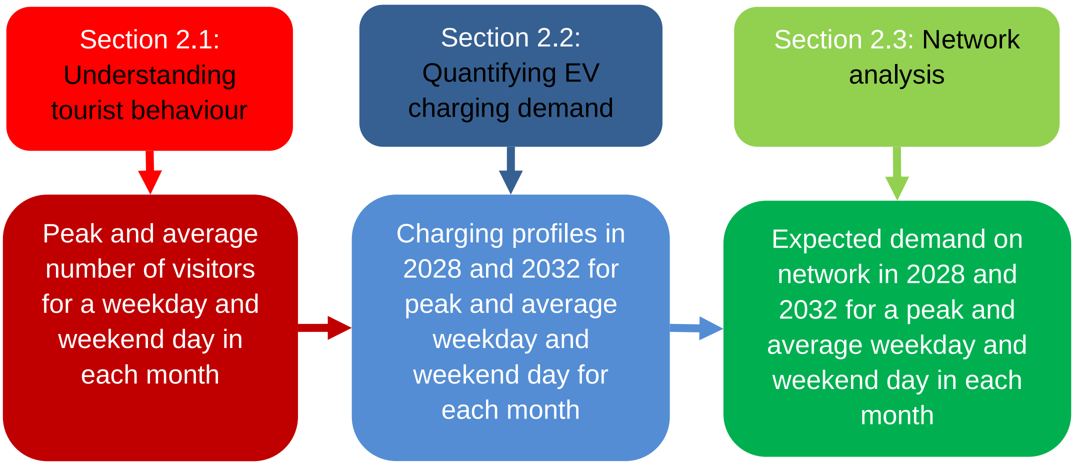

Figure 3: A schematic diagram demonstrating the approach taken in assessing network impact of tourist EV charging demand

2.1 Understanding tourist behaviour

Quantifying number of tourist cars annually

Two different approaches were used for determining the number of tourist cars at each case study. For tourist attractions and settlements, this was based on annual tourist visit statistics to the site. Assumptions were then made about the number of tourists that travelled to the site by car and the average number of tourists in a car, which allowed the number of tourist cars visiting a site annually to be estimated from the tourist visit statistics.

As no data for the number of tourist cars using routes were available, a different approach had to be taken to estimate the number of tourist cars using each of the routes considered in this study. This was done by analysis of Urquhart Castle, where a reliable figure for tourist annual visits was available and a nearby traffic count point on the A82 was the only major road that could be used to access the castle. By comparing traffic data to visitor numbers, it was determined that at least 17% of the car traffic on the route was due to tourists.[5] Based on this analysis, it was assumed that 17% of car traffic on all of the studied routes was due to tourists. While it is a large assumption that tourists will make up the same share of traffic on all routes, this was the most viable approach to determining tourist traffic on routes due

[4] This study is considering EV cars only and excluding EV vans as less tourists travel by van (49% use their own car while 3% use a campervan according to Scotland Visitor Survey 2015-2016), and the uptake of EV vans is expected to be significantly lower in 2032 (28% in our ECCo 'High' scenario, compared to 45% for cars). Tourist EV van charging demand will therefore be significantly smaller than EV car charging demand.

[5] Traffic flow data were obtained from Traffic Scotland's NTDS (https://ntds.trafficscotland.org/) between 2017 and 2018 for count point JTC00145 on the A82 between Invermoriston and Drumnadrochit (this is the closest count point to Urquhart Castle). This analysis assumed that 80% of tourists came to the castle by car and there were 2 people in each car).

to the lack of good quality data on tourist travel patterns. For each of the routes, these assumptions were applied to the count point measuring the highest number of vehicles in order to determine maximum tourist demand on the route.

Figure 4 shows that employment for sustainable tourism in Highland Local Authority has broadly increased from 2008 to 2017. However, tourism demand is affected by many social and economic factors, making it very difficult to predict how demand will change in the long term. This study has assumed that tourist demand and car trips stay constant at present day levels; as tourist demand tends to fluctuate between years, it was agreed that the most reasonable assumption to make is that there will be little to no change in visitor numbers over the study period.[6] Current uncertainties around changes in tourism demand due to the Covid-19 pandemic have not been discussed as this study is considering demand in 2028 and 2032 only, by which time any effects due to the pandemic should have passed. Once lockdown measures are lifted, international travel restrictions may lead to a short-term decrease in international visits. However, this may be compensated for by an increase in domestic tourism. As this is only expected to be a short-term effect, it is outside the scope of the study.

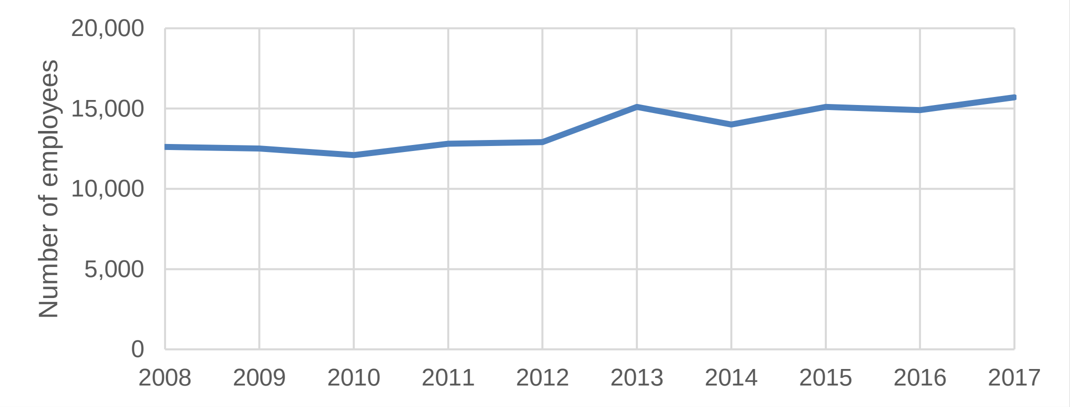

Figure 4: Sustainable tourism employment in Highland Local Authority from 2008 to 2017[7]

Determining tourist visit variation throughout the year

Once annual tourist car visits had been quantified, their variation throughout the year had to be understood, as tourist visit behaviour is highly seasonal, showing a peak in the summer months, and on weekends. As no good quantitative data on how tourist demand varied by month or weekday was available, further assumptions had to be made. The annual car visit numbers were divided by 365 to give the number of average cars per day. This was then multiplied by a factor accounting for monthly variation and a factor accounting for weekday variation in tourist trips in order to determine the number of car visits for an average weekday, peak weekday, average weekend day, and peak weekend day, for each month of the year.

Monthly visit variation was determined by considering how traffic on routes varied, as traffic counts are available by daily resolution. For sites, the closest available count point on a major road was used, while the same count point used to determine annual tourist car trips was used for each of the routes. Figure 5 shows an example of how this factor varies throughout the year for Urquhart Castle.

[6] This assumption was informed by consultation with Visit Scotland
[7] Scottish Annual Business Statistics 2017

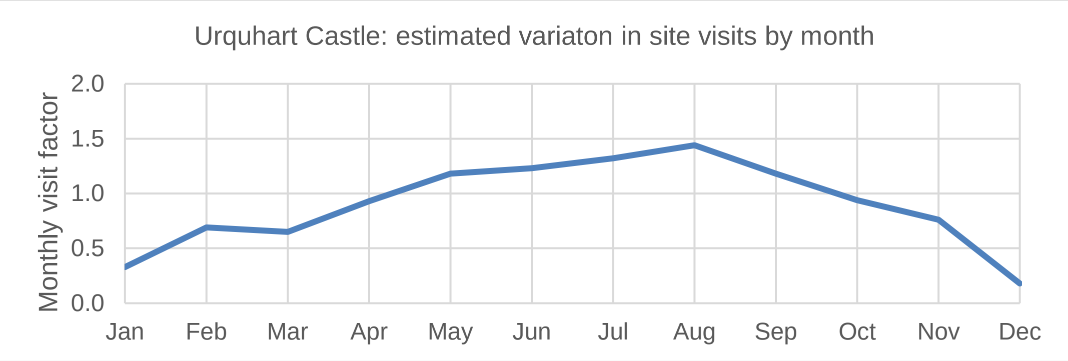

Figure 5: Monthly visit factors for tourist demand at Urquhart Castle[8]

Daily visit variation was determined by using Google Maps, which gives comparative data on how busy sites are throughout the week. Figure 6 shows two of the charts used to perform this analysis. By comparing the total areas of the bars for each weekday, daily visit factors can be determined. Due to data availability, this analysis was performed for Urquhart Castle and the same variation was assumed for other sites. While data was available for routes at daily resolution, traffic is dominated by non-tourist cars, and traffic is higher on weekdays than weekends, which is not representative of tourist behaviour. Figure 7 shows the daily visit factors determined.

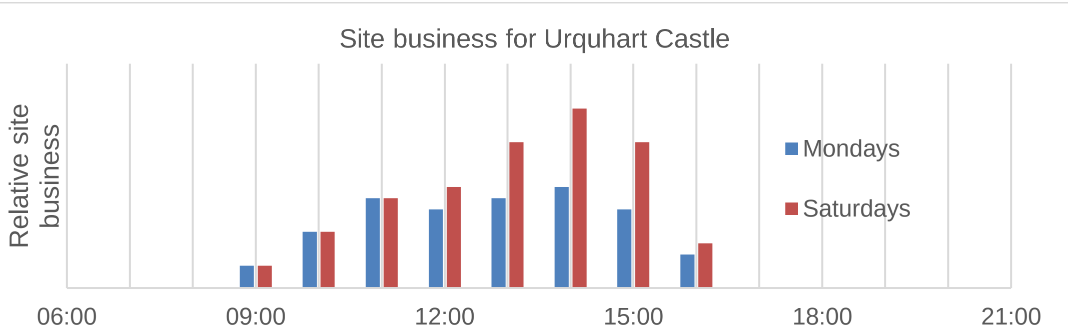

Figure 6: Relative tourist demand at Urquhart Castle on Mondays and Saturdays. Source: Google Maps

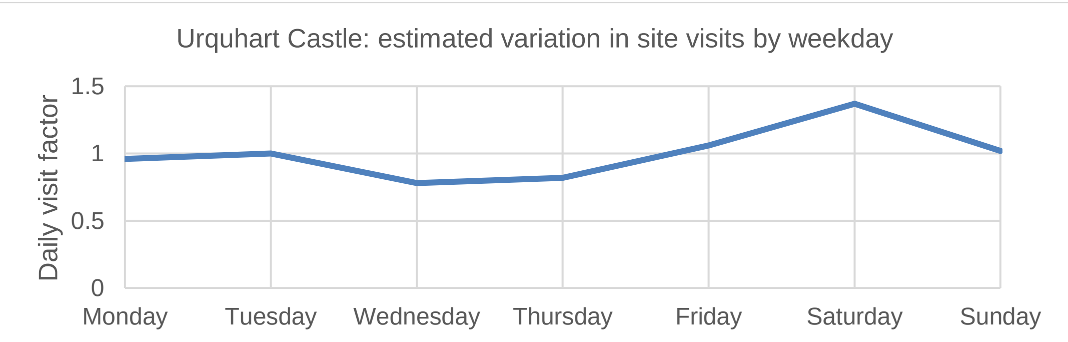

Figure 7: Daily visit factors determined by analysis of Google Maps data for Urquhart Castle

[8] Traffic flow data were obtained from Traffic Scotland's NTDS (https://ntds.trafficscotland.org/) between 2017 and 2018 for count point JTC00145 on the A82 between Invermoriston and Drumnadrochit (this is the closest count point to Urquhart Castle). The monthly visit factors shown are calculated as the ratio of average daily flows by month to the annual average daily flow

Understanding tourist travel behaviour

Research into tourist travel patterns was undertaken to determine how far tourists travel during the day and the charging energy required to provide sufficient energy for tourists to travel this daily distance. For tourist attractions and settlements, a 'most likely' tourist route was assumed based on sites that tourists are likely to be travelling from, where they are likely to visit and where they are likely to be staying overnight.

The situation is more complicated for routes as not all tourists will travel along the entire route and may use alternative routes – for example, it is unlikely that tourists would drive entirely along the A82 from Glasgow to Inverness as faster routes are available. For each route, four traffic points were considered which were approximately evenly spaced along the route. The difference between annual average daily traffic counts from one point to the next was used to estimate the number of vehicles travelling along each stretch of the route. These were used to determine the average distance travelled by a car along the route, which was taken to be the daily distance travelled by a tourist car along the route.

2.2 Quantifying EV charging demand

Once tourist visit patterns had been quantified, EV uptake scenarios and charging behaviour were considered to convert car visit estimates into charging demand projections.

EV uptake scenarios

Two EV uptake scenarios have been used in this study – one for Scottish cars and one for cars from the rest of GB.[9,10] It was assumed that 37% of tourists using cars in each study year were from Scotland, 40% were form the rest of GB, 11% were from the rest of Europe, and 11% were from the rest of the world.[11] It was assumed that tourists coming from outside the UK hired cars in Scotland, making 60% of the vehicles used from Scotland.[12] Therefore, an overall EV uptake scenario was derived as a 60:40 split of the Scottish and rest of GB uptake scenarios. EV uptake projections in 2028 and 2032 can be seen for the Scottish, rest of GB, and overall uptake scenarios, in Figure 8.

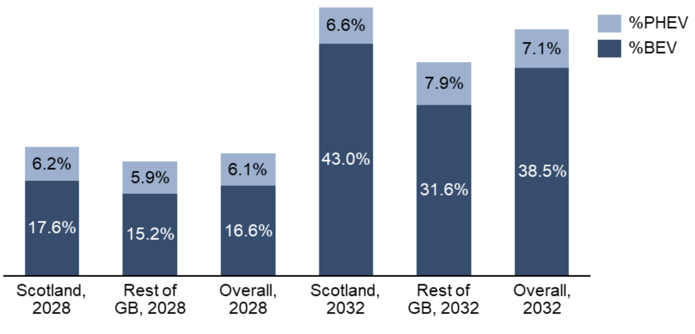

Figure 8: Projected EV stock for the Scottish, rest of GB, and overall EV uptake scenarios, for the two key years in the study

[9] The Scottish EV uptake scenario is from an analysis by Element Energy for Transport Scotland
[10] The rest of GB EV uptake scenario is the 'High' scenario from the Element Energy Consumer Choice Model (ECCo). More information on ECCo can be found at http://www.element-energy.co.uk/sectors/low-carbon-transport/project-case-studies/#project_1
[11] Based on analysis of VisitScotland Visitor Survey, 2015 & 2016. Percentages do not sum to 100% due to rounding
[12] This assumption is made purely to determine EV uptake – as the Scottish EV uptake scenario predicts more EVs than the UK, this assumption gives an upper bound on expected EV uptake.

Charging behaviour assumptions

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. EVCPs have been assumed to have a power of either 7 kW or 50 kW. In some cases, a higher share of tourists using EVCPs or a longer charging time has been assumed on peak days, to represent the maximum expected charging demand. 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.

EV charging demand profiles

Several charging archetypes have been produced, each with its own representative demand profile:

- Tourist attractions: all charging is assumed to be performed during site opening hours at public charge points,
- Settlements: a mix of public and overnight charging is assumed,
- Routes: charging demand is based on a profile generated from current charging demand.

The hourly demand profiles for these charging archetypes are normalised to a total energy demand of 1 kWh / day. When multiplied by the total daily EV charging demand in kWh at a particular site, they represent how charging demand is expected to vary throughout the day at that site.[13]

2.3 Network analysis

Once the charging demand profiles for the eight case studies had been calculated, this demand was distributed across network assets (which include points where electricity is converted to a lower voltage for distribution to consumers, known as substations, and the cables that connect these points, known as feeders). Two types of substation are considered in this report; primary substations, which typically convert 33 kV electricity to 11 kV for local distribution via high voltage (HV) feeders, and secondary substations, which convert 11 kV electricity from HV feeders to 400 or 240 V for supplying households and small businesses by low voltage (LV) feeders.

As mentioned in Section 1.1, this study is only considering additional electricity demand due to tourist EV charging. This approach has been used deliberately to determine areas where tourist EV demand specifically is likely to lead to constraints on the network. This is likely to occur in sparsely populated areas, which have tourist attractions and where public transport is limited. As current electricity demand will be low, the network may not have sufficient capacity to accommodate tourist EV charging.

The purpose of this analysis is to determine if demand can be met by use of flexibility services and if not, where and when network upgrades will be required; in order to determine this, an understanding of where network constraints (the physical limits of the existing distribution network) are expected to be breached, how often these breaches may occur and how long they are expected to last on a given day, is required. The relevant primary and

[13] 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.

secondary substations were first selected, and the distribution of EV charging demand among these assets was then performed, to determine whether, and if so, where and when constraints were expected to be reached on the network.

Selection of relevant primary and secondary substations

Three sites are served by a single primary substation: Fairy Pools, Portree, and Urquhart Castle. Fairy Pools and Urquhart Castle are also served by a single secondary substation, so their secondary substations were included in the analysis. The Uig and Tarbert ferry terminals are also each served by a single primary and secondary substation, so these network assets were included.

The routes and Dundee are all served by multiple primary substations. Splitting demand across all these primary substations and analysing network data for each of them would provide limited additional insight, so key sites were selected for analysis. Along the routes, primary substations that serve popular stopping points and service stations were selected. Secondary substations that serve popular service stations were also selected, to analyse the impact of installing EVCPs at these sites. In Dundee, primary substations that serve existing charging hubs and Dundee Airport were selected.

Addition of EV charging demand

Half hourly demand data from April 2018 to March 2019 was obtained for each of the primary substations and used to produce weekday average, weekday peak, weekend day average, and weekend day peak demand profiles.[14] For secondary substations, a peak day profile was produced rather than separate weekday and weekend day peak profiles. This was done as the only data available was a single estimate of the maximum demand observed at the substation in the past year. Furthermore, it was deemed to be likely that demand would peak on the weekend for secondary substations at tourist sites when tourist visits are highest, whereas demand at primary substation level generally peaks on a weekday. Profiles were produced for secondary substations by assuming the network demand profile had the same shape as the relevant primary substation profile, but primary substation demand was scaled down by multiplying by the maximum demand indicator of the secondary substation and dividing by the maximum demand at the primary substation.

For case studies served by multiple primary substations, charging demand was distributed among primary substations based on the current provision of EVCPs and future EV uptake to account for the installation of additional EVCPs. Where charging demand was distributed to secondary substations, it was assumed that the entirety of the charging demand on the relevant primary substation was caused by EVCPs connected to the secondary substation being considered, so the charging demand on the secondary substation and its connected primary substation were the same.

Summary data tables

For each case study where the network has been analysed at secondary substation level, a table giving key projections has been produced. The table includes the following information:

- Rated capacity: the maximum power the secondary substation is capable of continuously supplying. While it is possible for assets to go over their rated capacity for short periods of time, exceeding rated capacity for an extended period of time means there are constraints on the network that may require mitigation.

[14] 'Peak' refers to the busiest day in terms of tourist daily visits by month

- Peak demand (for today, 2028, and 2032): the maximum power expected to be supplied by the secondary substation. If this is significantly above rated capacity, it is possible that network capacity upgrades will be required.
- Number of days when constraints are expected (for 2028 and 2032): as well as showing the number of days when constraints are expected the shading of the cell represents the expected network status in the given year:
  - Green: no constraints are expected.
  - Amber: constraints are expected, however capacity breaches are either small or short duration, and may be manageable using flexibility services.
  - Red: constraints expected with large or long duration capacity breaches, which will require network capacity upgrades to mitigate.

The number of days when constraint is expected has been estimated using the following formula:

$$Days\ of\ constraint = 365 \times \left(\underbrace{\frac{1}{7} \times \frac{n_{peak}}{12}}_{\text{Peak day term}} + \underbrace{\frac{5}{7} \times \frac{n_{average\ weekday}}{12}}_{\text{Average weekday term}} + \underbrace{\frac{1}{7} \times \frac{n_{average\ weekend}}{12}}_{\text{Average weekend term}} \right)$$

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

- Peak days: every Saturday is assumed to be a peak day, meaning that one day in seven in each month on average is a peak day. The factor of $\frac{1}{7}$ is multiplied by $\frac{n_{peak}}{12}$, the share of months where the peak day profile exceeds rated capacity.
- Average weekdays: this is assumed to cover every weekday, which accounts for five days in seven for each month on average. The factor of $\frac{5}{7}$ 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.

A further table which summarises just the network status and number of days when constraint is expected for all case studies is provided in the Executive Summary and Conclusions sections of the report.

The following sections of the report present the results of the analysis performed for each of the eight case studies. The structure of these sections follows the approach that has been outlined in this section: tourist visit trends and behaviour are presented first, followed by charging demand forecasts. Key findings from the network analysis and the scale of expected constraints are presented at the end of each section.

3 Ferry Route from Uig to Outer Hebrides

3.1 Tourist Destination Overview

3.1.1 Context

The Scottish Western Isles of the Outer Hebrides are a diverse chain of inter-connected islands which offer visitors a rich history conveyed in a selection of museums and monuments, stunning natural landscapes, and a glimpse of the islands' own unique way of life. The ferry service running from Uig on the Isle of Skye to Tarbert on the Isle of Harris is one of the main ferry services connecting the Outer Hebrides to mainland Scotland.

Figure 9: Harbour at Tarbert (image from Pixabay)

The service is operated by Caledonian MacBrayne and the crossing takes approximately 1 hour 40 minutes, running 7 days a week. There is usually one crossing a day in each direction, but in times of high demand there can be two crossings a day in each direction. The ferry accommodates up to 612 passengers and 98 cars.

The Uig Port is located in north west Skye, the closest village is Uig with a population of 200 and is approximately 2.5 km from the port. Portree, the main town on Skye with a population of 2,400 is 25 km from Uig. The Tarbert Port is located on the southern part of the Isle of Harris.

Many of the Scottish islands can only be accessed by ferry. Therefore, this case study has been selected as it is illustrative of the impact of increased electric vehicle demand at ferry ports.

Figure 10: Uig to Tarbert Ferry crossing location (© OpenStreetMap contributors)

3.1.2 Visiting the destination

Users of the Uig-Tarbert Ferry service will usually be travelling by car and in many cases, taking their vehicle across on the ferry with them.

Many of the tourists who do bring cars are likely to have driven from Inverness. However, car hire is available on the Outer Hebrides and Skye, with both locations also popular with cyclists. Due to the ferry timings and the number of attractions on both islands, it is likely that most visitors stay overnight on the islands once they have arrived. Visiting the Outer Hebrides by way of this route is commonplace in the summer months. Visitors will often arrive in Tarbert then explore the Outer Hebrides before returning to the mainland.[15] The ferry terminal is within walking distance of the village, shops, cafe, hotel, post office, bank, Tourist Information and bus stop.

The ferry service runs all year/every day of the week except in times of extreme weather. Visitor numbers are significantly higher in the peak season between April and September. Shipped and landed car data for the ferry route from 2016 – 2019 has been used to estimate peak daily car visits.[16]

[15] From Outer Hebrides Visitor Survey 2017, available here, most tourists travel to the Outer Hebrides by the Uig-Tarbert of Uig-Lochmaddy ferry service.
[16] Data obtained by request to Transport Scotland. The share of tourist cars using the route has been assumed to be 17%, based on analysis on Urquhart Castle, where reliable data on both tourist and non-tourist travel was available. The ferry car carrying data is available at a day-by-day resolution. This was used to determine how tourist visits varied by weekday and by weekday.

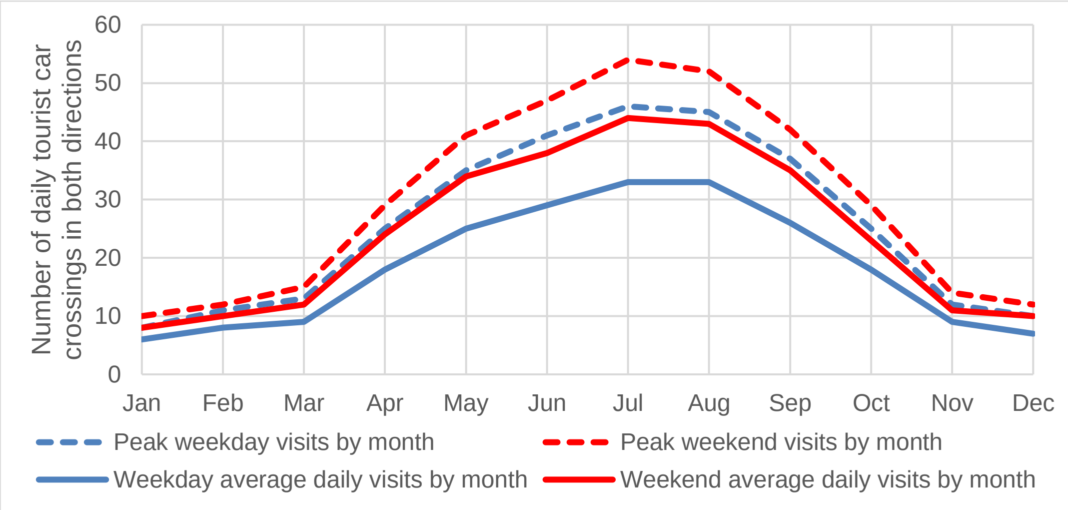

Figure 11: Tourist daily car visits between Uig and Tarbert ferry terminals

The key visitor statistics for the Uig to Tarbert Ferry are summarised in Table 5.

Table 5: Key visitor assumptions and statistics for the Uig to Tarbert Ferry

Estimated number of tourist cars visiting per year (assuming 17% of traffic on the ferry is due to tourists)	8,000
Average daily tourist car visits (assuming that the service operates 365 days a year)	22
Peak daily tourist car visits (derived from analysis of ferry car carrying data)[17]	54

3.2 Charging demand

At present, free parking is available at Uig ferry terminal with approximately 50 spaces available. At Tarbert car park there are approximately 50 spaces and a rapid EV charging point has been installed for short-term charging.[18] More than 20 EV charging points are available across the Outer Hebrides which are available for short-term and overnight charging.

The following assumptions have been used in estimating demand for charging in 2032:

- The number of visitors and profile of visiting times will remain constant from figures estimated for today.
- The proportion and profile of visitors travelling by private car (including rentals and car club vehicles) will remain constant.
- The share of tourist cars that are EVs in 2032 will be 46%.
- Visitors are likely to be based in Skye or Inverness and drive around the isles with an average daily driving distance of 210 km – this is not expected to change in the worst-case scenario.
- Energy expended has been estimated assuming 0.2 kWh / km, so the average energy use per tourist EV is 42 kWh.

[17] See Section 2.1 for more information on how this figure was determined
[18] https://www.calmac.co.uk/ports/tarbert-harris

- All tourist cars arriving at either port travel on the ferry i.e. no tourist vehicles are left in the car park while drivers/passengers take the ferry.
- Time spent charging has been capped at one hour as it is assumed that tourists will not want to stop long at ferry terminals.
- Expect 30% of tourists driving EVs to want to charge on an average day. This may increase slightly on busier days due to other charging points being busier. However, a large change is not expected as most tourists will probably board the ferry as soon as they can.

Table 6: Charging assumptions for infrastructure deployed at both Uig and Tarbert Ferry Terminals for the average day and the worst-case scenario.

	Average day	Worst-case scenario
Time spent charging at site (hours)	1.0	1.0
Share of EVs using on-site charging per day	30%	40%
Share of EVs using overnight charging per day	0%	0%
Share of EVs not charging at site	70%	60%

When charging demand is modelled based on tourist visit numbers assuming a fully diversified charging profile, the charging rate at both the ferry terminal sites is very low (often below 7 kW, the lowest power EVCP likely to be installed), due to the low numbers of tourist EVs using the ferry.[19] In reality, minimum demand would be at least the power of one EVCP being used, so using a fully diversified profile is unrealistic for this case study. Three separate non-diversified charging profiles have been assumed; a constant demand of 7 kW, constant demand of 14 kW, and constant demand of 50 kW to assess the impact of installing a single 7 kW, two 7 kW, and a single 50 kW charger respectively. While these profiles would only result from the installed EVCP always being in use, which is unrealistic, they give a better indication of the network impact of installing an EVCP. If the charging profiles generated from tourist travel behaviour were used for network planning, they would underestimate the possible maximum demand on the network and could lead to underinvestment in flexibility planning or network reinforcement.

3.3 Network impact findings

As a maximum charging demand of 50 kW is being considered at each site, the impact on the total primary substation load is negligible. As maximum demand on the Uig secondary substation is currently 182 kW, 93% of the rated capacity of 196 kW, installation of a 50 kW charger may lead to capacity issues at the secondary substation on a peak day, as shown in Figure 12. However, such issues are not expected if two 7 kW chargers or a 7 kW charger are installed – the case for two 7 kW chargers is shown in Figure 13.

Tarbert's secondary substation has a lower maximum demand of 119 kW and a higher rated capacity of 309 kW, so this capacity is not expected to be exceeded, even on a peak day, if a 50 kW charger is installed.

[19] 'Diversity' refers to the idea that as more EVCPs are used, the charging profile will have a smoother, more continuous shape, rather than showing discrete jumps as drivers plug into and unplug from EVCPs. Fully diversified profiles assume that there are sufficient EVCPs installed to produce a smooth profile, however this is not a valid assumption when only one or two EVCPs are being considered, as is the case for the ferry terminals.

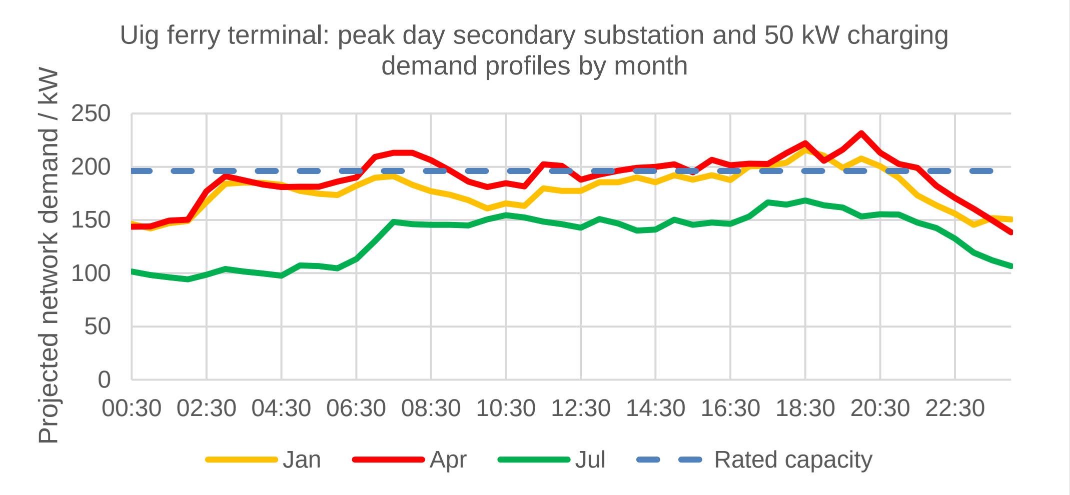

Figure 12: Peak day secondary substation demand at Uig ferry terminal for installation of a 50 kW charger

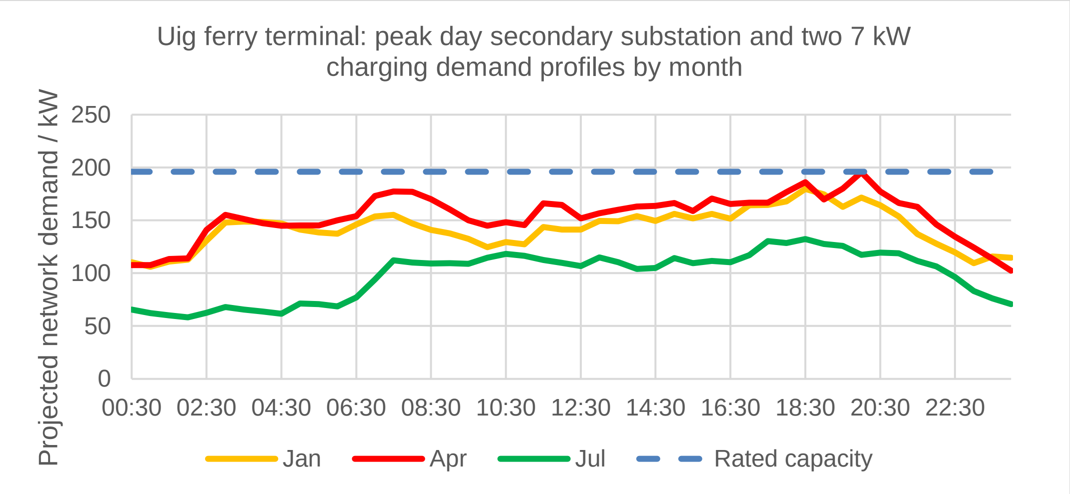

Figure 13: Peak day secondary substation demand at Uig ferry terminal for installation of two 7 kW chargers

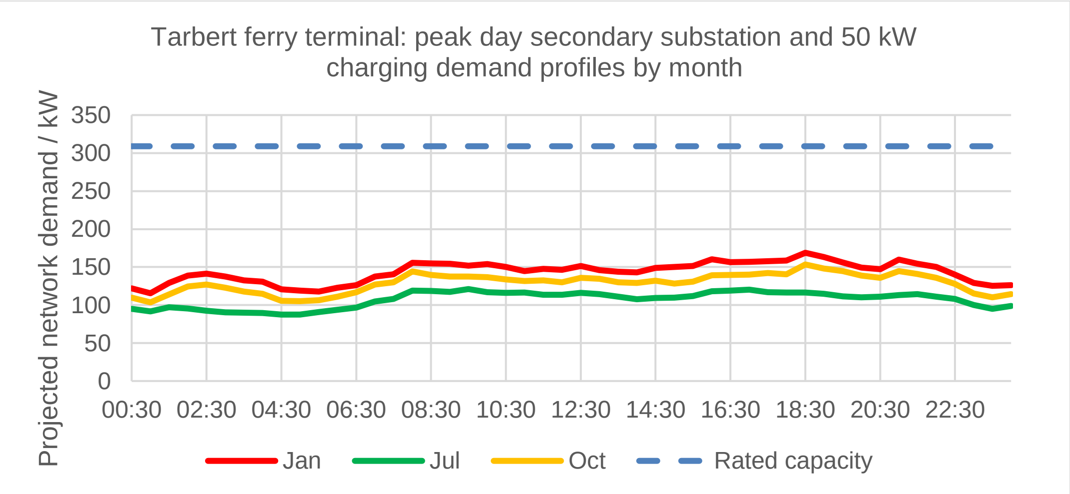

Figure 14: Peak day secondary substation demand at Tarbert ferry terminal for installation of a 50 kW charger

Summary of findings

Table 7 shows key results from the network impact analysis performed for the Uig Pier and Tarbert Pier secondary substations. No constraints are expected on the Tarbert Pier secondary substation, and constraints are only expected at Uig Pier if a 50 kW charger is installed. Even in this case, constraints are expected to only occur for 35 days in the year, and the rated capacity is never exceeded by more than 40 kW, so constraints should be manageable using flexibility services.

Table 7: Summary of results from the network analysis for secondary substations that serve the Uig and Tarbert ferry terminals.[20]

Secondary substation	Uig Pier	Tarbert Pier
Rated capacity (kW)	196	309
Current peak demand (kW)	182	119
2028 peak demand (kW)	232	169
2032 peak demand (kW)	232	169
Days of constraint expected in 2028	35	0
Days of constraint expected in 2032	35	0

Green: no constraints expected

Amber: constraints expected, however capacity breaches are either small or short duration, and may be manageable using flexibility services

Red: constraints expected with large or long duration capacity breaches, which will require network capacity upgrades to mitigate

[20] Note that figures given for 2028 and 2032 are assuming that a 50 kW charger has been installed and is operating continuously, as discussed above

4 Fairy Pools on Skye

4.1 Tourist Destination Overview

4.1.1 Context

The Fairy Pools on Skye are a popular nature-based tourist attraction with thousands of visitors from around the globe every year. The Fairy Pools are located on the south west of the island, approximately 32 km from Portree, and are accessed by a single-track road with passing places. The Glen Brittle car park where visitors park to access the Fairy Pools has approximately 100 spaces, and this does not service any other destinations or amenities.[21] The popularity and remote location of the Fairy Pools is a common feature of Scottish tourist attractions.

Figure 15: Fairy Pools on Skye (image from [Pixabay](#))

Figure 16: Fairy Pools location on Skye (Map data © 2020 Google)

[21] https://forestryandland.gov.scot/what-we-do/communities/community-asset-transfer-scheme/previous-asset-transfer-requests/fairy-pools

4.1.2 Visiting the destination

Visitors to the Fairy Pools usually travel via car, camper van, or coach. The destination is not served by any major roads, and public transport is not an option. There is limited parking on site (approx. 100 spaces), with a £5 charge for the day, run by a local Community Organisation. Visitors to the Fairy Pools typically spend 2-3 hours there.[22]

The Fairy Pools are open anytime to visitors throughout the year, but visitor numbers are significantly higher in the peak season between April and September with the highest visitor numbers in July and August. Traffic flow data and visit data from Google Maps has been used to estimate peak daily tourist car visits. The data suggests higher numbers of tourists travelling to the area in the peak season, with the weekend peak representing 10% more visitors than the weekday peak (see Figure 17 below).[23]

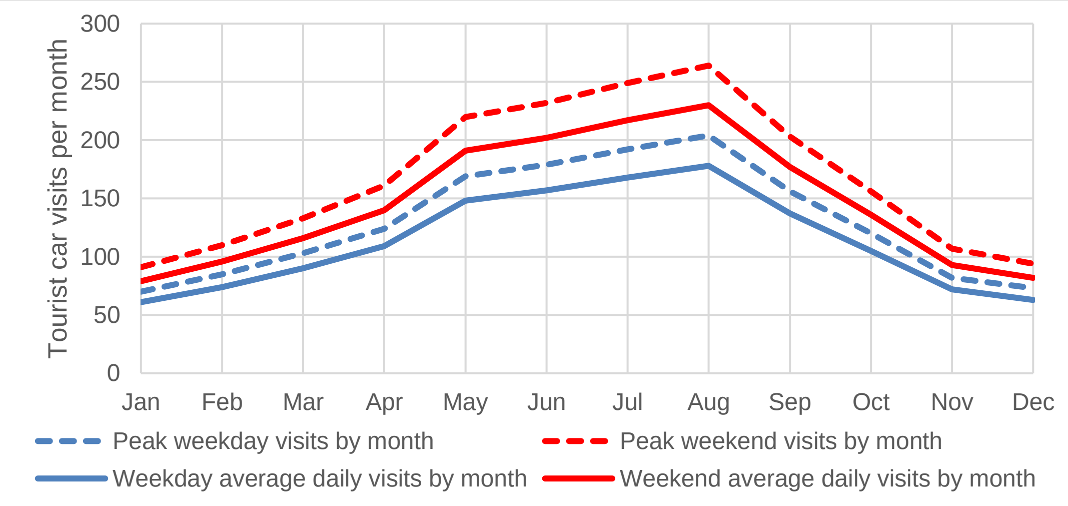

Figure 17: Tourist daily car visits to the Fairy Pools

The key visitor statistics for the Fairy Pools are summarised in Table 8 below.

Table 8: Key visitor assumptions and statistics for the Fairy Pools

Estimated number of tourists visiting per year[24]	87,000
Estimated number of tourist cars visiting per year (assuming 100% of visitors travel by car and an average of 2 people per car)	43,500
Average daily tourist car visits (assuming that site is open 365 days a year)	120
Peak daily tourist car visits (derived from the traffic flow variations)	260

[22] Sourced from TripAdvisor: https://www.tripadvisor.co.uk/Attraction_Review-g186585-d2335113-Reviews-Fairy_Pools-Isle_of_Skye_The_Hebrides_Scotland.html

[23] Traffic flow data were obtained from Traffic Scotland's NTDS (https://ntds.trafficscotland.org/) between 2015 and 2017 for count point ATC01127 on the A87 outside of Portree (selected as the most suitable point as Fairy Pools is served by narrow single-track roads, and Portree is also a popular tourist destination on Skye therefore assumed to show similar visit behaviour). The ratio of monthly visits to the annual average from traffic data was used to determine how tourist demand varied by month. Data from Google Maps was used to determine how tourist demand varied by weekday.

[24] As limited data was available on visits to the Fairy Pools, it has been assumed that 50% of visitors to Portree visit the Fairy Pools.

4.2 Charging demand

There are currently no charge points located at the Fairy Pools and the nearest charging facilities are in Portree, 32km away.

The following assumptions have been used in estimating demand for charging in 2032:

- The number of visitors and profile of visiting times will remain constant.
- The proportion and profile of visitors travelling by private car (including rentals and car club vehicles) will remain constant.
- The share of tourist cars that are EVs in 2032 will be 46%.
- Visitors are likely to be based in Portree and do a round-trip of Skye, with an average daily driving distance of 160 km – this is not expected to change in the worst-case scenario.
- Energy expended has been estimated assuming 0.2 kWh / km, so the average energy use per tourist EV is 32 kWh.
- With there being no overnight accommodation provision at the site, it is assumed that in the future, demand for charging will be during the day (see Table 9).
- With charge points in Portree, on an average day it is assumed that few EVs will need to charge at the Fairy Pools (see Table 9).

Table 9: Charging assumptions for Fairy Pools

	Average day	Worst-case scenario
Time spent charging at site (hours)	2.5	3.0
Share of EVs using on-site charging per day	20%	50%
Share of EVs using overnight charging per day	0%	0%
Share of EVs not charging at site	80%	50%

Modelling based on these assumptions and the available data suggests the 2032 demand profiles illustrated in Figure 18. The peak day profiles are based on the worst-case scenario assumptions being applied in the selected months. The seasonal effect on visitor numbers illustrates how demand in the peak August weekend is almost five times the demand on an average August weekday (see Figure 18).

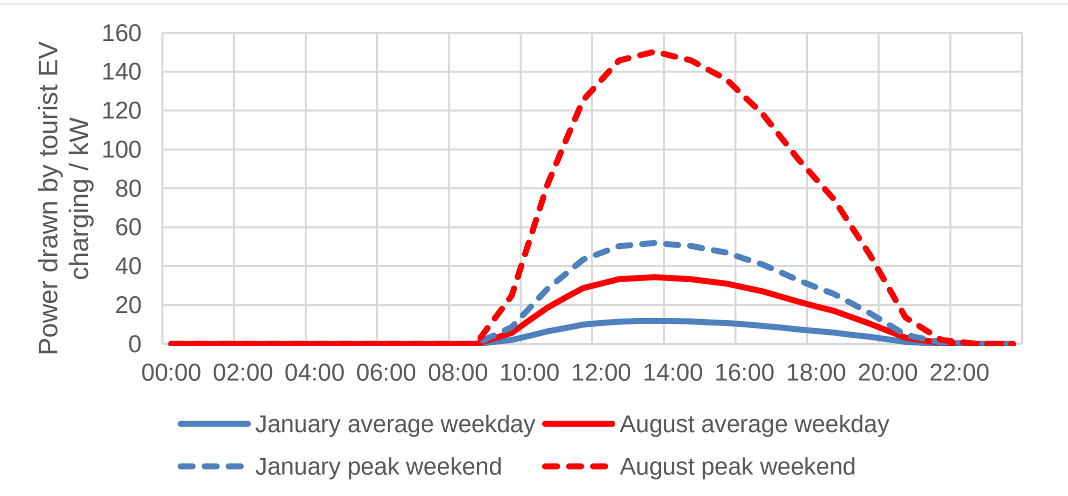

Figure 18: Charging demand profiles for Fairy Pools in 2032

This modelling suggests the highest hourly demand will reach 150 kW drawn from 21 vehicles charging simultaneously (assuming all are charging at a rate of 7 kW).

4.3 Network impact findings

The secondary substation currently installed at Fairy Pools has a very low rated capacity of 24.5 kW. While the existing demand on the secondary substation is negligible (maximum demand indicator is 0 kW), the substation would only be able to support three 7 kW chargers operating simultaneously without breaching its rated capacity. The rated capacity is breached for the modelled peak day in every month in 2028 (see Figure 19); however, charging demand on the average weekend day in 2028 is not expected to exceed rated capacity (see Figure 20). In 2032 the modelled demand for EV charging is expected to exceed the current secondary substation rated capacity for almost the entirety of the site opening time for the peak day on each month (see Figure 21).

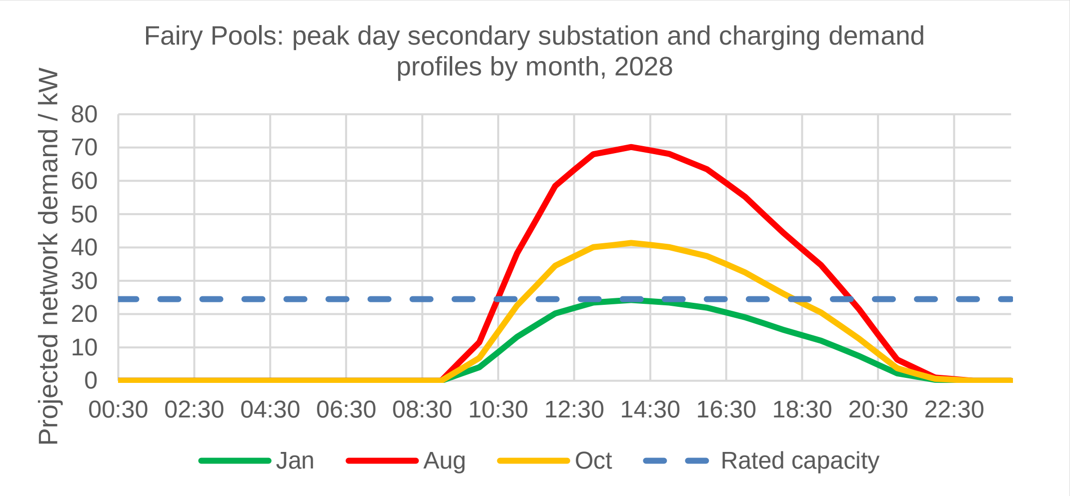

Figure 19: Projected demand on the secondary substation at the Fairy Pools for a peak day in 2028 by month

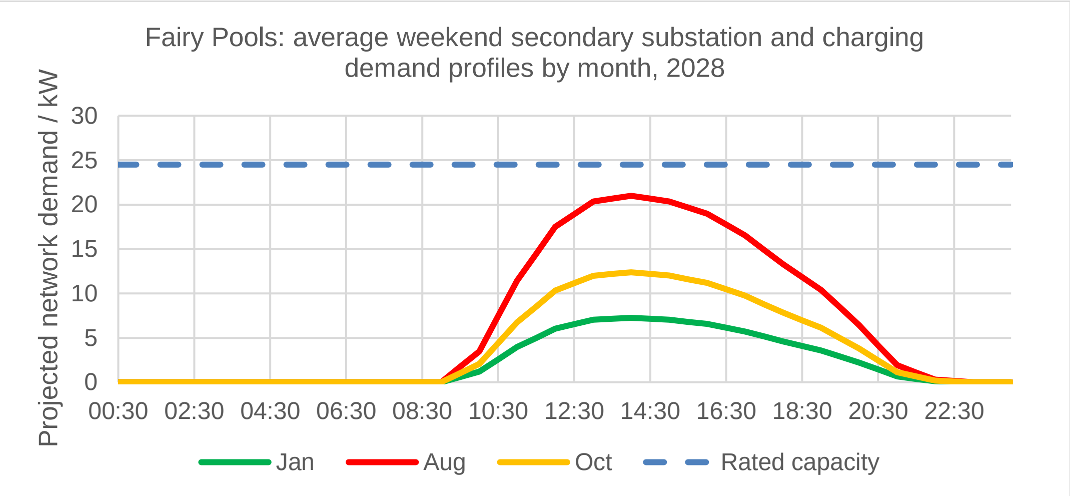

Figure 20: Projected demand on the secondary substation at the Fairy Pools for an average weekend day in 2028 by month

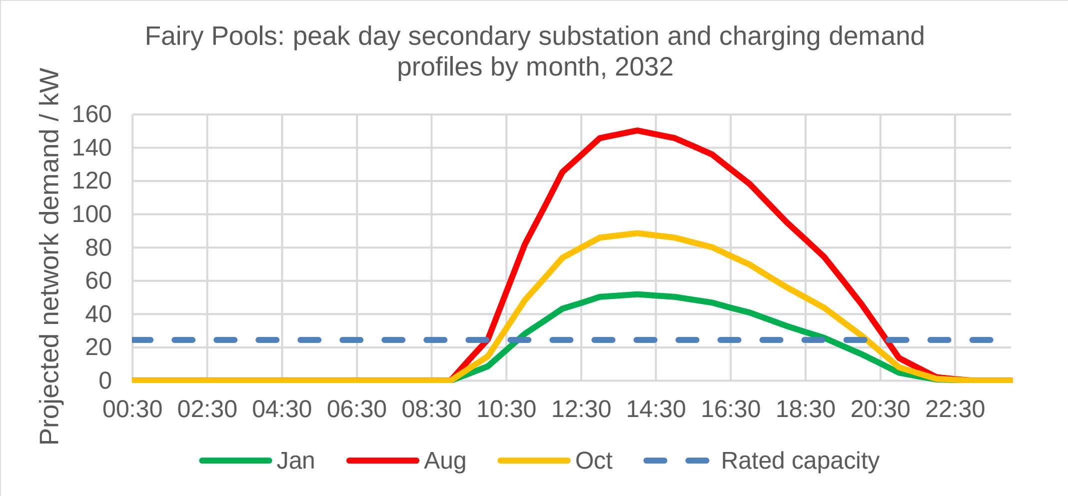

Figure 21: Projected demand on the secondary substation at the Fairy Pools for a peak day in 2032 by month

Summary of findings

Table 10 shows key results from the network impact analysis performed for the Fairy Pools Car Park secondary substation. Constraints are expected on some days in 2028, which may be manageable with flexibility services. In 2032 constraints are expected on more than half the days in the year, with peak demand being up to six times the rated capacity. Network upgrades will very likely be needed if charging infrastructure is to be installed at Fairy Pools.

Table 10: Summary of results from the network analysis for the secondary substation that serves Fairy Pools

Secondary substation	Fairy Pools Car Park
Rated capacity (kW)	25
Current peak demand (kW)	0
2028 peak demand (kW)	70
2032 peak demand (kW)	150
Days of constraint expected in 2028	43
Days of constraint expected in 2032	191

Green: no constraints expected

Amber: constraints expected, however capacity breaches are either small or short duration, and may be manageable using flexibility services

Red: constraints expected with large or long duration capacity breaches, which will require network capacity upgrades to mitigate

5 Portree, Skye

5.1 Tourist Destination Overview

5.1.1 Context

The island of Skye is a popular tourist destination, with visitors travelling to this north west corner of Scotland to explore the stunning scenery, the world class distilleries, and the other attractions the island has to offer. Portree is a town of approximately 2,400 located in the north of the island of Skye. Portree is the largest town and capital of Skye. The town is home to many amenities for the local population, including a supermarket and petrol station. Its popularity as a tourist destination has sometimes led to concerns from residents of overcrowding. However, there is generally a positive relationship between locals and tourists.[25]

Figure 22: View of Portree (image from Pixabay).

Figure 23: Location of Portree on Skye (© OpenStreetMap contributors)

[25] https://www.telegraph.co.uk/news/2017/08/09/dont-come-skye-unless-have-room-night-say-police/

5.1.2 Visiting the destination

Visitors to Portree usually travel by either car or coach to the town. Portree is connected to mainland Scotland over the Skye road bridge and visitors can also access the island by car ferry from the south. There are five public car parks in Portree, with many visitors driving around the island stopping for supplies in the town. For context, a round trip to some popular points of interest on Skye (e.g. Old man of Storr, Dunvegan Castle, the Fairy Pools) is approximately 130 km.

Portree has visitors throughout the year, but visitor numbers are significantly higher in the peak season between April and September. Traffic flow data has been used to estimate peak daily tourist car visits.[26] The data suggests a higher numbers of tourists travelling to the area in the peak season (see Figure 24 below), with 50% more visitors on weekend days than the weekday average (see Figure 24 below).

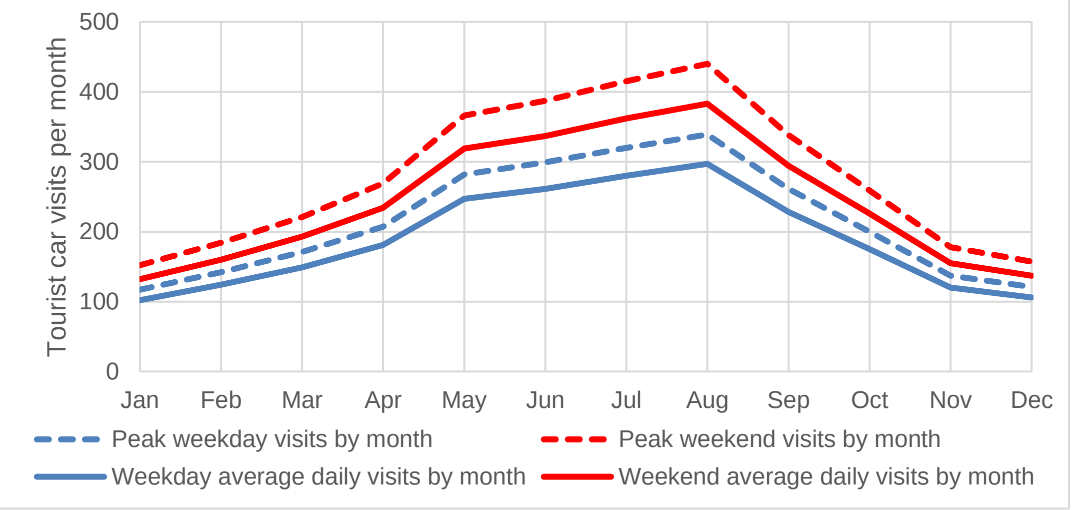

Figure 24: Tourist daily car visits to Portree

The key visitor statistics for Portree are summarised in Table 11.

Table 11: Key visitor assumptions and statistics for Portree

Number of tourists visiting per year (averaged over 2016 – 2018)[27]	174,000
Estimated number of tourist cars visiting per year (assuming 80% of visitors travel by car and an average of 2 people/ car)	69,600
Average daily tourist car visits	200
Peak daily tourist car visits	440

[26]Traffic flow data were obtained from Traffic Scotland's NTDS (https://ntds.trafficscotland.org/) between 2015 and 2017 for count point ATC01127 on the A87 outside of Portree. The ratio of monthly visits to the annual average from traffic data was used to determine how tourist demand varied by month. Data from Google Maps on how busy the site was by weekday was used to determine how tourist demand varied by weekday.

[27] Number of visits was obtained by special request to VisitScotland. 147,000 domestic tourists visited Skye per year on average between 2016 and 2018. Of these, 80% were assumed to visit Portree. Additionally, there were 56,000 international visitors to Portree per year on average between 2016 and 2018, giving 174,000 visitors in total.

5.2 Charging demand

There are currently two charge points located in Portree: one rapid and one fast.[28] This represents limited provision for short-term or overnight charging. The following assumptions have been used in estimating demand for charging in 2032:

- The number of visitors and profile of visiting times will remain constant.
- The proportion and profile of visitors travelling by private car (including rentals and car club vehicles) will remain constant.
- The share of tourist cars that are EVs in 2032 will be 46%
- With visitors assumed to be travelling from Inverness, the average daily mileage is assumed to be 185 km per day.
- Energy expended has been estimated assuming 0.2 kWh / km, so the average energy use per tourist EV is 37 kWh.

Table 12: Charging assumptions for Portree for the average day and the worst-case scenario

	Average day	Worst-case scenario
Time spent charging during the day (hours)	2.0	2.5
Time spent charging during the night (hours)	8.0	8.0
Share of EVs using on-site charging per day	30%	40%
Share of EVs using overnight charging per day	50%	50%
Share of EVs not charging at site	20%	10%

Modelling based on these assumptions and the available data suggests the 2032 demand profiles illustrated in Figure 25. The peak day profiles are based on the worst-case scenario assumptions being applied in the selected months.

Due to the seasonal effect on visitor numbers, demand in the peak summer weeks is almost ten times the demand for the peak winter weeks, peaking at 21:30 due to vehicles charging overnight.

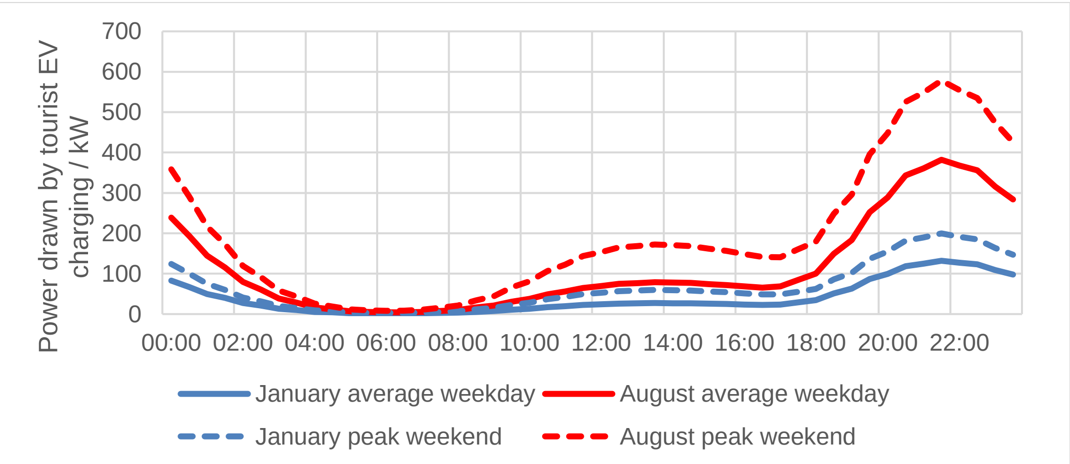

Figure 25: Estimated tourist charging demand in 2032 at Portree

[28] https://www.zap-map.com/live/

This modelling suggests the highest hourly demand will reach 578 kW drawn from 83 vehicles charging simultaneously (assuming all are charging at a rate of 7 kW)

5.3 Network impact findings

As Portree is served by multiple secondary substations, analysis was only conducted at primary substation level. There is significant spare capacity on the primary substation and additional demand from EV charging does not exceed 0.6 MW, so the impact of tourist EV charging is expected to be minimal at the primary substation level. Figure 26 and Figure 27 show expected primary substation demand by month for a peak weekend day in 2028 and 2032 respectively.

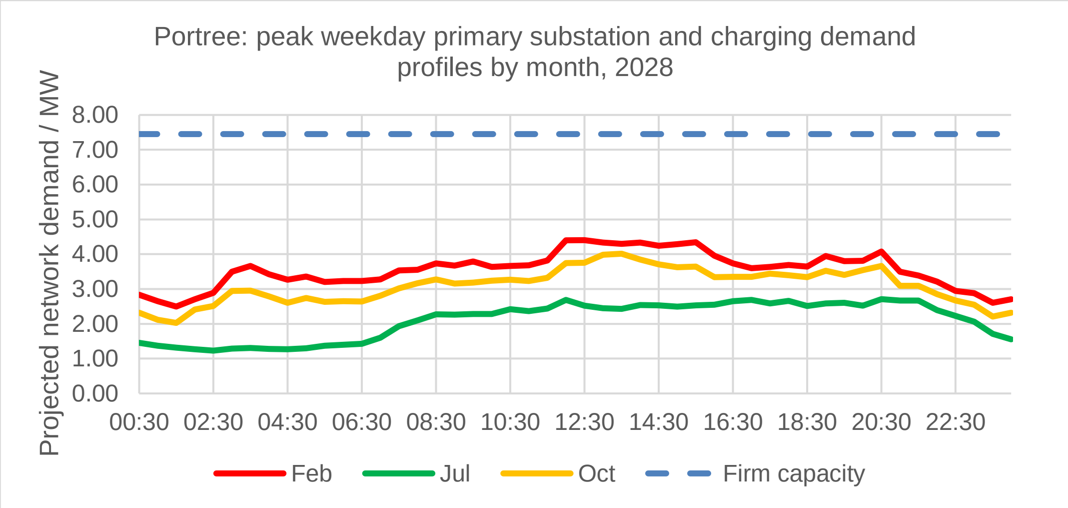

Figure 26: Projected demand on the primary substation at Portree for a peak weekend day in 2028 by month

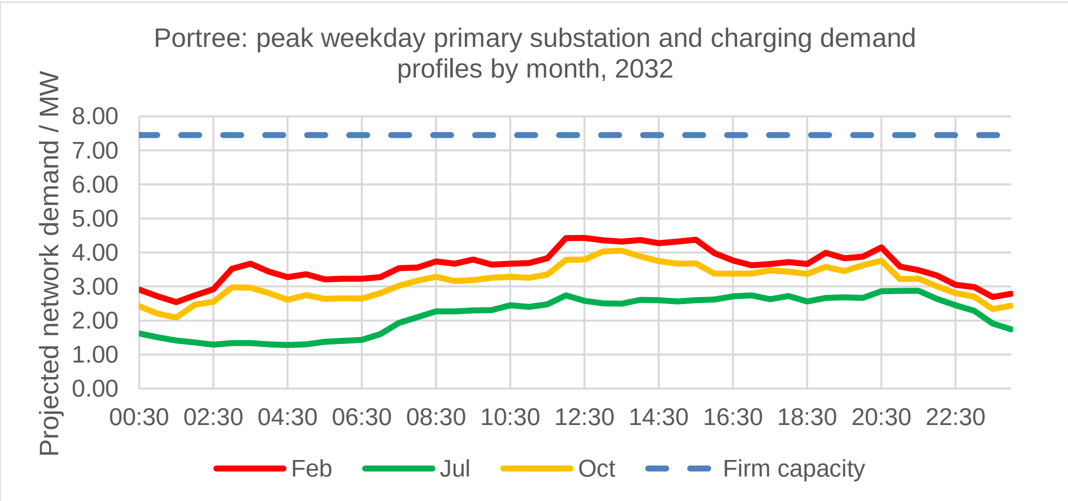

Figure 27: Projected demand on the primary substation at Portree for a peak weekend day in 2032 by month

6 Inverness to Skye road route via A82 and A87

6.1 Tourist Destination Overview

6.1.1 Context

The Inverness to Skye route follows the A82 and A87. The journey is approximately 180 km long and takes around three hours. This route links Scotland's most northern city with one of the busiest Scottish islands, with many international visitors flying into Inverness and hiring cars to visit many popular Highland attractions.

Figure 28: Skye bridge (image from Pixabay)

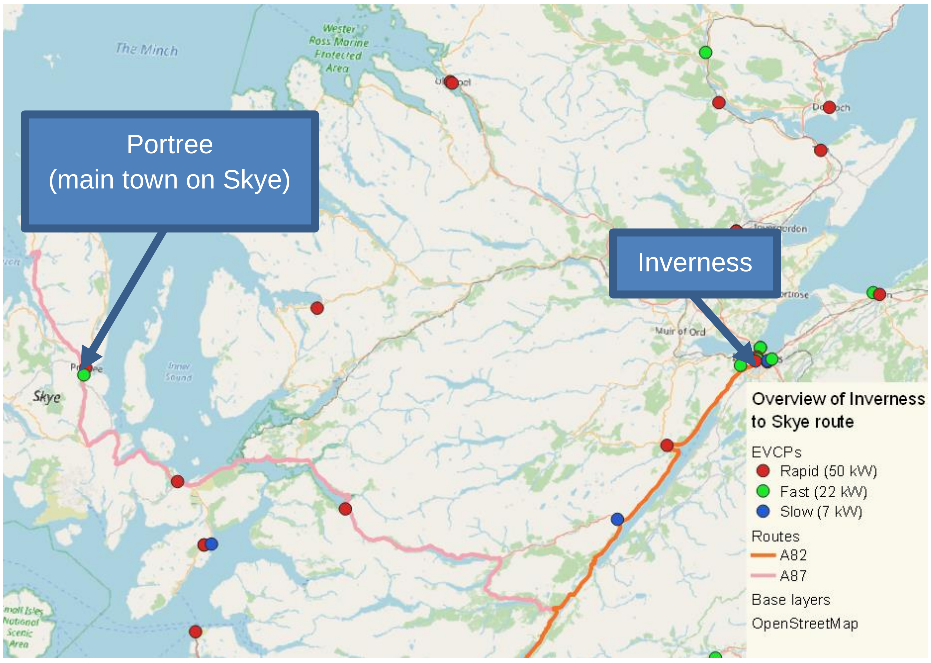

Figure 29: An overview of the route from Inverness to Skye along the A82 and A87 (© OpenStreetMap contributors)

6.1.2 Visiting the destination

Road users can hire cars in Inverness, where there are over 10 car hire companies. Road traffic data indicates that traffic is highly seasonal, as shown in Figure 30.[29]

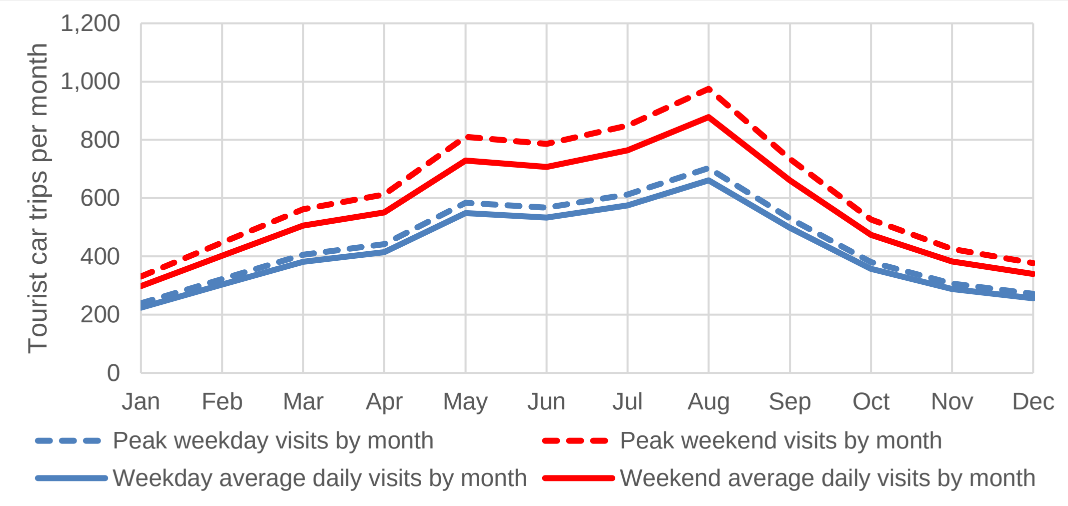

Figure 30: Tourist daily car trips along Inverness to Skye route

The key visitor assumptions for the Inverness to Skye route are summarised in Table 13.

Table 13: Key visitor assumptions for Inverness to Skye Route

Average daily tourist car trips	480
Peak daily tourist car trips	980

6.2 Charging demand

There currently four charge points en-route: three rapid and one slow. These can be seen on the map in Figure 29.

The following assumptions have been used in estimating demand for charging in 2032:

- The number of visitors and profile of visiting times will remain constant.
- The proportion and profile of visitors travelling by private (including rentals and car club vehicles) car will remain constant.
- The share of tourist cars that are EVs in 2032 will be 46%.
- Visitors are likely to travel 70 km along the route on average – this accounts for cars not travelling all the way along the route or using alternative routes.
- Energy expended has been estimated assuming 0.2 kWh / km, so the average energy use per tourist EV is 14 kWh.

[29] Traffic flow data were obtained from Traffic Scotland's NTDS (https://ntds.trafficscotland.org/) between 2014 and 2019 for count point 174100 on the A87 by Kyle of Lochalsh. It was assumed that 17% of traffic was due to tourists, based on analysis on Urquhart Castle, where reliable data on both tourist and non-tourist travel was available. The ratio of monthly visits to the annual average from traffic data was used to determine how tourist demand varied by month. From analysis of tourist sites where visit data was available, a weekend to weekday trip ratio of 1:1.3 was assumed.

- With charge points in Inverness and Skye, tourists are assumed to stop for a short time, so charging is capped to 1 hour (see Table 14).
- While tourists may stop overnight in some locations along the route, this is considered outside the scope of the case study as the objective is to assess the network impact of rapid en-route charging. Therefore, charging has been assumed to only occur due to tourists travelling and charging along the route.

Table 14: Charging assumptions for the Inverness to Skye (A87/A82) road for the average day and the worst-case scenario

	Average day	Worst-case scenario
Time spent charging at site (hours)	1.0	1.0
Share of EVs using on-site charging per day	30%	40%
Share of EVs using overnight charging per day	0%	0%
Share of EVs not charging at site	70%	60%

Modelling based on these assumptions and the available data suggests the 2032 demand profiles illustrated in Figure 31. The peak day profiles are based on the worst-case scenario assumptions being applied in the selected months.

Due to the seasonal effect on visitor numbers, the demand on a peak summer day is expected to be almost ten times the demand on a peak winter day.

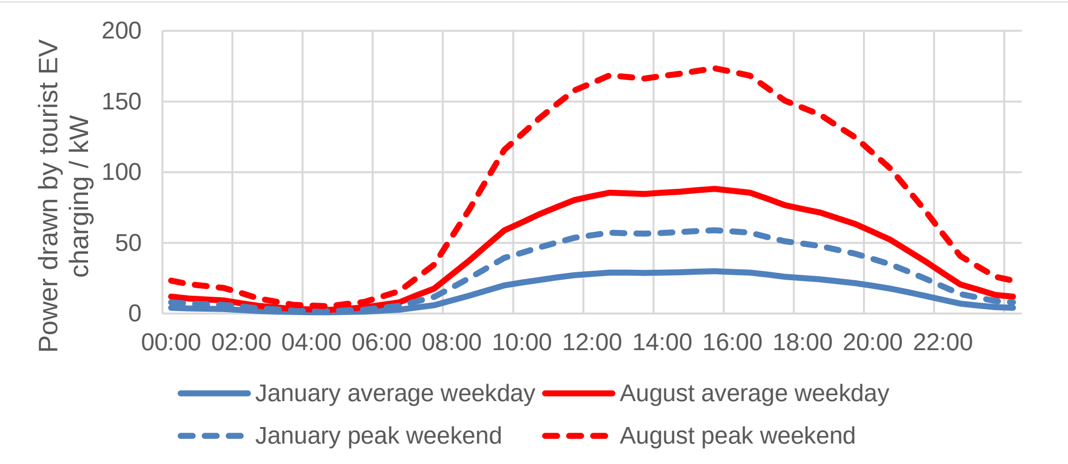

Figure 31: Estimated tourist charging demand in 2032 on Inverness to Skye route

This modelling suggests the highest hourly demand will reach 173 kW drawn from four vehicles charging simultaneously (assuming that all vehicles are charging at 50 kW).

6.3 Network impact findings

Five of the nine primary substations along the route have been included in the analysis. Table 15 shows how demand has been distributed among substations considered in the analysis for 2028 and 2032.

Charging demand on the primary substations peaks at 19 kW (for Skulamus in 2032). As this is significantly below 50 kW, the minimum power charging point likely to be installed along a route, the impact of installing a 50 kW charger has been assessed by assuming a constant load of 50 kW at each primary substation. While this profile would only result from the installed charger always being in use, which is unrealistic, it gives a better indication of the network impact of installing a charger. If the charging profiles generated from tourist travel behaviour were used for network planning, they would underestimate the possible maximum demand on the network and could lead to underinvestment in reinforcement or flexibility planning.

Table 15: Distribution of total charging demand predicted for the Inverness to Skye route to primary substations along the route in 2028 and 2032. Column totals may not sum to 100% due to rounding

Primary substation	Share of demand in 2028	Share of demand in 2032
Bunoich[30]	9.9%	10.5%
Drumnadrochit[31]	10.7%	10.9%
Kyle	9.9%	10.5%
Nostie Bridge	9.9%	10.5%
Skulamus	10.7%	10.9%
Other primary substations	49.0%	46.7%

None of the primary substations are near capacity and the addition of 50 kW of demand has little effect at this level. The Central Filling Station on the route has been identified as a likely stopping point for EV charging in the future, so an analysis of Stoney Lane, the secondary substation that serves this station, has been performed. Figure 32 demonstrates that no constraint is expected on this secondary substation. This analysis suggests that there would even be sufficient capacity for installing a 150 kW EVCP to allow for even faster en-route charging, as there is predicted to be over 300 kW of spare capacity on Stoney Lane secondary substation in 2032.

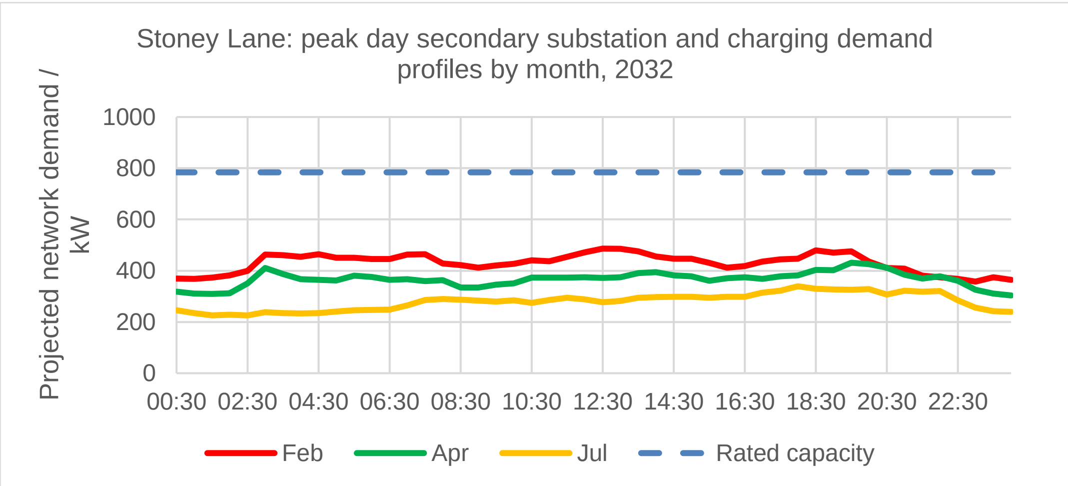

Figure 32: Projected demand on the secondary substation at Central Filling Station for a peak day in 2032 by month

[30] Note that Bunoich forms part of the Inverness to Skye and A82 case studies. The effect of adding the demand from both these case studies onto the primary substation has been investigated and no constraints are expected at primary substation level.
[31] Note that Drumnadrochit serves the Inverness to Skye and A82 routes as well as Urquhart Castle. The effect of adding the demand from all these case studies onto the primary substation has been investigated and no constraints are expected at primary substation level.

Summary of findings

Table 16 shows key results from the network impact analysis performed for Stoney Lane secondary substation. As the impact of installing a 50 kW charger has been considered, results are the same for 2028 and 2032. There is currently plenty of spare capacity on the secondary substation so no constraints are expected by 2032.

Table 16: Summary of results from the network analysis for the secondary substation that serves the Central Filling Station

Secondary substation	Stoney Lane
Rated capacity (kW)	784
Current peak demand (kW)	446
2028 peak demand (kW)	496
2032 peak demand (kW)	496
Days of constraint expected in 2028	0
Days of constraint expected in 2032	0

Green: no constraints expected

Amber: constraints expected, however capacity breaches are either small or short duration, and may be manageable using flexibility services

Red: constraints expected with large or long duration capacity breaches, which will require network capacity upgrades to mitigate

7 A82 Glasgow to Inverness Route

7.1 Tourist Destination Overview

7.1.1 Context

The Glasgow to Inverness route follows the A82. The journey is approximately 280 km long and takes over 4 hours. Glasgow is Scotland's largest city, and many visitors to the highlands would choose this scenic route to explore the scenery of the Great Glens and beyond. Several popular tourist destinations can be found on this route, including Loch Lomond and Urquhart Castle.

Figure 33: A82 through Glen Coe (image from Pixabay)

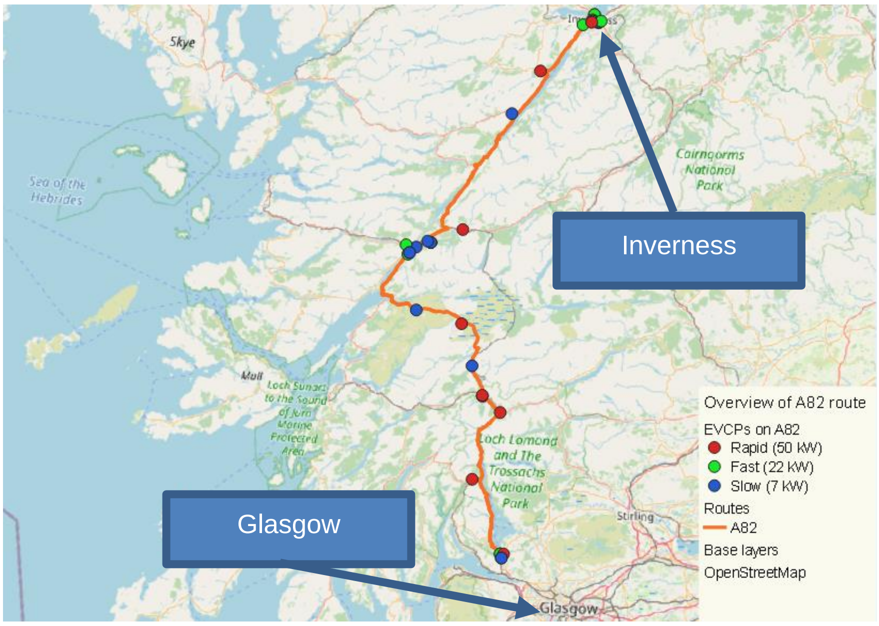

Figure 34: An overview of the route from Glasgow to Inverness along the A82 (© OpenStreetMap contributors)

7.1.2 Visiting the destination

Road users can hire cars in either Glasgow or Inverness, with many car hire companies in both cities. Road traffic data indicates that traffic is highly seasonal, with daily traffic almost doubling between January and August (see Figure 35).[32]

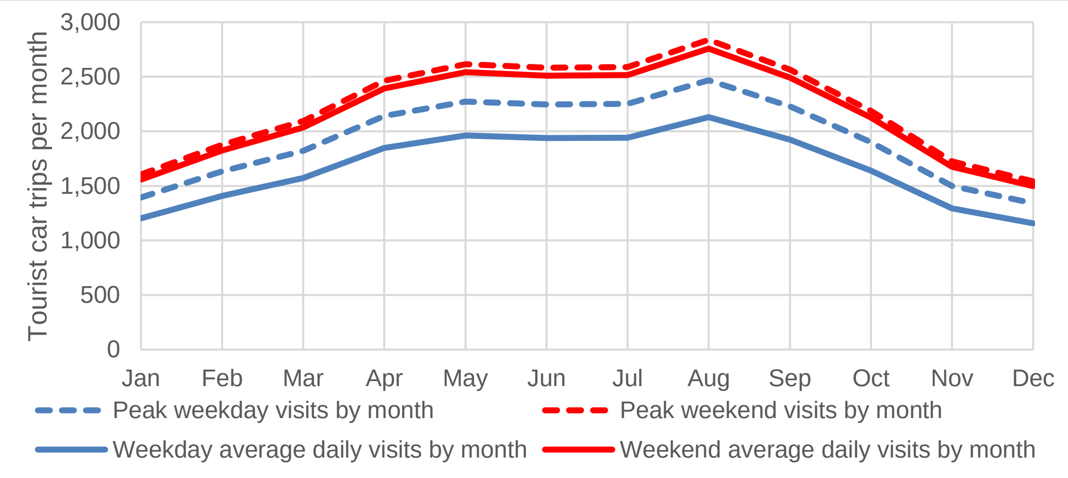

Figure 35: Tourist daily car trips along A82 Glasgow to Inverness route

The key visitor assumptions for the Glasgow to Inverness A82 road route are summarised in Table 17.

Table 17: Key visitor assumptions for Inverness to Skye Route

Average daily tourist car trips	1,890
Peak daily tourist car trips	2,840

7.2 Charging demand

There currently 19 EVCPs en-route: 8 rapid (50kW), 3 fast (22kW), and 8 slow (7kW). The locations of these EVCPs are given in Figure 34.

The following assumptions have been used in estimating demand for charging in 2032:

- The number of visitors and profile of visiting times will remain constant.
- The proportion and profile of visitors travelling by private (including rentals and car club vehicles) car will remain constant.
- The share of tourist cars that are EVs in 2032 will be 46%.
- Visitors are likely to travel 82 km along the route on average – this accounts for cars not travelling all the way along the route or using alternative routes.
- Energy expended has been estimated assuming 0.2 kWh / km, so the average energy use per tourist EV is 16 kWh.
- With EVCPs in Glasgow and Inverness, tourists are assumed to stop for a short time, so charging is capped to 1 hr (see Table 18).

[32]Traffic flow data were obtained from Traffic Scotland's NTDS (https://ntds.trafficscotland.org/) between 2014 and 2018 for count point JTC 08223 on the A82 by Loch Lomond. It was assumed that 17% of traffic was due to tourists, based on analysis on Urquhart Castle, where reliable data on both tourist and non-tourist travel was available. The ratio of monthly visits to the annual average from traffic data was used to determine how tourist demand varied by month. From analysis of tourist sites where visit data was available, a weekend to weekday trip ratio of 1.3 was assumed. Note that this same method is used to estimate tourist travel from traffic flow data in other case studies in this report.

- While tourists may stop overnight in some locations along the route, this is considered outside the scope of the case study as the objective is to assess the network impact of rapid en-route charging. Therefore, charging has been assumed to only occur due to tourists travelling and charging along the route.

Table 18: Charging assumptions for the Inverness to Skye (A87/A82) road for the average day and the worst-case scenario

	Average day	Worst-case scenario
Time spent charging at site (hours)	1.0	1.0
Share of EVs using on-site charging per day	50%	75%
Share of EVs using overnight charging per day	0%	0%
Share of EVs not charging at site	50%	25%

Modelling based on these assumptions and the available data suggests the 2032 demand profiles illustrated in Figure 36. The peak day profiles are based on the worst-case scenario assumptions being applied in the selected months.

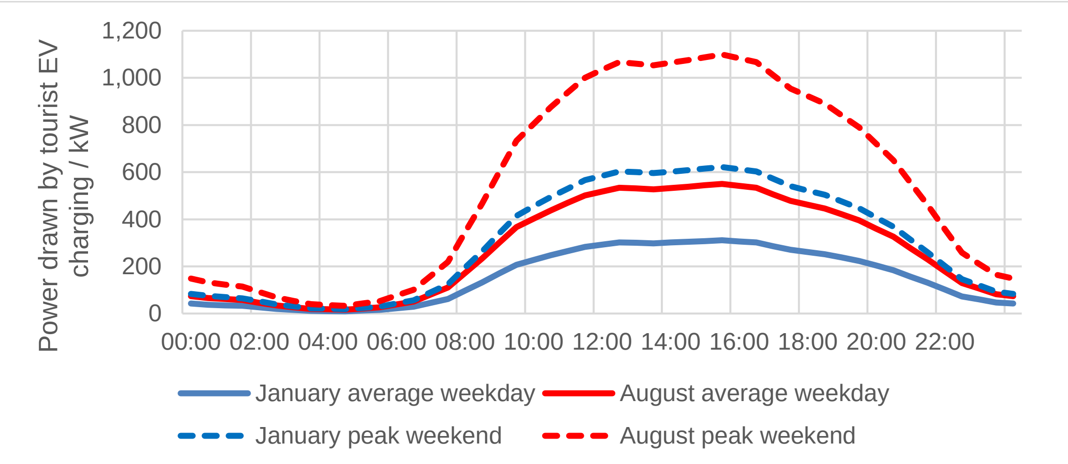

Figure 36: Estimated tourist charging demand for A82 Glasgow to Inverness route in 2032

This modelling suggests the highest hourly demand will reach 1,099 kW drawn from 22 vehicles charging simultaneously (assuming that all vehicles are charging at 50 kW).

7.3 Network impact findings

Of the 11 primary substations along the A82, seven were analysed in this study. Table 19 shows how charging demand has been distributed among primary substations in 2028 and 2032.

Charging demand on the primary substations peaks at 49 kW in 2028 (for Inverlochy). As charging demand never reaches 50 kW, the minimum power charging point likely to be installed along a route, the impact of installing a 50 kW charger has been assessed by assuming a constant load of 50 kW at each primary substation for 2028. While this profile would only result from the installed charger always being in use, which is unrealistic, it gives a better indication of the network impact of installing a charger. If the charging profiles generated from tourist travel behaviour were used for network planning, they would underestimate the possible maximum demand on the network and could lead to underinvestment in reinforcement or flexibility planning.

Table 19: Distribution of total charging demand predicted for the A82 route to primary substations along the route in 2028 and 2032. Column totals may not sum to 100% due to rounding

Primary substation	Share of demand in 2028	Share of demand in 2032
Blairlinnans	10.0%	9.6%
Bunoich[33]	8.1%	8.6%
Drumnadrochit[34]	8.5%	8.8%
Inverlochy	10.3%	9.7%
Glencoe	8.3%	8.7%
Sloy	8.6%	8.9%
Tyndrum	9.3%	9.2%
Other primary substations	36.8%	36.6%

In 2032, demand on primary substations exceeds 50 kW, so profiles calculated from distributing predicted charging demand from tourist travel behaviour have been used. None of the primary substations are near capacity and the addition of 50 kW of demand has little effect at this level. Claymore Filling Station (on Glencoe primary substation) and The Green Welly (on Tyndrum primary substation) on the route have been identified as likely stopping points for EV charging in the future, so an analysis of the secondary substations that serves these service stations was performed.

Figure 37 demonstrates that constraint is expected for a peak winter day on Lorn Drive, the secondary substation that serves Claymore Filling station, while demand is close to and occasionally exceeds the rated capacity for peak days in the rest of the year. In contrast, Figure 38 suggests that no constraint is expected on the Green Welly Stop secondary substation in 2032, and peak demand is expected to occur in August. This difference between the two sites can be explained by the current network demand; maximum demand on Lorn Drive is currently 191 kW, only 5 kW below the rated capacity of 196 kW, while maximum demand on Green Welly Stop is 33 kW, with a rated capacity of 196 kW.

Network demand peaks in the winter and exceeds charging demand at Lorn Drive, leading to peak demand in 2032 being expected to occur in February. For Green Welly Stop, charging demand peaks in the summer and exceeds the low network demand, so peak demand in 2032 is expected in August. Based on the difference between maximum demand and rated capacity for the two secondary substations, there is 5 kW spare capacity on Lorn Drive at current peak network demand, while there is 163 kW spare capacity on Green Welly Stop. Therefore, installation of a 150 kW EVCP for very rapid en-route charging would require network upgrades or flexibility services at Claymore Filling Station, but installation of a 150 kW EVCP may be possible at Green Welly without incurring network upgrade costs.

[33] Note that Bunoich forms part of the Inverness to Skye and A82 case studies. The effect of adding the demand from both these case studies onto the primary substation has been investigated and no constraints are expected at primary substation level.
[34] Note that Drumnadrochit serves the Inverness to Skye and A82 routes as well as Urquhart Castle. The effect of adding the demand from all these case studies onto the primary substation has been investigated and no constraints are expected at primary substation level.

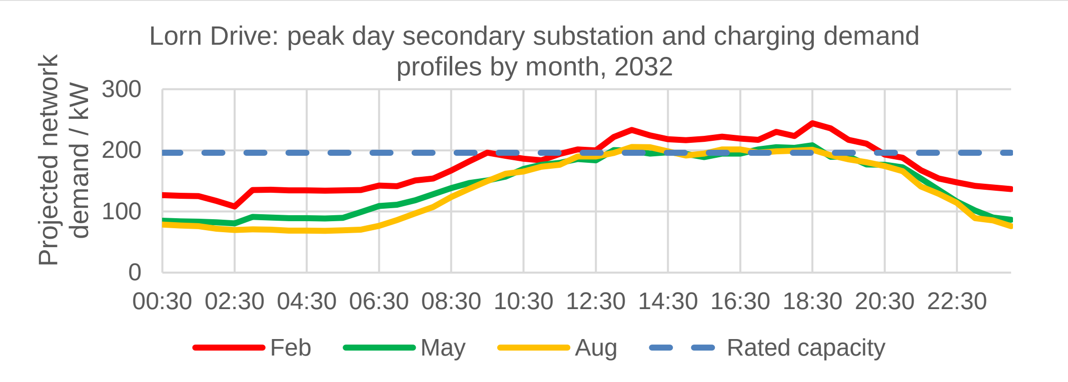

Figure 37: Projected demand on the secondary substation at Claymore Filling Station for a peak day in 2032 by month

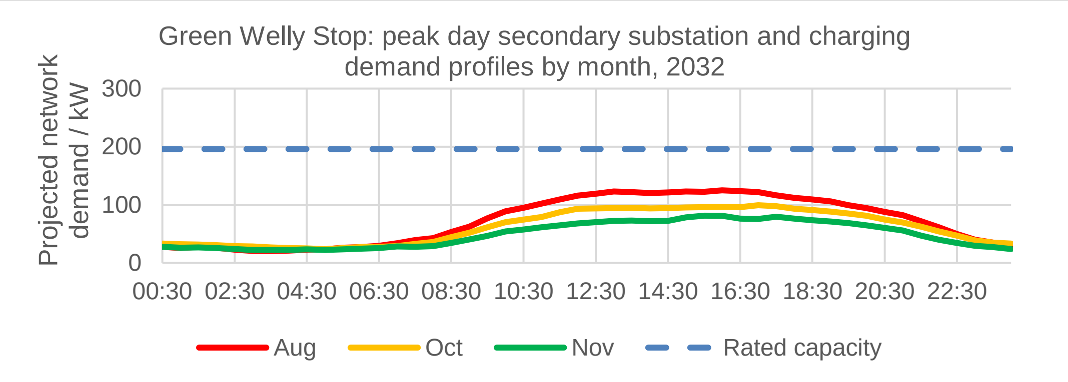

Figure 38: Projected demand on the secondary substation at The Green Welly for a peak day in 2032 by month

Summary of findings

Table 20 shows key results from the network impact analysis performed for the Lorn Drive and Green Welly Stop secondary substations. No constraints are expected on the Green Welly Stop secondary substation as there is currently significant spare capacity. While Lorn Drive is expected to show 200 days of constraint, capacity breaches tend to be short lived and not greatly exceed rated capacity, so constraints may be manageable through employment of flexibility services.

Table 20: Summary of results from the network analysis for secondary substations that serve the Claymore Filling Station and Green Welly[35]

Secondary substation	Lorn Drive	Green Welly Stop
Rated capacity (kW)	196	196
Current peak demand (kW)	191	33
2028 peak demand (kW)	241	83
2032 peak demand (kW)	244	125
Days of constraint expected in 2028	200	0
Days of constraint expected in 2032	200	0

[35] Green: no constraints expected; Amber: constraints expected, however capacity breaches are either small or short duration, and may be manageable using flexibility services

8 Urquhart Castle

8.1 Tourist Destination Overview

8.1.1 Context

Urquhart Castle is managed by Historic Environment Scotland, and is one of their most popular sites with visitor numbers growing significantly each year.[36] This site has been chosen as a case study because it is a popular tourist destination in the Scottish Highlands, it is relatively inaccessible by public transport, and it is not co-located with any other destinations or amenities.

Figure 39: Urquhart Castle (image from Pixabay)

Urquhart Castle is located on the west side of Loch Ness in the Highlands. The closest village to the attraction is Drumnadrochit with a population of 1,110 approximately 3 km away, and the closest city is Inverness with a population of 23,500 approximately 30 km away. There are areas of natural beauty, such as Glen Affric, that are close to the attraction that tourists would also visit whilst in the area.

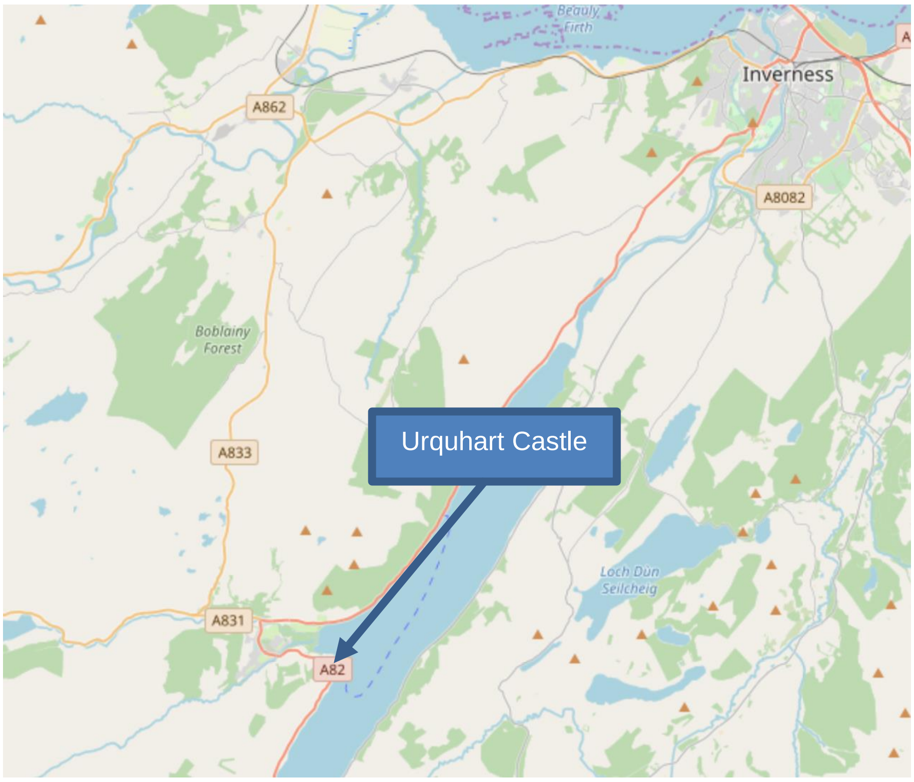

Figure 40: Location of Urquhart Castle (© OpenStreetMap contributors)

[36] https://www.pressandjournal.co.uk/fp/news/highlands/1985075/new-pontoon-could-encourage-more-visitors-to-come-to-urquhart-castle-by-boat/

8.1.2 Visiting the destination

Visitors to Urquhart Castle usually travel by either car, coach or ferry to the site. The site is approximately a 40 minute walk from the village of Drumnadrochit; cycling is unappealing on the A82. Car hire is available in Inverness, and the site can be visited as a day trip from the city. Visiting the castle by way of a coach or ferry tour is commonplace in the summer months. These tours often start in Inverness and take visitors around selected sites in the Highlands or along the Great Glens. There is very limited parking on site and during the summer months there is an overflow car park ('park and walk') in a field nearby. Typical visit time to Urquhart Castle is between 1-2 hours and there are no other destinations or amenities served by the same car park.[37]

Urquhart Castle is open to visitors throughout the year. Traffic flow data has been used to estimate peak daily tourist car visits as shown in Figure 41.[38] The data suggests a higher numbers of tourists travelling to the area in the peak season and with average weekends representing significantly more visitors than even the busiest weekdays in a given month. The key visitor statistics for Urquhart Castle are summarised in Table 21.

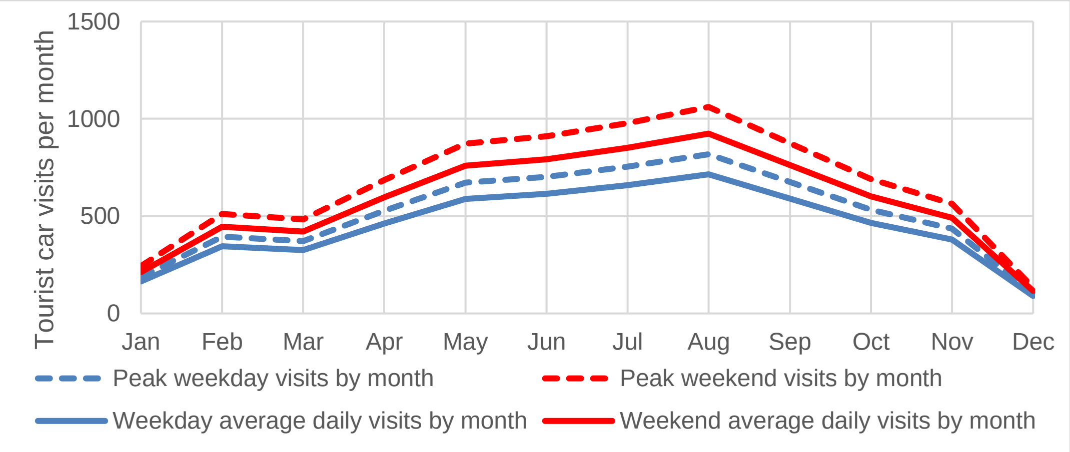

Figure 41: Monthly variation in estimated daily tourist car visits to Urquhart Castle

Table 21: Key visitor assumptions and statistics for Urquhart Castle

Number of tourists visiting per year (2017)[39]	488,136
Estimated number of tourist cars visiting per year (assuming 80% of visitors travel by car and an average of 2 people/car)	195,250
Average daily tourist car visits (assuming that site is open 365 days a year)	540
Peak daily tourist car visits (derived from the traffic flow variations)	1,070

[37] Sourced from TripAdvisor: Link to source
[38] Traffic flow data were obtained from Traffic Scotland's NTDS (https://ntds.trafficscotland.org/) between 2017 and 2018 for count point JTC00145 on the A82 between Invermoriston and Drumnadrochit (this is the closest count point to Urquhart Castle). This was compared against annual visit data to determine that at least 17% of traffic was due to tourist cars (assuming that 80% of tourists came by car and there were 2 people in each car). This figure of 17% was assumed to be the share of road traffic due to tourist cars on routes, as no data on the number of tourists using routes was available. The ratio of monthly visits to the annual average from traffic data was used to determine how tourist demand varied by month. Data from Google Maps on how busy the site was by weekday was used to determine how tourist demand varied by weekday.
[39] VisitScotland Highlands and Islands Factsheet 2017

8.2 Charging demand

There currently no charge points located at Urquhart Castle. The following assumptions have been used in estimating demand for charging in 2032:

- The number of visitors and profile of visiting times will remain the same as they were in 2017, when statistics were most recently available.
- The proportion and profile of visitors travelling by private (including rentals and car club vehicles) car will remain constant.
- The share of tourist cars that are EVs in 2032 will be 46%.
- With visitors assumed to be travelling from Inverness, the average daily mileage is assumed to be 110 km per day.
- Energy expended has been estimated assuming 0.2 kWh / km, so the average energy use per tourist EV is 22 kWh.
- With there being no overnight accommodation provision at the site, it is assumed that in the future demand for charging will be during the day (see Table 22).
- With charge points in Drumnadrochit, Inverness and Fort Augustus, it is assumed that many EVs will not need to charge at Urquhart Castle (see Table 22).

Table 22: Charging assumptions for Urquhart Castle for the average day and the worst-case scenario

	Average day	Worst-case scenario
Time spent charging at site (hours)	2	2.5
Share of EVs using on-site charging per day	30%	60%
Share of EVs using overnight charging per day	0%	0%
Share of EVs not charging at site	70%	40%

Modelling based on these assumptions and the available data suggests the 2032 demand profiles illustrated in Figure 42. The peak day profiles are based on the worst-case scenario assumptions being applied in the selected months.

The seasonal effect on visitor numbers illustrates how demand in the peak summer weeks is almost ten times the demand on a peak winter week, peaking at approximately 13:30 with visitor numbers.

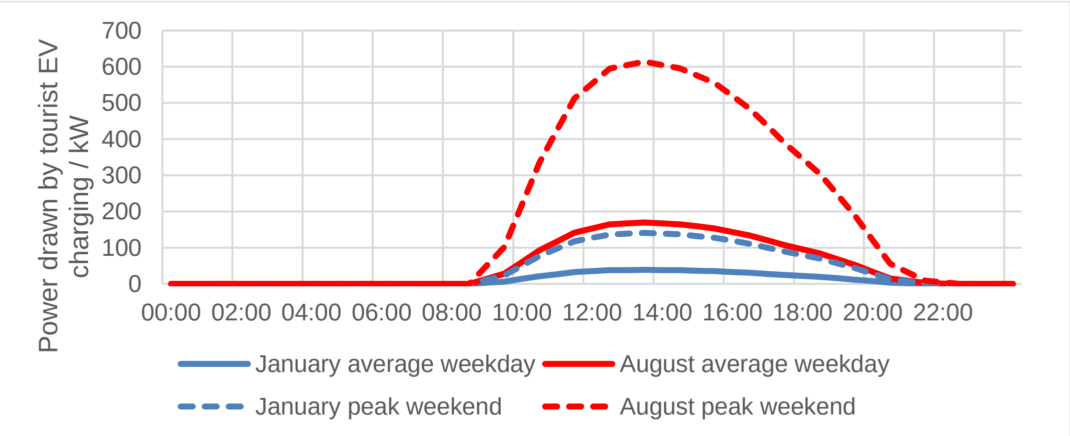

Figure 42: Estimated tourist charging demand in 2032 at Urquhart Castle

This modelling suggests the highest hourly demand will reach 614 kW drawn from 88 vehicles charging simultaneously (assuming that all vehicles are using 7 kW chargers).

8.3 Network impact findings

The Urquhart Castle secondary substation has a rated capacity of 196 kW and current maximum demand is 200 kW, meaning that rated capacity is already sometimes exceeded.[40] Demand on peak days is expected to exceed rated capacity in all months in 2028 (see Figure 43). However, the average weekend day is expected to reach but not exceed rated capacity in 2028 (see Figure 44). In 2032, demand on the secondary substation greatly exceeds rated capacity as shown in Figure 45.

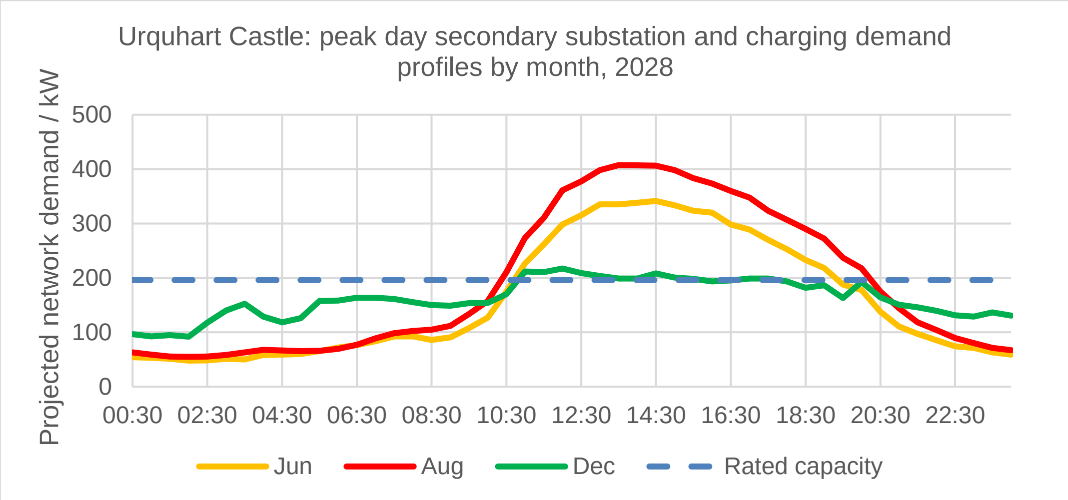

Figure 43: Projected demand on the secondary substation at Urquhart Castle for a peak day in 2028 by month

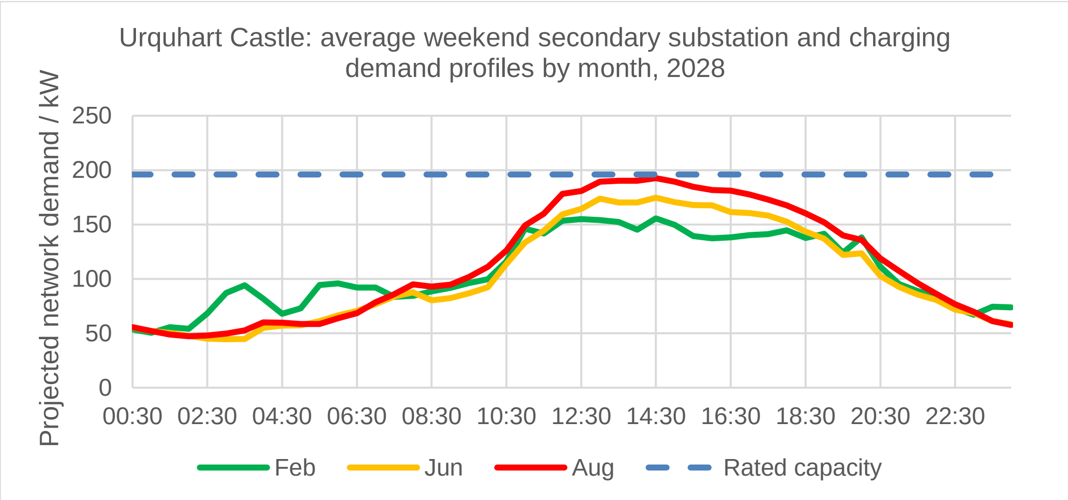

Figure 44: Projected demand on the secondary substation at Urquhart Castle for an average weekend day in 2028 by month

[40] Note that this secondary substation is connected to Drumnadrochit primary substation, which also serves the Inverness to Skye and A82 case studies. Charging demand from these case studies has not been added to the Urquhart Castle secondary substation as tourists charging en-route will not be connected to this secondary substation as the castle is not a point where tourists will stop for a short time to charge while en-route.

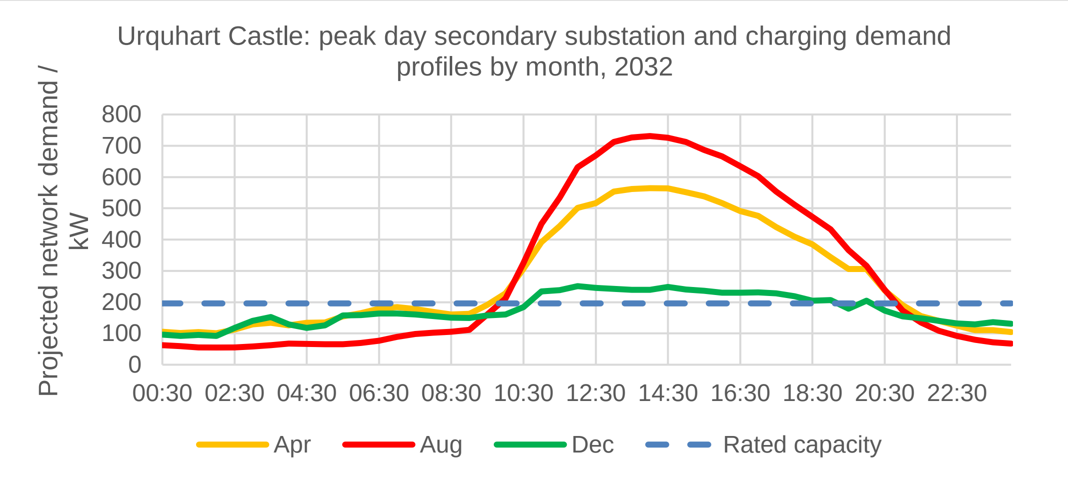

Figure 45: Projected demand on the secondary substation at Urquhart Castle for a peak day in 2032 by month

Summary of findings

Table 23 shows key results from the network impact analysis performed for Urquhart Castle secondary substation. While some large capacity breaches are expected to occur in 2028, they are expected to be restricted to summer peak days, so may be manageable with flexibility services. By 2032 constraints are expected on most days, so network upgrades will likely be required.

Table 23: Summary of results from the network analysis for the secondary substation that serves Urquhart Castle

Secondary substation	Urquhart Castle
Rated capacity (kW)	196
Current peak demand (kW)	200
2028 peak demand (kW)	407
2032 peak demand (kW)	731
Days of constraint expected in 2028	52
Days of constraint expected in 2032	322

Green: no constraints expected

Amber: constraints expected, however capacity breaches are either small or short duration, and may be manageable using flexibility services

Red: constraints expected with large or long duration capacity breaches, which will require network capacity upgrades to mitigate

9 A9 route from Perth to Inverness

9.1 Tourist Destination Overview

9.1.1 Context

The Perth to Inverness route follows the A9. The journey is approximately 180 km long and takes around 2.5 hours. There are a number of key stopping points along the route such as Pitlochry, Dalwhinnie and Aviemore. From Inverness, highland tourist attractions such as Urquhart Castle and Loch Ness are within a short drive. Alternatively, tourists may explore the scenery in the north by following the North Coast 500 route.

Figure 46: Drumochter Pass on the A9 (© Mick Knapton / [CC-BY-SA-3.0](CC-BY-SA-3.0))

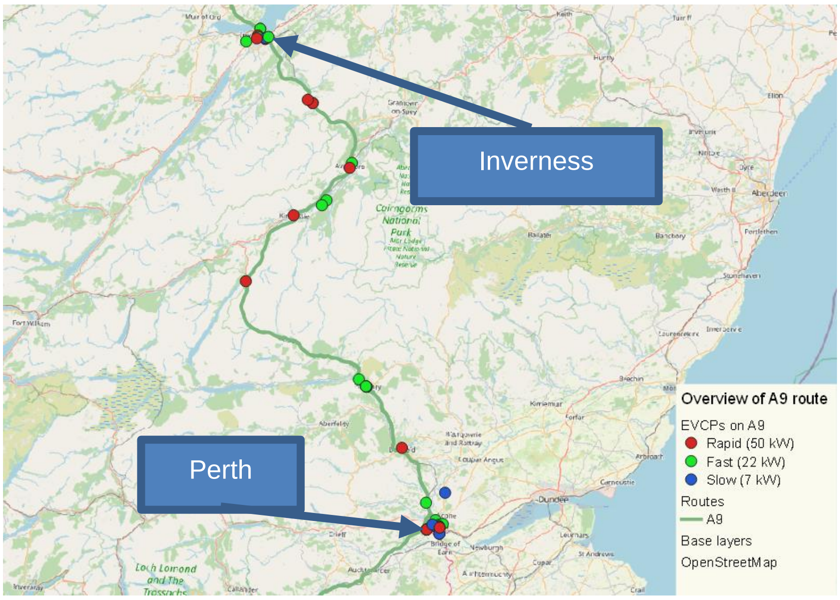

Figure 47: An overview of the A9 route from Perth to Inverness (© OpenStreetMap contributors)

9.1.2 Visiting the destination

Road users can hire cars in either Perth or Inverness, with multiple car hire companies in both cities. Road traffic data indicates that traffic is highly seasonal, with daily traffic 25% higher in August than January (see Figure 48).[41]

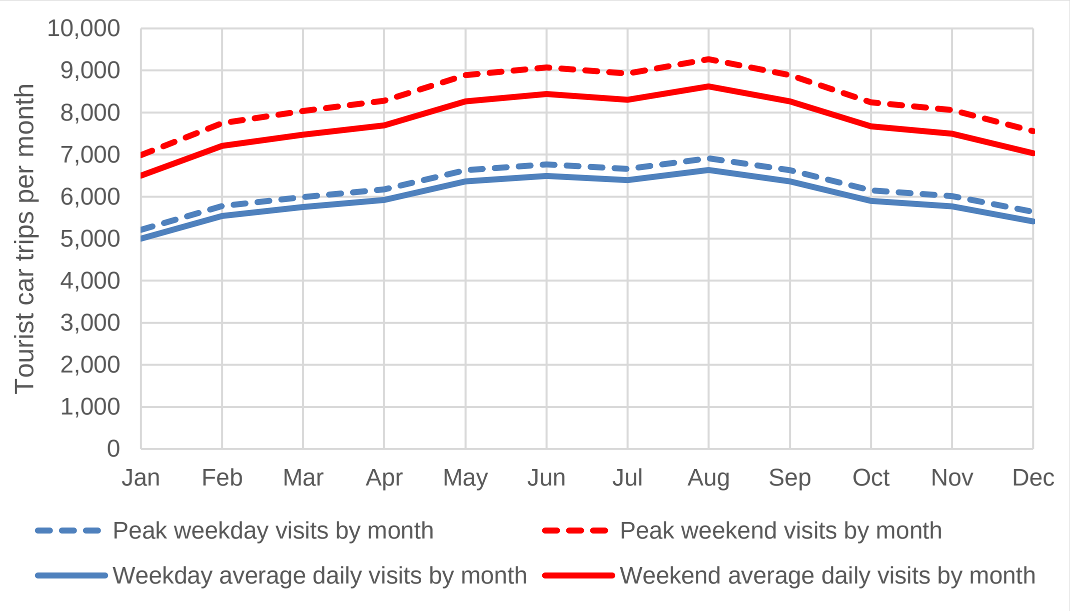

Figure 48: Tourist daily car trips along A9 Perth to Inverness route

The key visitor assumptions for the Perth to Inverness A9 road route are summarised in Table 24.

Table 24: Key visitor assumptions for Inverness to Skye Route

Average daily tourist car trips	6,480
Peak daily tourist car trips (Calculated from peak month on peak weekend day)	9,270

9.2 Charging demand

9.2.1 Current provision

Currently, there are many EVCPs available in Perth and Inverness. Additionally, the 'electric A9' is under construction, where charge points will be installed in communities along the A9 no more than 30 km apart. There are currently six rapid, six fast, and one slow charge point along the route.

[41]Traffic flow data were obtained from Traffic Scotland's NTDS (https://ntds.trafficscotland.org/) between 2017 and 2019 for count point ATC01008 on the A9 near Inverness. It was assumed that 17% of traffic was due to tourists, based on analysis on Urquhart Castle, where reliable data on both tourist and non-tourist travel was available. The ratio of monthly visits to the annual average from traffic data was used to determine how tourist demand varied by month. From analysis of tourist sites where visit data was available, a weekend to weekday trip ratio of 1.3 was assumed.

9.2.2 Demand forecast

The following assumptions have been used in estimating demand for charging in 2032:

- The number of visitors and profile of visiting times will remain constant.
- The proportion and profile of visitors travelling by private (including rentals and car club vehicles) car will remain constant.
- The share of tourist cars that are EVs in 2032 will be 46%.
- Visitors are likely to travel 76 km along the route on average – this accounts for cars not travelling all the way along the route or using alternative routes.
- Energy expended has been estimated assuming 0.2 kWh / km, so the average energy use per tourist EV is 15 kWh.
- With charge points in Perth and Inverness, tourists are assumed to stop for a short time, so charging is capped to one hour (see Table 25).
- While tourists may stop overnight in some locations along the route, this is considered outside the scope of the case study as the objective is to assess the network impact of rapid en-route charging. Therefore, charging has been assumed to only occur due to tourists travelling and charging along the route.

Table 25: Charging assumptions for the Perth to Inverness (A9) road for the average day and the worst-case scenario

	Average day	Worst-case scenario
Time spent charging at site (hours)	1.0	1.0
Share of EVs using on-site charging per day	40%	60%
Share of EVs using overnight charging per day	0%	0%
Share of EVs not charging at site	60%	40%

Modelling based on these assumptions and the available data suggests the 2032 demand profiles illustrated in Figure 49. The peak day profiles are based on the worst-case scenario assumptions being applied in the selected months.

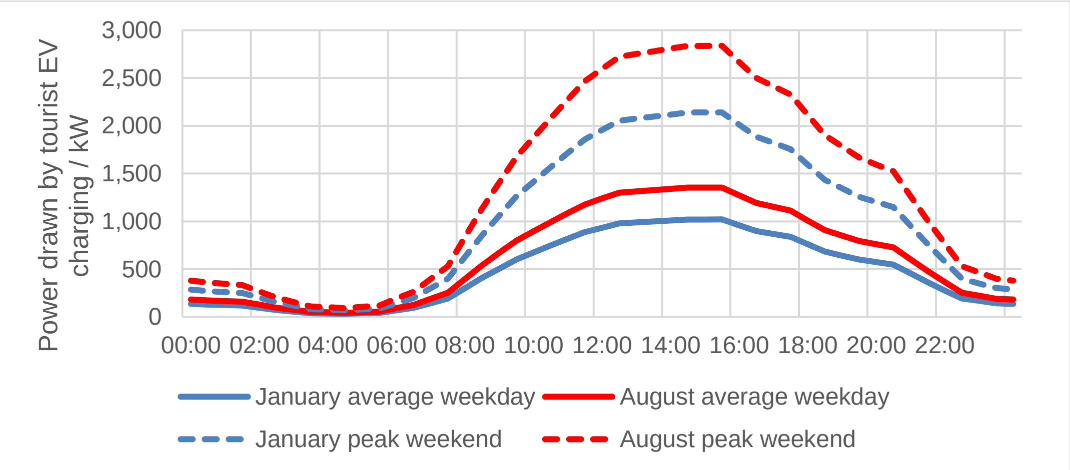

Figure 49: Estimated tourist charging demand for A9 Perth to Inverness route in 2032

This modelling suggests the highest hourly demand will reach 2,837 kW drawn from 57 vehicles charging simultaneously (assuming all vehicles are charging at 50 kW).

9.3 Network impact findings

Of the 12 primary substations along the A82, six were analysed in this study. Table 26 shows how charging demand has been distributed among primary substations in 2028 and 2032.

Table 26: Distribution of total charging demand predicted for the A9 route to primary substations along the route in 2028 and 2032. Column totals may not sum to 100% due to rounding

Primary substation	Share of demand in 2028	Share of demand in 2032
Aviemore	9.1%	8.7%
Calvine	7.4%	7.9%
Dalwhinnie	7.4%	7.9%
Kingussie	8.4%	8.4%
Pitlochry	9.0%	8.7%
Tomatin	7.5%	7.9%
Other primary substations	51.2%	50.6%

Peak charging demand on each primary substation is expected to reach 247 kW (at both Aviemore and Pitlochry in 2032). This is not expected to lead to any constraint at primary substation level. Dalwhinnie Filling Station and Aviemore BP have been identified as likely stopping points so the secondary substations that serve these sites have also been analysed.

On Dalwhinnie South secondary substation which serves Dalwhinnie Filling Station, rated capacity is expected to be exceeded on the peak day in every month in 2028 (see Figure 50). On an average weekend in 2028 demand is expected to approach but rarely exceed rated capacity (see Figure 51). In 2032, demand is expected to greatly exceed rated capacity, as shown for a peak day each month in Figure 52.

Grampian Court secondary substation, which serves Aviemore BP, shows similar behaviour. Some months exceed rated capacity on a peak day in 2028 as shown in Figure 53, and demand approaches but rarely exceeds rated capacity on an average weekend day in 2023, as shown in Figure 54. This secondary substation is expected to be less constrained than Dalwhinnie South in 2032, as some months are not expected to exceed rated capacity on an average weekend, shown in Figure 55.

There is currently insufficient spare capacity to install a 150 kW EVCP on either Dalwhinnie South or Grampian Court secondary substation. This higher charging rate would allow for very rapid en-route charging, but would require flexibility services to be employed or network upgrades.

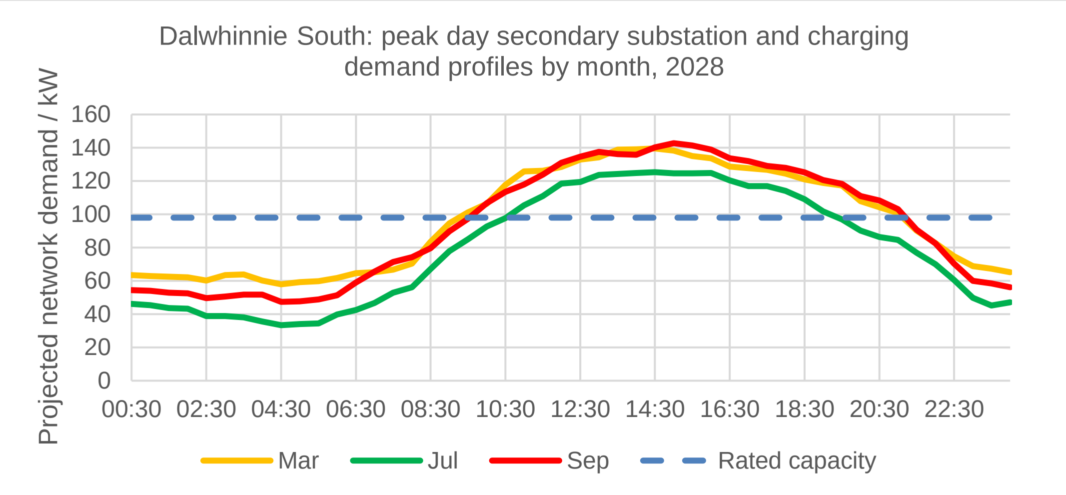

Figure 50: Projected demand on the secondary substation at Dalwhinnie Filling Station for a peak day in 2028 by month

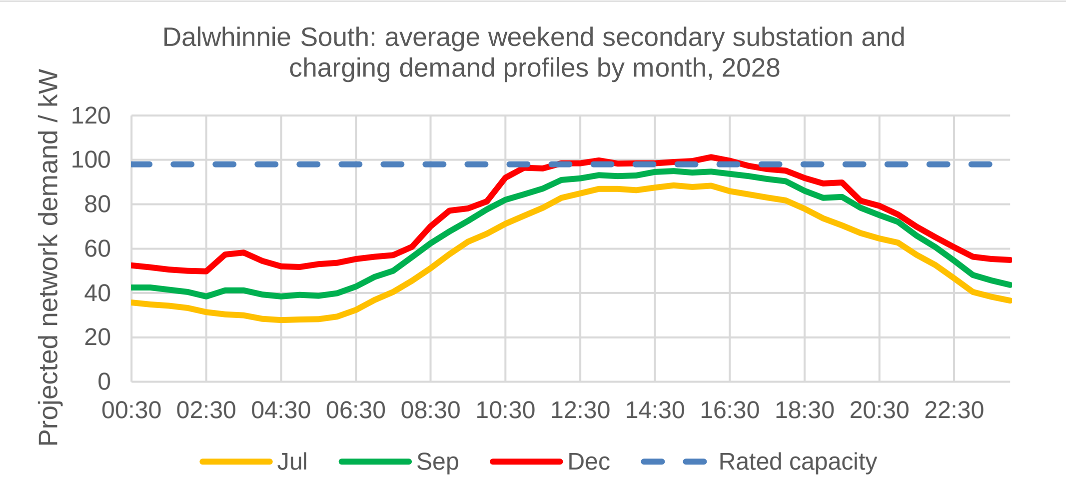

Figure 51: Projected demand on the secondary substation at Dalwhinnie Filling Station for an average weekend day in 2028 by month

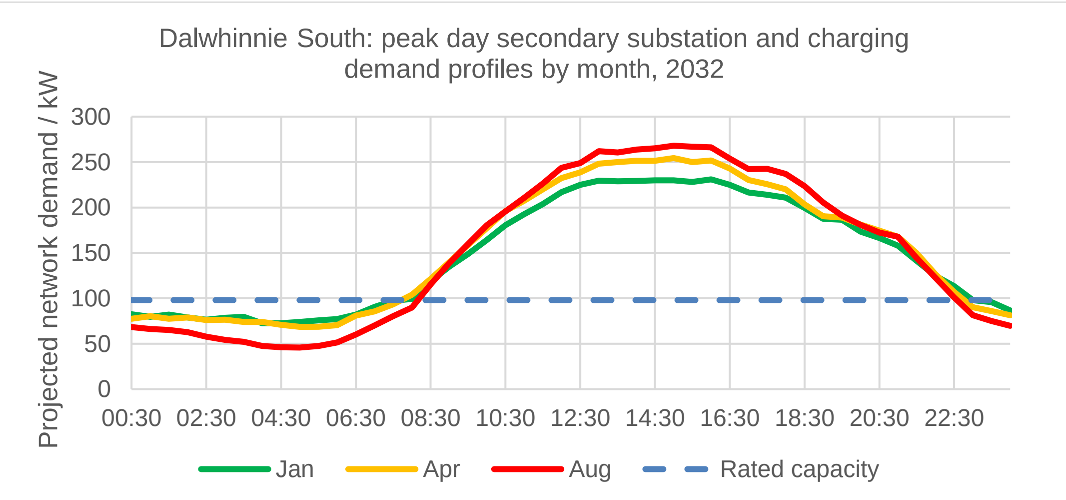

Figure 52: Projected demand on the secondary substation at Dalwhinnie Filling Station for a peak day in 2032 by month

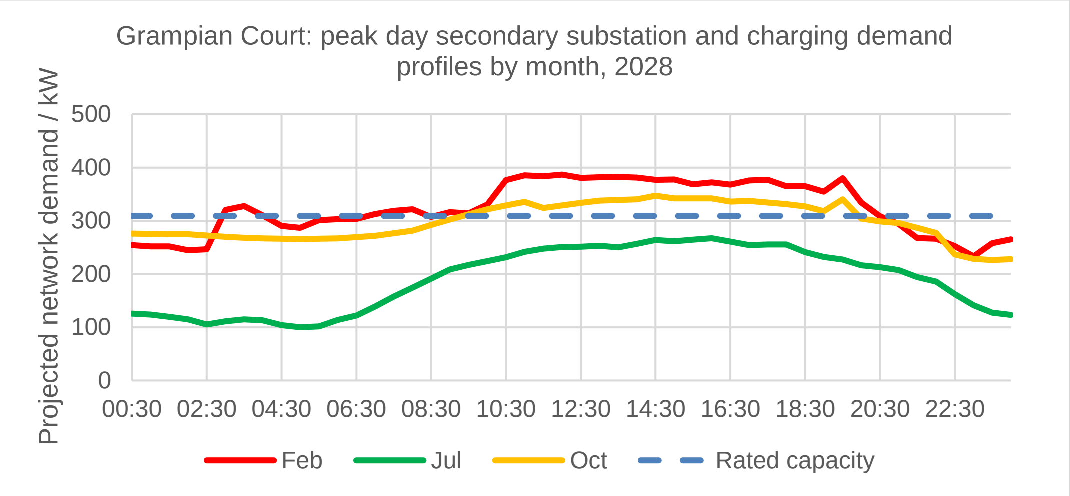

Figure 53: Projected demand on the secondary substation at Aviemore BP for a peak day in 2028 by month

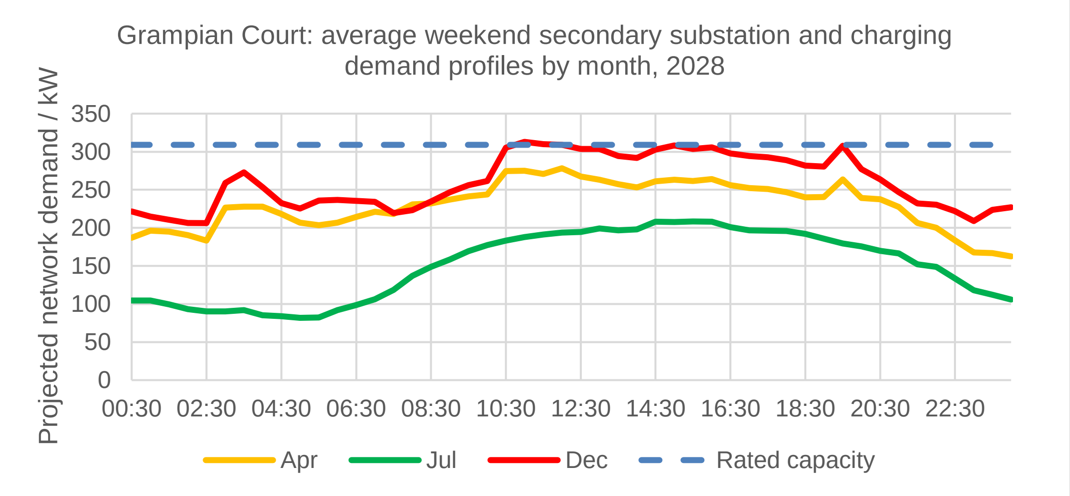

Figure 54: Projected demand on the secondary substation at Aviemore BP for an average weekend day in 2028 by month

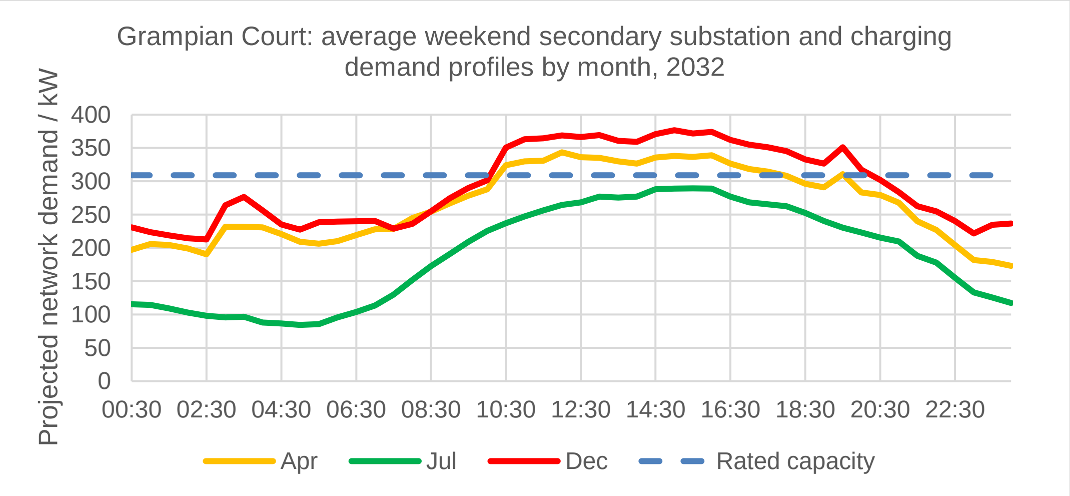

Figure 55: Projected demand on the secondary substation at Aviemore BP for an average weekend day in 2032 by month

Table 27 shows key results from the network impact analysis performed for the Dalwhinnie South and Grampian Court secondary substations. Both secondary substations show capacity breaches in 2028. However, these are typically small and short-lived, so may be managed by using flexibility services. By 2032, large capacity breaches are expected most days at both secondary substations, which will likely require network upgrades to mitigate.

Table 27: Summary of results from the network analysis for secondary substations that serve the Dalwhinnie Filling Station and Aviemore BP

Secondary substation	Dalwhinnie South	Grampian Court
Rated capacity (kW)	98	309
Current peak demand (kW)	81	322
2028 peak demand (kW)	143	387
2032 peak demand (kW)	270	492
Days of constraint expected in 2028	169	56
Days of constraint expected in 2032	365	213

Green: no constraints expected

Amber: constraints expected, however capacity breaches are either small or short duration, and may be manageable using flexibility services

Red: constraints expected with large or long duration capacity breaches, which will require network capacity upgrades to mitigate

10 Dundee City Centre

10.1 Tourist Destination Overview

10.1.1 Context

Dundee city centre has become a popular destination for tourists in recent years. The opening of the V&A in September 2018 saw a large growth in tourism building on established attractions such as Verdant Works, McManus Art Gallery, HMS Discovery and HMS Unicorn.

Figure 56: Dundee City as seen from Dundee Law

Dundee has been ahead of the curve in policies and infrastructure deployment to support the growth of EVs. These policies have resulted in electrification of over 19% of the taxi fleet, three rapid charging hubs in the city, and a high adoption of EVs in the private car market as well as one of the largest local authority fleets of electric vehicles in the UK. The city has also supported its neighbouring authorities to install infrastructure to support the movement of residents and tourists in the area. For these reasons, it is an interesting case study to consider.

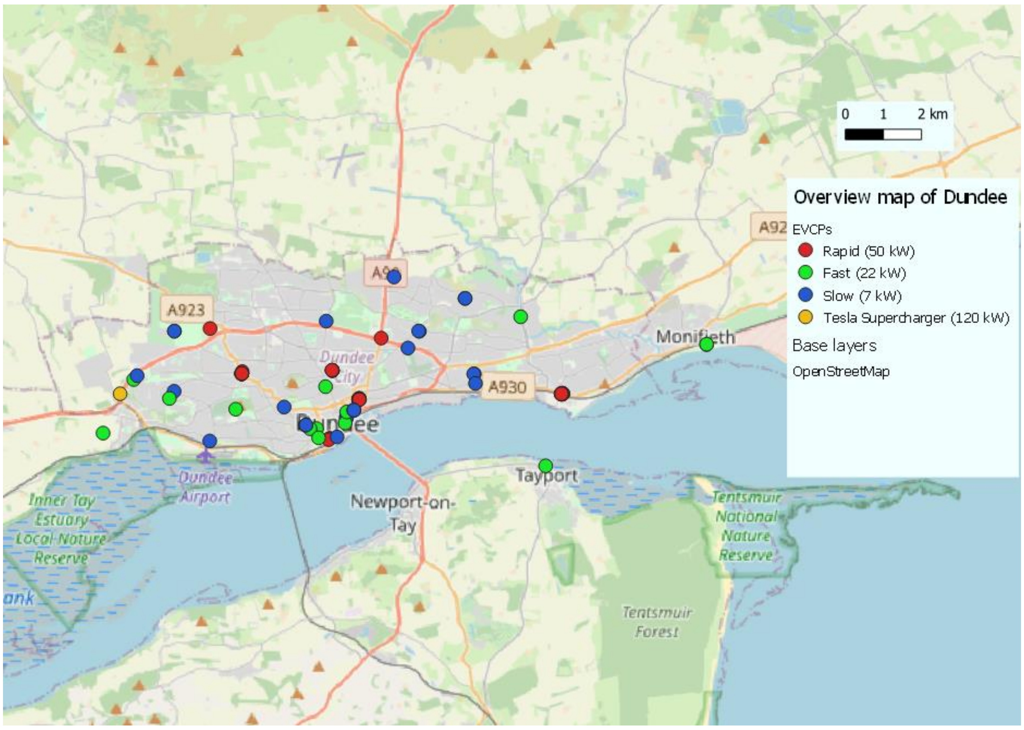

Figure 57: An overview of Dundee city centre ([© OpenStreetMap contributors](https://www.openstreetmap.org/copyright))

10.1.2 Visiting the destination

Visitors to Dundee City Centre usually travel by either car or public transport. The city is approximately 100 km from Edinburgh – accessible for a day trip, and only 30 km from Perth and the A9 route north to the Highlands. For those that arrive by public transport, car hire is available in the city and from Edinburgh airport. With the opening of the V&A, it is now common for cruise ships and coaches to stop in the city for the day for tourists to explore. The city sits at the centre of some of the country's oldest and most prestigious golf courses and is used as a centre for golf tourism and associated visitors.

The city centre has several car parks. During the week, these car parks are usually filled with commuters. However, at the weekend tourists and visitors often park here. In the city centre, there is very limited on street parking, with short stay limits.

Dundee City centre has visitors throughout the year. Visitor numbers fluctuate from month to month and are slightly higher in the peak season between May and August. Traffic flow data has been used to estimate peak daily tourist car visits.[42] Any recreational day trip or overnight stay is assumed to be a tourist visit. The data suggests a higher number of tourists travelling to the area at the weekends (see Figure 58 below).

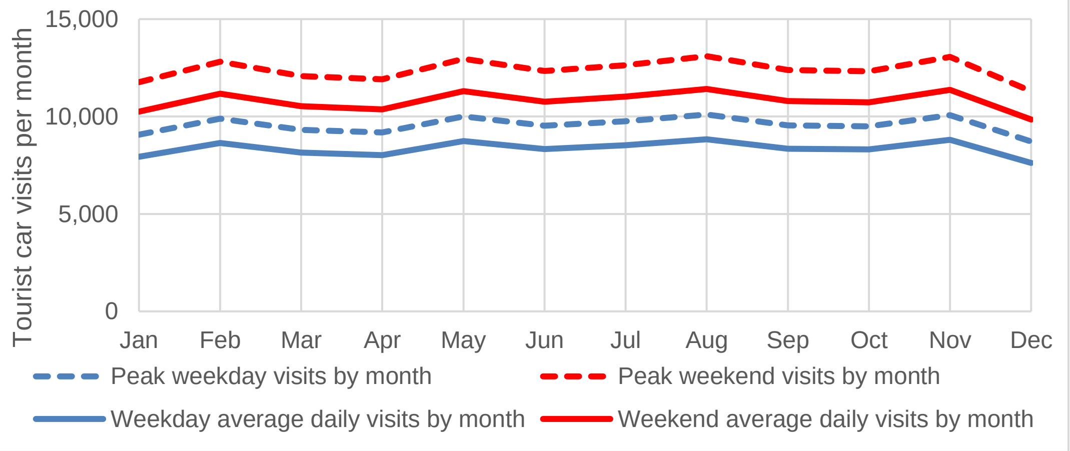

Figure 58: Tourist daily car trips to Dundee

The key visitor statistics for Dundee City centre are summarised in Table 28.

Table 28: Key visitor assumptions and statistics for Dundee City

Number of tourists visiting per year (2018)[43]	8,276,000
Estimated number of tourist cars visiting per year (assuming 80% of visitors travel by car and an average of 2 people per car)	3,310,400
Average daily tourist car visits (assuming that site is open 365 days a year)	9,070
Peak daily tourist car visits (derived from the traffic flow variations)	13,100

[42]Traffic flow data were obtained from Traffic Scotland's NTDS (https://ntds.trafficscotland.org/) between 2014 and 2019 for count point JTC00555 on the A90 north of Dundee. This was used to determine how tourist demand varied by month. Data from Google Maps was used to estimate how tourist demand varied by weekday.
[43]https://www.visitscotland.org/binaries/content/assets/dot-org/pdf/research-papers-2/regional-factsheets/dundee-and-angus-factsheet-2018-v2.pdf
Note the annual visit statistic used is for Dundee and Angus. While this may overestimate tourist cars visiting Dundee, EV drivers are more likely to visit Dundee (even if just passing through to charge) due to the provision of EVCPs, so this figure accounts for EV drivers in surrounding areas passing through Dundee.

10.2 Charging demand

10.2.1 Current provision

Currently there is a good coverage of charge points both in terms of charging speed and geographic spread in Dundee city. The council worked closely with members of the local Dundee Partnership, which includes NHS Tayside, the University of Dundee as well as taxi companies and businesses to deliver a unique city-wide approach to charging infrastructure. Senior level political buy-in ensured that the city was encouraged to bid for large scale infrastructure grants from both Scottish and UK governments and became one of only eight Go Ultra Low Cities in the UK, being Scotland's only representative. The city's proactive approach to installing innovative infrastructure has ensured that it continues to receive significant funding and support from key agencies involved in the promotion of electric vehicles.

10.2.2 Demand forecast

The following assumptions have been used in estimating demand for charging in 2032:

- The number of visitors and profile of visiting times will remain constant.
- The proportion and profile of visitors travelling by private (including rentals and car club vehicles) car will remain constant.
- The share of tourist cars that are EVs in 2032 will be 46%.
- The most likely route is assumed to be visitors travelling from Edinburgh, so the average daily mileage is assumed to be 100 km per day (not including return trip for tourists doing a day trip).
- Energy expended has been estimated assuming 0.2 kWh / km, so the average energy use per tourist EV is 20 kWh.
- Many tourists are assumed to visit Dundee for the day, therefore it is assumed that most of the demand for charging will be during the day rather than at night (see Table 29).

Table 29: Charging assumptions for Dundee City centre for the average day and the worst-case scenario

	Average day	Worst-case scenario
Time spent charging during the day (hours)	2.0	2.5
Time spent charging during the night (hours)	8.0	8.0
Share of EVs using on-site charging per day	40%	60%
Share of EVs using overnight charging per day	5%	5%
Share of EVs not charging at site	55%	35%

Modelling based on these assumptions and the available data suggests the 2032 demand profiles illustrated in Figure 59. The peak day profiles are based on the worst-case scenario assumptions being applied in the selected months.

This modelling suggests the highest hourly demand generated by tourists will reach 6,643 kW. It should be noted that this is only an estimate of the additional demand created by tourists to the city centre on top of the demand from other EVs in the city utilising the same charging infrastructure.

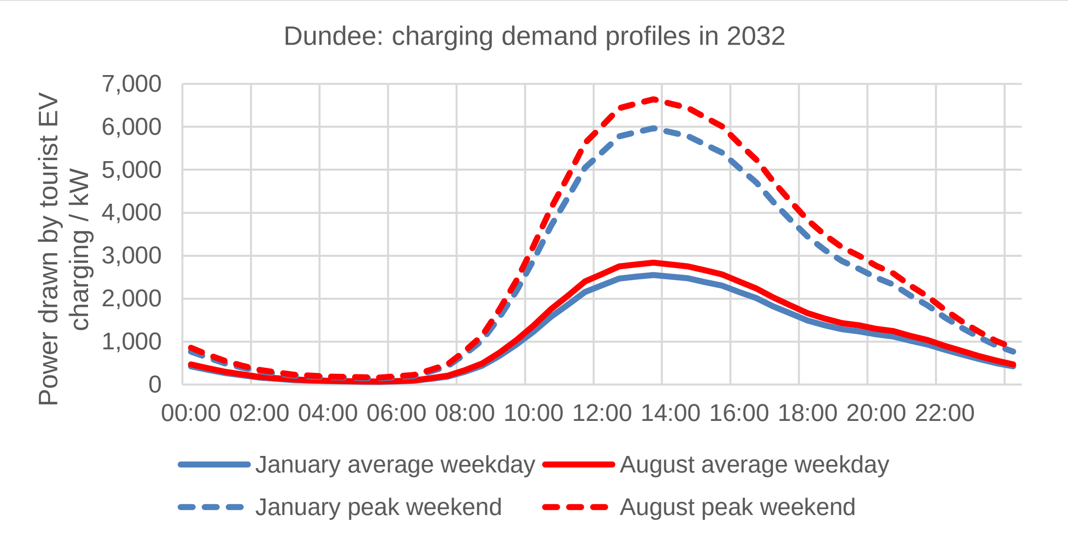

Figure 59: Estimated tourist charging demand for Dundee in 2032

10.3 Network impact findings

Of the 12 primary substations in the centre of Dundee, six were analysed in this study. Table 30 shows how charging demand has been distributed among primary substations in 2028 and 2032.

Across Dundee, primary substations have more than enough spare capacity to accommodate tourist EV charging demand, when considered in isolation from other sources of increased electricity demand (e.g. domestic EV uptake and installation of heat pumps). While constraints may occur on secondary substations, the number of these makes an exhaustive network analysis at secondary substation level prohibitively difficult. In addition, tourist EV charging demand will be greatly outweighed by residential EV charging demand as there are 68,700 cars registered in Dundee, more than five times the peak tourist car visits expected in a day.[44] Therefore any network upgrades planned to provide capacity for residential EV charging will also provide extra capacity for tourist EV charging. However, it is worth adding approximately 20% additional capacity to what would be required for residential EV charging to account for demand from tourist EV charging.

Table 30: Distribution of total charging demand predicted for Dundee to primary substations in Dundee in 2028 and 2032. Column totals may not sum to 100% due to rounding

Primary substation	Share of demand in 2028	Share of demand in 2032
Broughty Ferry	8.4%	8.4%
Constable Street	10.2%	9.2%
Lochee	10.6%	9.5%
Menzieshill	7.5%	7.9%
Ninewells	7.4%	7.9%
Overgate	8.7%	8.4%
Other primary substations	47.2%	48.6%

[44] Cars registered in Dundee calculated from number of cars in DD1 – DD5 postcodes from Department for Transport's VEH0122 table (2019) https://www.gov.uk/government/statistical-data-sets/all-vehicles-veh01

Figure 60 and Figure 61 show projected demand on Constable Street primary substation for a peak weekday in 2028 and 2032 respectively. Peak projected EV charging demand on Constable Street changes from 306 kW in 2028 to 602 kW in 2032 – the change of 0.3 MW is barely noticeable compared to the current demand on the primary substation, which is on the order on several MW.

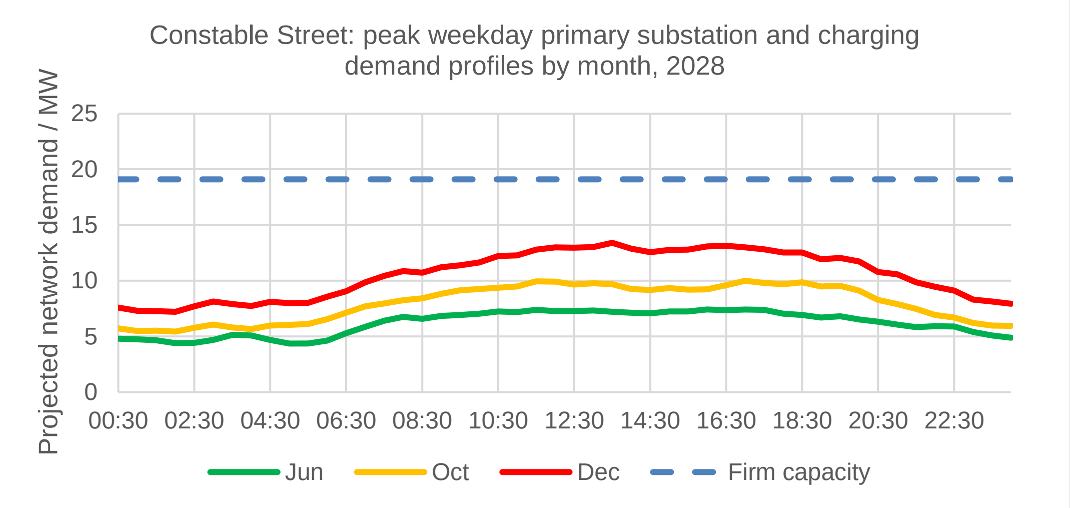

Figure 60: Projected demand on Constable Street primary substation at a peak weekday in 2028 by month

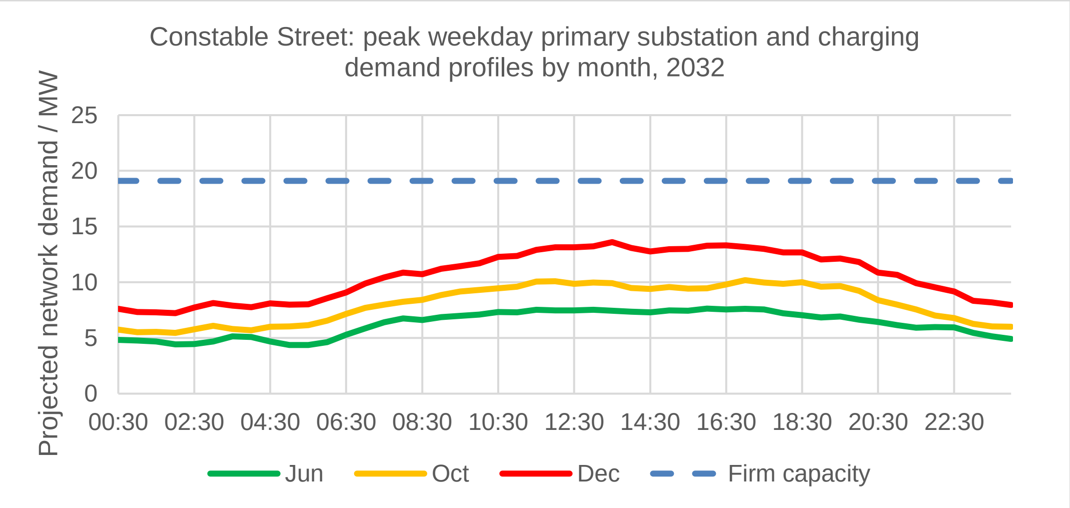

Figure 61: Projected demand on Constable Street primary substation at a peak weekday in 2032 by month

11 Conclusions and next steps

11.1 Key findings from the study

The growth in tourist EV usage across northern Scotland is not expected in itself, to lead to constraints on primary substations, as the additional demand due to EV charging is small compared to current demand at primary substation level. However, constraints are expected to occur on secondary substations in some case studies, as EV charging demand is comparable to or exceeds current demand on the low voltage network, and there is insufficient spare capacity to accommodate this increased demand at several sites. The areas likely to be worst affected are those that are popular tourist destinations with a small residential population, as the electricity grid here often has lower capacity and therefore less ability to accommodate additional demand than more populated towns and cities. These sites will require the provision of flexibility services, where feasible, or network capacity upgrades, to allow for installation and use of EVCPs.

Table 31 gives an overview of the findings for secondary substations from the network analysis. Table 32 summarises tourist visit estimates for the eight case studies, and

Table 33 compares projected charging demand for peak days in January and August 2032.

Table 31: Summary of findings from network analysis of secondary substations

Case study	Secondary substation	Current network status	Days of constraint expected in 2028	Days of constraint expected in 2032
Uig to Tarbert Ferry	Uig Pier		35	35
	Tarbert Pier		0	0
Fairy Pools	Fairy Pools Car Park		43	191
Portree	-	(analysis conducted at primary station level only)		
Inverness to Skye (A82, A87)	Stoney Lane		0	0
A82 route	Lorn Drive		200	200
	Green Welly Stop		0	0
Urquhart Castle	Urquhart Castle		52	322
A9 route	Dalwhinnie South		169	365
	Grampian Court		56	213
Dundee	-	(analysis conducted at primary station level only)		

Green: no constraints expected

Amber: constraints expected, however capacity breaches are either small or short duration, and may be manageable using flexibility services

Red: constraints expected with large or long duration capacity breaches, which will require network capacity upgrades to mitigate

The long-term impacts of the Covid-19 pandemic on tourism are not currently understood. In order to determine if the pandemic is expected to alter the results predicted for 2028 and 2032, it would be worth reviewing tourist visit numbers at a later date, for example, in two years' time. If numbers are different to those expected, then a correction factor can be applied to results from this study as needed. While the pandemic may delay or accelerate how quickly sites reach network capacity, the relative risk of different case studies reaching capacity is not expected to change – for example, Fairy Pools, Urquhart Castle and the A9 route are expected to be the case studies most at risk of network constraint regardless of any long-term effects of Covid-19.

Table 32: Summary of tourist visit estimates for the eight case studies

Case study	Daily average tourist cars visiting	Winter peak daily cars visiting	Summer peak daily cars visiting	Average daily distance travelled / km
Uig to Tarbert Ferry	20	15	54	210
Fairy Pools	120	156	264	160
Portree	200	226	440	185
Inverness to Skye (A82, A87)	480	562	975	70
A82 route	1890	2187	2839	82
Urquhart Castle	540	691	1061	110
A9 route	6480	8246	9268	76
Dundee	9070	13,057	13,099	100

Table 33: Summary of tourist EV charging demand, for peak days in January and August 2032, for each of the eight case studies

Case study	January peak day, 2032		August peak day, 2032	
	Total daily charging demand / kWh	Peak charging demand / kW	Total daily charging demand / kWh	Peak charging demand / kW
Uig to Tarbert Ferry[45]	N/A	50	N/A	50
Fairy Pools	401	52	1,160	150
Portree	1,587	200	4,596	578
Inverness to Skye (A82, A87)	716	59	2,109	172
A82 route	7,556	621	13,336	1,083
Urquhart Castle	1,088	139	4,737	614
A9 route	24,433	2,139	32,405	2,837
Dundee	57,841	5,968	64,385	6,543

[45] As charging demand was lower than 7 kW at both ferry terminals, the impact of installing different charger types has been assessed by assuming a constant charging demand dependant on charger type – see Section 3.2 for further details. This removes visibility over total daily charging demand but gives a better indication of peak charging demand that is expected

11.2 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:

- Visit statistics are often not available from any official sources, and when they are, these are only available as annual totals. Many assumptions were required to estimate how tourist visit numbers varied by month and day of the week.
- Data on tourist cars visiting attractions and using key routes is not available, so assumptions had to be made to determine numbers of tourist cars visiting sites, using routes, and the distance travelled by these vehicles.
- 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.
- This study has only been able to assess network impact on selected primary and secondary substations. However, the modelling performed in this work is being used to inform power flow analysis of the distribution network to determine the impact of additional electricity demand on other network assets, such as feeders.[46]

11.3 Next steps

This analysis will inform the next stages of the E-tourism project. Outputs from network modelling will be used to perform a power flow analysis of the distribution network. Findings from this study and the power flow analysis are being used to determine opportunities for minimising or avoiding network upgrade costs by employment of flexibility services where possible, and where network upgrades will be required. Research will be undertaken to determine what flexibility services and local solutions could be suitable, and these services may be trialled as part of the later stages of this project to determine their effectiveness. On a larger scale, the findings from these case studies and subsequent analysis will be used to inform network upgrade strategies for other tourist sites not considered in the study.

[46] This power flow analysis is currently being undertaken; for more information contact futurenetworks@sse.com