# Project EPIC

## Work Package 6:

## Network investment results for Use Case 1: EV Charger Strategy

## Final Draft

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# 1. Glossary of Terms

| Abbreviation | Term |
|---|---|
| **BEZ** | Bath Enterprise Zone |
| **BU** | Bottom Up: Bottom Up analysis starts by modelling the load at individual distribution substations and aggregating up to HV feeder level. |
| **CAPEX** | Capital Expenditure |
| **CBA** | Cost Benefit Analysis |
| **DFES** | Distribution Future Energy Scenarios |
| **DNO** | Distribution Network Operator |
| **ENA** | Energy Networks Association |
| **ESA** | Electricity Supply Area |
| **EPIC** | Energy Planning Integrated with Councils |
| **EV** | Electric Vehicle |
| **HV** | High Voltage |
| **HV NAT** | High Voltage Network Analysis Tool |
| **INM** | Integrated Network Model |
| **LCT** | Low Carbon Technology |
| **LV** | Low Voltage |
| **LV NIFT** | Low Voltage Network Investment Forecasting Tool |
| **MWh** | Megawatt Hour i.e. the energy used by consuming 1MW of power for an hour. |
| **NPC / NPV** | Net Present Cost / Net Present Value |
| **OPEX** | Operational Expenditure |
| **SPA** | Strategic Planning Area |
| **TD** | Top Down: Top Down analysis uses monitored HV feeder load profiles as a starting point to add the impact of LCT uptake. |
| **TOTEX** | Total Expenditure, the sum of all cost categories on either the network or society. |
| **WECA** | West of England Combined Authority |
| **WP** | Work Package |
| **WPD** | Western Power Distribution |
| **WS CBA** | Whole System Cost Benefit Analysis |

**Clarification on the meaning of 'Whole Systems'**

The project EPIC trial sought to consider the impacts of different investment strategies across the electricity and gas networks and on wider society. The term 'whole systems' has been used to reflect this intent, and appears throughout this report.

The results discussed do contain a whole systems element, with impacts on the electricity network and society being considered alongside each other. However, without gas network impacts incorporated into these results, 'whole systems' only constitutes these two stakeholders.

Further, there is the view that the term 'whole systems' should be reserved for analyses considering impacts from generation/production through transportation/storage, and on to end use. This goes far beyond the 'whole systems' results covered in this report.

The specific impacts considered in this report are detailed within section 4.1.3.

# 2. Document purpose and associated project deliverable

The Energy Planning Integrated with Councils (EPIC) Project trial is investigating the whole systems impact of a number of Low Carbon Technology (LCT) deployment strategies and investment approaches. Five use cases, set out in Work Package 2 (WP2) are being investigated, these are summarised in Table 1, below. Each use case passes results from High Voltage (HV) and Low Voltage (LV) network analysis tools, specified in WP4, through a Whole System Cost Benefit Analysis (WS CBA) tool. This WS CBA tool was developed outside of project EPIC by the Energy Networks Association (ENA) as part of their 'Open Networks"project, its specification and usage are detailed in Work Package (WP)3.

This document forms part of WP6 of the EPIC Trial. It describes the results of this whole systems cost benefits analysis for **Use Case 1**, assessing the impact on the network and society of an EV charger strategy reliant on a higher deployment of HV rapid charging hubs, versus a reliance on more on-street residential LV connected chargers. In addition, a sensitivity considering the impact of a low uptake of managed charging is tested.

*Table 1: The project EPIC Trial use cases*

| | |
|---|---|
| **Use Case 1: EV charger deployment** | **Comparing the network impact two EV charger deployment strategies, one with a greater reliance on LV connected on-street residential chargers, the other with a greater reliance on HV connected rapid charging hubs.** |
| Use Case 2: Energy Efficiency | Comparing the network impact of a high, low and medium standard of energy efficiency across residential and commercial customers. |
| Use Case 3: Hybrid Heat pumps | Exploring the impact of using the gas network and hybrid heat pumps to reduce peak electricity demand and electricity network costs. |
| Use Case 4: Just in Time vs. Fit for | Comparing a BAU network upgrade to meet immediate demand growth, or an investment in upgraded assets to meet longer term future demand growth. |

| | |
|---|---|
| Future | |
| Use Case 5: Flexibility | Invest in an asset upgrade or contract a flexibility solution to delay or avoid the upgrade requirement. |
| Use Case 6: Solar | Investigating the network impact of a higher deployment of large scale ground mounted solar. This is only trialled in one Strategic Planning Area (SPA) (South Bristol) |
| Use Case 7: Heat Network | Exploring the whole systems impact of using a heat network to meet all heating demand from new developments in the SPA. This is only trialled in one SPA (Bath Enterprise Zone). |

The analysis was conducted over three primaries, one in each SPA: Dorchester St, Nailsea and Cribbs causeway; this document describes the results on all three primaries. Not contained within this report are project learnings, which will be collated for all the use cases within the WP7 learnings report and largely focus on procedural and systemic learnings rather than conclusions drawn from individual results. More detailed discussion around individual LV and HV results, and their origins in network modelling assumptions, will be covered within the LV NIFT and HV NAT results which will be produced as part of WP5.

# 3. Key outcomes and conclusions

The high rapid charging hubs strategy has acted to increase HV network costs. The concentration of demand at single points in the network has led to more constraints than if load was more evenly dispersed on the LV network, as it is with the high on street strategy. This effect is greatest on the Nailsea primary, followed by Dorchester St and Cribbs Causeway.

There are also significant differences in the number of roadworks undertaken with each strategy. The high rapid charging hubs strategy has significantly more roadworks required, and this translates into a higher societal cost of roadworks out to 2050. This is most pronounced in Nailsea, with a 13% increase, Dorchester St has a 4% increase; Cribbs Causeway is less impacted.

On the LV side of the network, the high charging hubs strategy had very little effect on network costs. Only Nailsea saw the expected savings in LV CAPEX, OPEX and roadworks resulting from less reliance on LV connected on-street chargers.

Across all the primaries, a high uptake of the managed charging profile was generally consistent in having ***marginal (less than 2%) impacts*** on LV network costs. The sensitivity's less consistent but more significant impacts were on HV OPEX, a 3% and 5% decrease in Dorchester St and Cribbs Causeway respectively, and a 5% increase in Nailsea.

Because of these relatively small impacts captured here, and some modelling simplifications and difficulties discussed below, a rule of thumb cannot be suggested without further analysis. This suggests that Local Authorities can plan adopting either strategy without the risk of incurring far greater costs than if an alternative strategy were adopted. While there has been an attempt to capture the benefits under each strategy, there was no metric that could be easily applied to determine the convenience to customers of having the different mixes of charging locations. If it were found that the inclusion of more rapid charging hubs significantly improved the ability of customers to charge at a time and place convenient to them, and provided more confidence in drivers to overcome range anxiety then it could well be that any additional costs borne on the HV network were good value for money. Similarly, while in the long term it would be beneficial to have facilities to enable managed charging, the increased costs from unmanaged charging appear to be relatively small and so if managed chargers are not available then installing more basic chargers initially, rather than waiting, would be a reasonable approach.

Since the start of the project there have been changes in how upgrade costs are apportioned between the individual customer requesting a new connection or increase in capacity for an existing connection and the customer base as a whole with a greater proportion of the costs being socialised. This may result in the costs borne by local authorities installing HV connected EV chargers being lower than they were previously. Additionally, the development of packaged solutions for connection to the 33kV network to support motorway is being trialled in the Take Charge innovation project. This is likely to reduce the future costs of implementing EHV charging hubs so the potential charging options and their costs are both currently undergoing significant changes.

## 3.1. Limitations of the modelling

1) While the intention of this use case was to compare the impact on the network and society of two EV charger deployment strategies, this has been difficult. Demand from new developments on the LV network has not been modelled in the high rapid charging hubs runs of HV NAT and, as a result, the true cost impacts of this strategy are not clear. Figure 1, below, describes this issue.

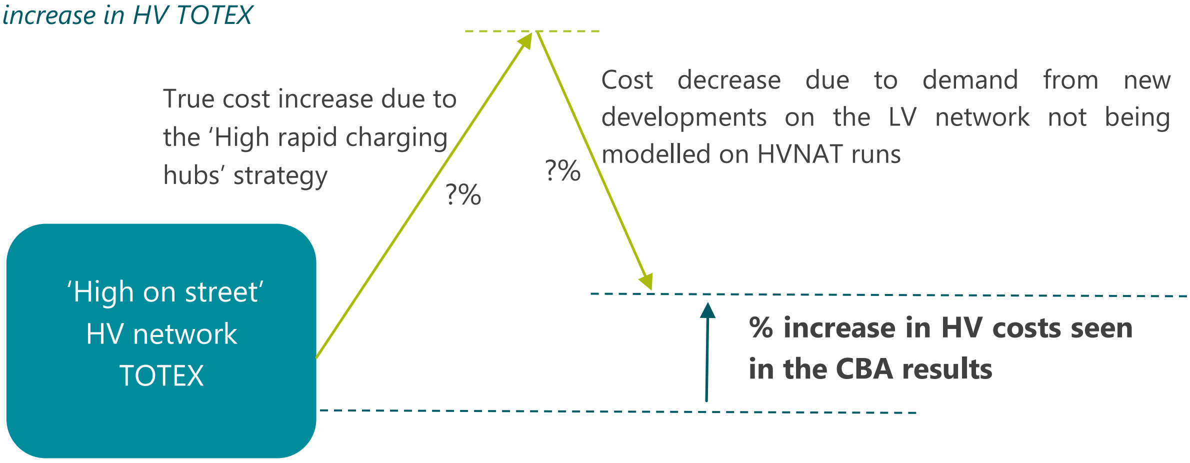
   While the true HV network costs of the high rapid charging hubs strategy are impossible to quantify at this stage, the trends discussed above (increased HV network and roadworks costs for the high rapid charging hubs strategy) are still valid.

2) The nature of the Cost Benefit Analysis method also means that significant impacts in some cost categories appear insignificant when summed into a Network or Societal TOTEX impact, or further, into a whole systems Net Present Cost (NPC).

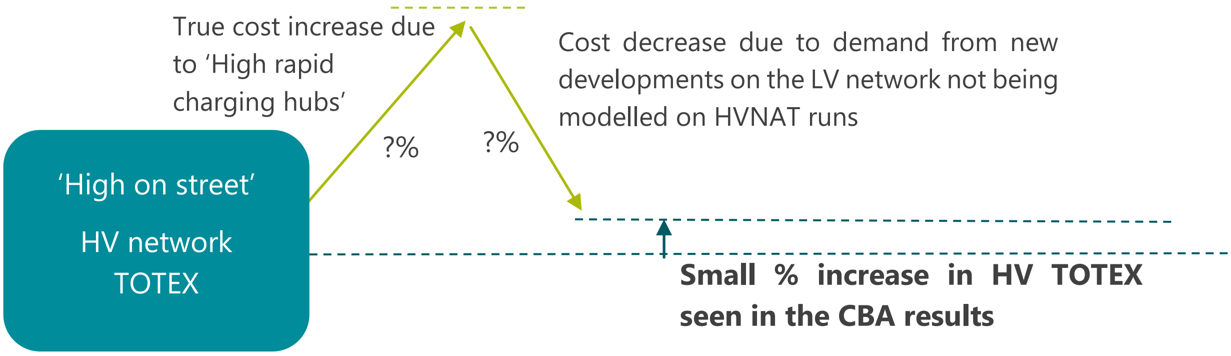
   The societal cost of emissions dominates the Societal TOTEX sum, this means that the demonstrated benefits of reduced roadworks from the high rapid charging hubs strategy do not result in a significant societal TOTEX percentage decrease. Similarly, when HV network costs are combined with LV and Societal costs into a whole system NPC, the demonstrated reductions in CAPEX and OPEX result in only marginal percentage decreases.

*Figure 1: Illustration of the impact of the 'high rapid charging hubs' strategy and the omission of demand from new developments on HV costs.*

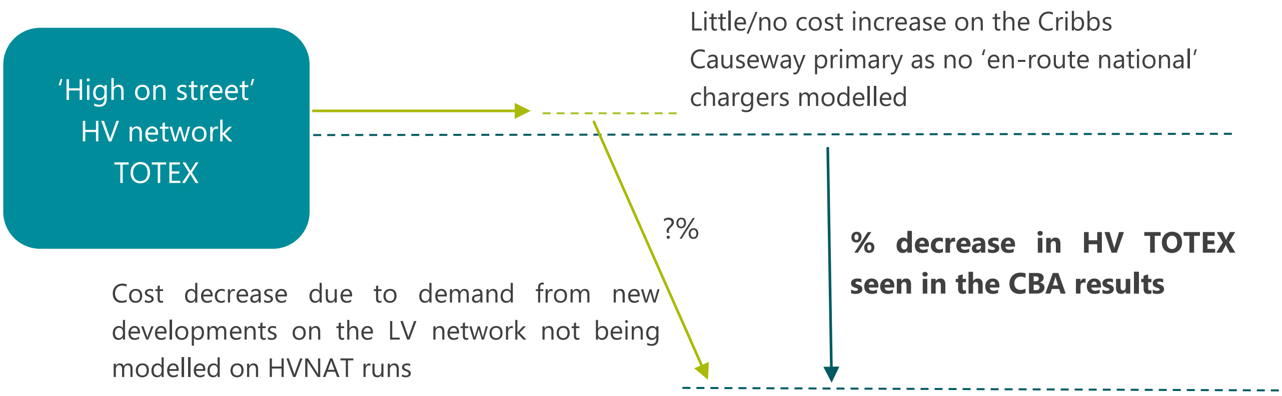
**Nailsea primary** *High Rapid charging increased HV TOTEX by an unknown amount, lack of new developments demand decreased HV TOTEX by an unknown amount. The result seen in the CBA is a net increase in HV TOTEX*




**Dorchester St primary** *High Rapid charging increased HV TOTEX by an unknown amount, Lack of New developments demand decreased HV TOTEX by an unknown amount. The result seen in the CBA is a small net increase in HV TOTEX*




**Cribbs Causeway primary** *High Rapid charging has marginal impact on HV TOTEX, as no 'en-route national' chargers were modelled. Lack of New developments demand decreased HV TOTEX by an unknown amount. The result seen in the CBA is a net decrease in HV TOTEX*



# 4. Project EPIC background

The aim of the EPIC project is to develop a network planning process that considers impacts on both the electricity and gas networks and reflects the strategic ambitions of the local authority, enabling better investment outcomes. These outcomes may lower overall cost to the consumer, offer improved risk management and also enable local partners to realise their own strategic outcomes including net zero decarbonisation, economic growth, industrial strategy and wider societal benefits. A number of previous work package deliverables have documented in detail the process of the EPIC trial, the flow chart below summarises those work packages. In light of the progress of the trial process so far, the "integrated energy development plan" output has been replaced by results reports and a series of workshops with Local Authority stakeholders which will communicate findings and discuss their impact on local energy planning.

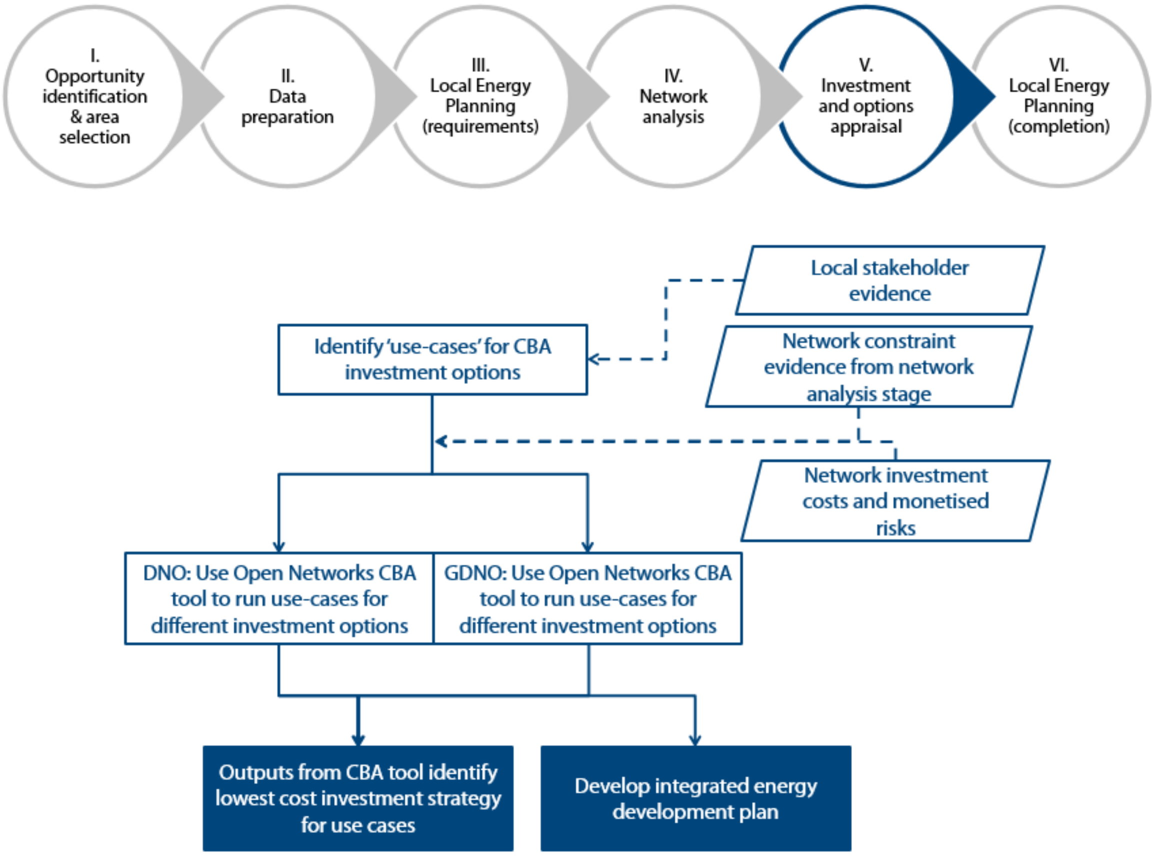



*Figure 3: The EPIC Trial Planning Process.*

## 4.1. Scope of the Whole System CBA

### 4.1.1. The Strategic Planning Areas (SPAs) and Primaries

The aim of the EPIC trial was to consider three SPAs selected in WP1, Bath Enterprise Zone (BEZ), the North Fringe and South Bristol. These were all served by multiple primary substations which were to be included in whole systems cost benefit analysis. At the time of the project, there was a change in HV modelling tool used within WPD from DINIS to PSS SINCAL. This also coincided with a change in the way the network model to be used by the HV modelling tool was provided, with the creation of an Integrated Network Model (INM). This introduced a high risk that there would be issues with the network model that would take a long time to correct. To limit that risk, the decision was taken to model only a single primary within each SPA for the analysis. For the Bath Enterprise Zone, this was Dorchester St Primary. For the North Fringe, this was Cribbs Causeway Primary, and for South Bristol this was Nailsea Primary. While results for the LV network on the remaining primaries were generated, and have been used in the LV report to discuss trends across different areas, they do not feature in the whole systems CBA. Similarly, some of the initial work to create baseline profiles on the HV analysis included a wider range of primaries.

### 4.1.2. Gas network costs

Project EPIC faced a number of challenges in integrating gas and electricity network impacts into a whole system cost benefit analysis, these are described in more detail within the learning reports but came at a number of levels.

The initial approach taken to estimate future gas demand within each SPA was to work from 2020 WPD DFES projections. These projections take the baseline of existing gas boilers (~85% of households nationally) and add additional gas boilers from new developments between now and 2025 (based on new build EPC records). The conversion of existing gas boilers to heat pumps, heat networks, hydrogen boilers and other non-gas heating is based on assumed uptake rates of the different low carbon heating technologies. For instance, heat pump uptake is based on:

- **On-gas vs off-gas**, with much more near-term uptake in off-gas homes.
- **Floorspace**, with larger homes seeing greater heat pump uptake in the near term due to more space and higher heat demand.
- **Detached/semi-detached and owner-occupied homes** in the near term, mirroring analysis of existing RHI heat pump installations.
- **Insulation**, with homes with an EPC of C or above seeing greater uptake of non-hybrid heat pumps in the near term, and homes with an EPC of D or below seeing greater uptake of hybrid heat pumps.
- **Local authority feedback** that indicated a low carbon heat strategy gave higher weighting to heat pump uptake in the near term. For those with a specific heat network strategy, deployment of standalone heat pumps was weighted away from these areas in the near term.

The remaining on-gas homes were considered to switch from natural gas to hydrogen over the coming decades, and any remaining off-gas homes not accounted for by heat pumps, direct electric heating or night storage heaters would be assumed to be using a biofuel like bioLPG or biomass.

**This 'postcode level' approach had the potential to work as a way of assigning electricity and gas network costs to the SPAs, offering a suitable granularity in gas/electricity demand changes.**

However, it was found that the postcode data on the electricity and gas network did not match; there was no way of confidently unifying the two networks by postcode. This meant an approach had to be taken which used gas low pressure networks. These networks are far larger than an equivalent Electricity Supply Area (ESA), more akin to the size of a region (Bristol and Bath), they dwarfed the SPAs and did not provide sufficient granularity on demand changes of the gas network. Furthermore, the likely approaches to decarbonising the gas grid (eg. hydrogen and biomethane) are relatively large-scale, centralised approaches, which are less suited to the geographical granularity used. For instance the development of a biomethane production plant in the Bath SPA is not feasible, but it's possible that plant remote from the SPA could provide a supply of low-carbon gas.

The scenarios that were investigated resulted in small overall demand reductions on the gas network with increases from new developments being counteracted in the same area by reductions reflecting the move from gas boilers to electric heat pumps. This resulted in a lack of reinforcement requirements but at the same time the reductions did not suggest decommissioning of assets would be a useful cost saving option either. While work has been completed in developing separate scenarios to test the process of modelling gas network upgrades, reflecting the work required to support hydrogen networks, this has also proved challenging. The gas network analysis tool does not export cost outputs, instead, the costing of solutions is a distinct activity carried out on a specific basis per project; further work on costing these solutions would have to take place before any inclusion in a whole system CBA. However, analysis and cost outputs were generated through a manual approach, so gas network impacts can be covered by the EPIC process in future.

### 4.1.3. Local Authority Costs

For the EV charger use case, a consideration of the costs to the local authority of installing and operating EV chargers was within scope of the whole systems CBA. With the help of project partners West of England Combined Authority (WECA), data was collected on CAPEX and OPEX of the different charger types.

The findings on costs for different charger types, and a basic assessment of the costs to local authorities to implement the two charger strategies are included in Appendix 4 of this report.

### 4.1.4. Cost Categories and CBA Process

The HV analysis was carried out by the HV Network Assessment Tool (HV NAT) developed by PSC and the LV analysis was provided by EA Technology using the Network Investment Forecasting Tool (NIFT). Work earlier in the project to determine which whole system costs could be considered by the network analysis tools arrived at the list of direct network and indirect societal impacts given below. Where necessary, these impacts have been monetised using calculations presented in the WP3 deliverable.

- **CAPEX:** Expenditure on asset intervention on the LV and HV networks.
- **LV OPEX:** Expenditure on LV network operation.
- **HV flexibility requirement (OPEX):** The total volume of flexibility needing to be procured on the HV network, valued at £300/MWh, as a measure of HV operating costs.

- **Losses:** Electrical losses on the HV and LV network, valued at £62/MWh.
- **Roadworks:** Number of instances of asset intervention which require roadworks. This is considered both as a direct cost for the Distribution Network Operator (DNO) at £244/instance, and indirectly on society at £1332/instance.
- **Final Demand (emissions):** The final demand met by the HV network and its associated emissions impact on society. This is valued using assumed grid carbon factors, and a societal value of carbon.
- **Spare Capacity:** The value to society of extra network capacity unlocked by network CAPEX intervention, resulting in cheaper connections. The valuation is based on an average cost per MW of LV and HV network: £199k/MW for the LV network, £298k/MW for the HV network.

Important to the estimation of the Net Present Cost (NPC) of each strategy was the provision of these costs on an annual basis out to 2050. This was possible on the LV network from LV NIFT. On the HV side, HV NAT output annual increments up to 2035, followed by five-yearly increments out to 2050.

Within the CBA tool, these costs are allocated to either the networks or to society. The diagram below outlines this allocation:.

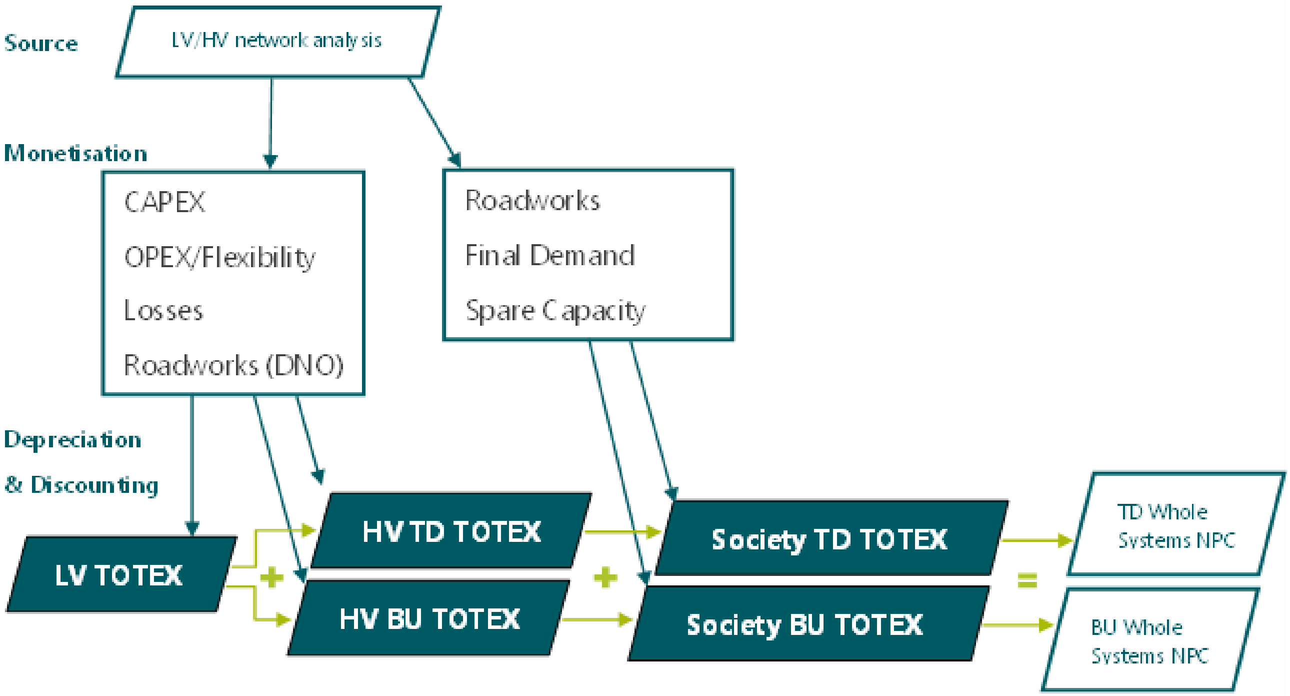



*Figure 4: The allocation of the cost categories to the networks and society.*

The diagram also illustrates how Top Down (TD) and Bottom Up (BU) analysis[1] of the HV network are considered. These two methods of analysis have produced separate results for the HV network which result in distinct societal and whole systems costs. The requirement for both Top Down and Bottom Up analysis reflects the different sources of data available and different approaches to planning for both HV and LV networks. Primary substations typically have monitoring installed at the 11kV feeder circuit breakers but most distribution substations are not monitored. Therefore while the total feeder load is know the loads at different distribution substations are estimated by pro-rating the total load, typically by transformer rating. Thus loads are allocated in a "Top-Down" method when modelling the HV networks. While this method has the advantage that the sum of the distribution loads will equal the monitored load for the feeder, it has the disadvantage that shape of the profiles at the distribution substations are all the same, rather than reflecting the particular mix of customers on that substation.

However when modelling LV networks estimated loads would be built up from knowledge of the connected customers for that substation and profiles for typical customer types. Adding expected customer loads would provide profiles at the distribution substation level that should be more accurate in terms of profile shape but may not sum together along the feeder to equal the observed load at the source circuit breaker. Currently there are advantages and disadvantages for both top-down and bottom-up approaches but over time, as more distribution substations are monitored and smart meter data informs the estimated load profiles at distribution substations, it is likely that the bottom-up approach will become more accurate and will inform HV modelling.

The CBA tool applies depreciation to CAPEX, sums annual costs into TOTEX and discounts the value of future costs in line with best practice in network investment planning and government guidelines. Summing the TOTEX values for the LV network, HV network and society gives a whole system NPC for each tested strategy.

# 5. Results – Use Case 1: EV Chargers

The results below convey the final iteration of network analysis runs which were able to be conducted in the timescale of the EPIC trial process. Early runs of network analysis identified results which were not consistent with expectations, for instance, the high HV connected rapid charging hubs strategy had lower requirements for HV network related roadworks. The processing of the CBA results helped sense check modelling assumptions and modifications to the HV model were followed by subsequent iterations of results. The WP7 learning report documents this in more detail.

[1] Top Down analysis uses monitored HV feeder load profiles as a starting point to add the impact of LCT uptake whereas Bottom Up analysis starts by modelling the load at individual distribution substations and aggregating up to HV feeder level.

This Use Case assesses the impact on the network and society of two EV charger strategies:

- "high on-street, high managed charging", relies on a high number of on-street residential chargers connected at LV level and that to a large degree the charging profiles will be managed to avoid use at peak times.
- "high rapid charging hubs", assumes a smaller amount of LV connected on-street chargers but also deploys a number of rapid charging hubs connected to 11kV feeders.

In addition, a sensitivity modelling a low uptake of ToU tariffs which incentivise drivers to charge overnight, is trialled. The flexed profile which results from these tariffs, seen below in Figure 6, shifts most charging demand to 10pm to 3am and should reduce peak demand on the networks, leading to reduced investment requirements. Further detail on the modelling assumptions that constructed these strategies can be found within WP5 deliverables.

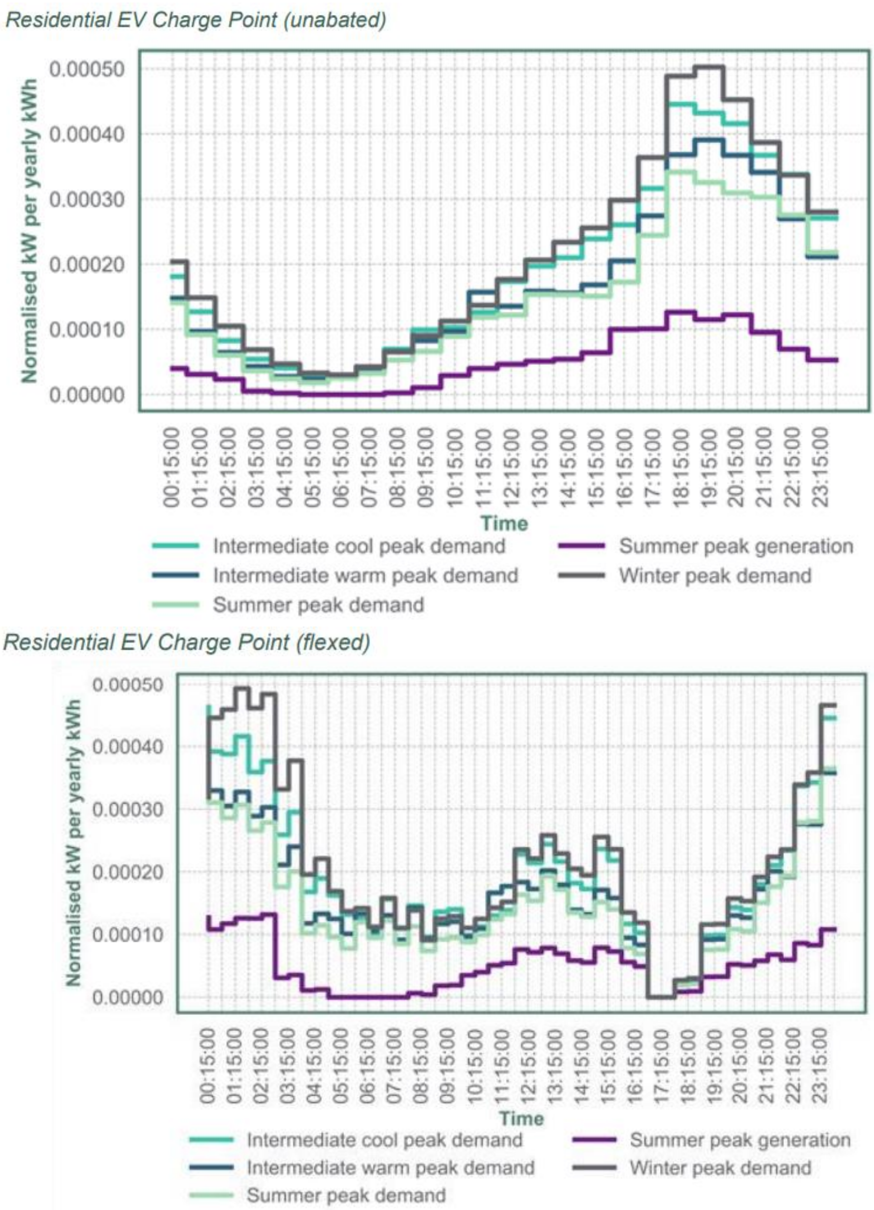



*Figure 5: Comparison of the unabated and flexed charging profiles. The "low managed charging" sensitivity models a low uptake of the flexed profile.*

Table 2 below describes the structure of the comparisons made in this report. While absolute costs have been calculated for each strategy, the focus of the report is on the relative costs/benefits of the different strategies and these will be expressed as percentages of the reference strategy.

In this case, **the reference strategy is the "high on-street, high managed charging" variation**, and **percentage increases or savings** for the **"high rapid charging hubs"** strategy and **"low managed charging sensitivity"** will be reported.

*Table 2: The EV charger strategies and sensitivities being tested in Use Case 1 and impacts discussed in this report.*

| | Strategy 1: **high on-street residential chargers** (reference strategy) | Strategy 2: **high rapid charging hubs** |
|---|---|---|
| Sensitivity 1: **high managed charging** | Reference strategy & sensitivity | % change in costs/benefits |
| Sensitivity 2: **low managed charging** | % change in costs/benefits | % change in costs/benefits |

Table 3, below, illustrates the relative impact of the high rapid charging hubs or low managed charging sensitivity on all cost categories. Grey cells cover those cost categories which have marginal (less than 2%) changes in overall cost between strategies/sensitivities. Those cost categories which do see some variation, 2 – 10%, are highlighted in orange, while variations over 10% are highlighted in red. What is immediately clear is the regularity of marginal or small impacts, and the near total absence of any significant impact when costs are summed into TOTEX and whole system costs, shown in Table 4.

*Table 3: Results overview for each cost category on each primary.*

| | CAPEX | | | OPEX | | | Losses | | | Roadworks | | | Emissions | | | Spare Capacity | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LV | HV BU | HV TD | LV | HV BU | HV TD | LV | HV BU | HV TD | LV | HV BU | HV TD | LV | HV BU | HV TD | LV | HV BU | HV TD |
| Dorchester St | | | | | | | | | | | | | | | | | | |
| Cribbs Causeway | | | | | | | | | | | | | | | | | | |
| Nailsea | | | | | | | | | | | | | | | | | | |

*Table 4: Results overview for TOTEX and whole systems cost on each primary.*

| | TOTEX | | | | | | |
|---|---|---|---|---|---|---|---|
| | LV | HV BU | HV TD | Societal BU | Societal TD | WHOLE SYSTEM TD | WHOLE SYSTEM BU |
| Dorchester St | | | | | | | |
| Cribbs Causeway | | | | | | | |
| Nailsea | | | | | | | |

| |
|---|
| Less than 2% difference in costs between strategies |
| 2 - 10% difference in costs between strategies |
| Over 10% difference in costs between strategies |

For those highlighted instances where there is over 2% difference between the strategies, the results are summarised below and illustrated graphically in Appendices 1-3.

An important caveat to these results is that for the runs of HV NAT which tested the high rapid charging hubs deployment, new developments connected on the LV network were not captured.

This will result in lower HV CAPEX, OPEX, losses and roadworks for the high rapid charging hubs strategy. Any savings in HV expenditure may be overstated, any increases in HV expenditure may be understated. As Cribbs Causeway has a significantly smaller LV network than the other two primaries, this effect will be less significant on the Cribbs Causeway comparisons.

We can also observe that the Cribbs Causeway primary seems to have a bigger difference in costs between strategies than the other two sites. This can be explained by the lack of the deployment of the En-route national chargers in this primary. Where a deployment of these chargers would increase CAPEX, the lack of these chargers meant that large savings were in fact a result of the lack of modelled LV new developments in the high rapid charging hubs runs.

## 5.1. CAPEX

### 5.1.1. Dorchester St

LV CAPEX is not significantly impacted by the high rapid charging hubs strategy or the low managed charging sensitivity.

The high rapid charging hubs strategy results in 8% increases in HV CAPEX over the high on street strategy, both in top down (TD) and bottom up (BU) analysis. This is to be expected as rapid charging hubs are increasing the HV load at specific points on the HV feeder compared to a more dispersed increase in load under the high on-street charging scenario. Due to the omission of new LV demand in the high rapid charging hubs run, this CAPEX increase may be understated.

The low managed charging sensitivity has zero impact on HV CAPEX on this primary.

### 5.1.2. Cribbs Causeway

LV CAPEX is not significantly impacted by the high rapid charging hubs strategy or the low managed charging sensitivity.

On this primary, the opposite trend is observed, with the high rapid charging hubs strategy delivering 2.5% savings in HV BU CAPEX on the high on street strategy. In TD analysis, the high rapid charger strategy delivers 35% savings. This is a notable result and driven by significantly reduced CAPEX in 2045. This is explained by a combination of modelling assumptions and omissions. In the EPIC data, the 'en-route national' charger sub-technology is not deployed in the Cribbs Causeway primary. This is the only charger sub technology which is modelled to have an impact on EV demand. While in the other primaries the deployment of these chargers results in CAPEX increases, on Cribbs Causeway there is no associated increase. This means that the cost reductions seen here are due to the lack of LV new developments being modelled in the high rapid charging hubs strategy.

The low managed charging sensitivity again has zero impact on HV CAPEX.

### 5.1.3. Nailsea

The LV network does see some significant results on this primary, with the high rapid charging hubs strategy having 4% savings on LV CAPEX. These LV Capex savings are expected, as the high rapid charging hubs strategy results in fewer on-street units being connected to the LV network.

The low managed charging sensitivity increases LV CAPEX by 2%.  Increases in capex are expected with this sensitivity scenario as it would tend to increase loads at the traditional peak time (but in some cases can create an alternative peak load at a different time of day.)

These impacts are only visible on the Nailsea LV network, as it is a significantly larger primary than Cribbs Causeway or Dorchester St both in terms of the number of customers it serves and the number of EV charge points already registered there.

On this primary, the high rapid charging hubs strategy has 5% increases in HV BU CAPEX over the high on street strategy, a similar result to Dorchester St. Again, top down analysis produces a significant result, 20% increases in HV CAPEX for the high rapid charging hubs strategy, driven by increased CAPEX requirements in 2033 and 2050. This is a similar result to Dorchester St; again these increases may be understated as a result of the omission of LV new developments in the modelling.

## 5.2. OPEX

OPEX results are highly dependent on the number of smart solutions being deployed by the LV NIFT and HV NAT models. It has not been possible to investigate specific results and interrogate where smart solutions have been deployed. However, as a constraint may be resolved with a smart solution, which has small CAPEX but large OPEX, or a traditional network asset intervention which will have large CAPEX and small OPEX, it can be assumed that strategies with an upwards OPEX impact have deployed more smart solutions.

The HV results summarised below follow a similar trend to the CAPEX results, with small overall impacts on Dorchester St and Nailsea and a larger difference seen on Cribbs Causeway. The high rapid charging hub strategy acts to increase HV OPEX. This upward impact is offset by the reductions in demand due to the lack of LV new developments in the high rapid charging hub runs. In Cribbs Causeway, where no en-route national chargers are deployed, there is no upward impact, and so the downward impact of the new developments omission is more pronounced.

### 5.2.1. Dorchester St

LV OPEX is not significantly impacted by the high rapid charging hubs strategy or the low managed charging sensitivity.

BU and TD analysis share similar results on this primary. The high rapid charging hubs strategy gives 2% savings in HV OPEX.

In addition, the low managed charging sensitivity does have an impact, leading to 3% OPEX increases. Though this is a small change, it is an expected result, with the managed charging profile shifting demand away from the evening peak and reducing associated network peak demand.

### 5.2.2. Cribbs Causeway

LV OPEX is not significantly impacted by the high rapid charging hubs strategy or the low managed charging sensitivity.

BU analysis gives a 15% saving in HV OPEX for the high rapid charging hubs strategy. This is due to consistent savings starting in 2030. TD analysis produces a larger 35% saving. This is due to significant savings in 2040, 2045 and 2050. This could be explained by the omission of LV new developments demand in the high rapid charging hubs runs.

Again, the low managed charging sensitivity leads to 5% increases in HV OPEX.

### 5.2.3. Nailsea

As with LV CAPEX, in Nailsea small differences are seen in LV OPEX, a 2% saving for the high rapid charging hubs strategy. The low managed charging sensitivity marginally increases LV OPEX.

BU analysis produces a 2% increase in HV OPEX for the high rapid charging hubs strategy. Again, the TD result is more dramatic, a 9% saving in HV OPEX for the high rapid charging hubs strategy. As with Cribbs Causeway and Dorchester St this appears to be a counter intuitive trend but could be explained by the omission of LV new developments demand in the high rapid charging hubs runs.

In contrast to the other two primaries, the low managed charging sensitivity here leads to a decrease in HV OPEX, by 5%.

## 5.3. Losses

HV losses are identical between strategies because losses have been modelled as a portion of final demand. With the total number of EVs and associated charging demand consistent across the strategies, overall HV demand does not change.

### 5.3.1. Nailsea

Small savings in LV losses are delivered by the high rapid charging hubs strategy post 2030. Totalling to a 2.5% savings by 2050.

## 5.4. Roadworks

The HV results summarised below follow a similar trend to the CAPEX and OPEX results, with smaller overall impacts on Dorchester St and Nailsea and a larger differences seen on Cribbs Causeway. The high rapid charging hub strategy acts to increase HV roadworks. This upward impact is offset by the reductions in demand due to the lack of LV new developments in the high rapid charging hub runs. In Cribbs Causeway, where no 'en-route national' chargers are deployed, there is no upward impact, and so the downward impact of the LV new developments omission is more pronounced.

### 5.4.1. Dorchester St

There is no significant difference in the LV roadworks result, with small differences between the strategies at somewhat regular intervals, leading to marginal overall impact.

There is more of a temporal trend with the HV roadworks, increases in interventions mainly occurring in the 2030s for the high rapid charging hubs strategy. These combine to a 4% increase in the cost of roadworks out to 2050.

### 5.4.2. Cribbs Causeway

There is no difference between the LV roadworks results on this primary. There are however, significant differences on the HV side, the high rapid charging hubs having 35% savings in HV roadworks, this is not the expected trend and is seen from both BU and TD analysis. As mentioned, this is explained by the lack of demand from LV new developments in the high rapid charging hubs runs.

### 5.4.3. Nailsea

There is significant variation in LV roadworks between strategies on this primary. 15% savings for the high rapid charging hubs strategy and 13% increases for the low managed charging sensitivity. This is an intuitive result, but significant in that it is the only primary where there are non-marginal differences in LV roadworks. The LV impacts showing up on this primary could be explained by an on average longer feeder length, when compared to the other primaries.

From BU analysis, The HV network sees a 15% increase in roadworks for the high rapid charging hubs strategy, this is the expected trend. The TD result is similar but not as severe (7% increase for the high rapid charging hubs strategy). The low managed charging sensitivity has a small upward impact on roadworks.

## 5.5. Emissions (Final Demand)

Emissions impact is calculated though final demand on the HV network. As both strategies and sensitivities assume equal final demand, there is no change in emissions between strategies.

## 5.6. Spare Capacity

The method of assessing spare capacity did not result in any significant differences between the strategies. It is suspected that the large 2019 CAPEX interventions played a role in making any subsequent CAPEX interventions and their additional spare capacity benefit negligible.

## 5.7. TOTEX

Summing the above cost categories produces TOTEX values for the LV and HV network, and for society who are impacted by any variations in roadworks, spare capacity and emissions.

As described above there are negligible differences between the Spare Capacity delivered by the different strategies. The scale of the emissions valuation described above means that the societal TOTEX sum is dominated by emissions. The negligible changes seen in emissions between strategies, means that the societal TOTEX sums all present negligible societal impact. This is despite there being identifiable impacts in roadworks.

As illustrated in Table 4 above, the only significant TOTEX variations produced by the results come on the HV network on the Cribbs Causeway and Nailsea primary.

On the Cribbs Causeway primary, the high rapid charging hubs strategy has 2.5% or 7% reduced HV TOTEX from the BU and TD models respectively, this being driven by the CAPEX variations outlined above. The low managed charging sensitivity has negligible effect.

On the Nailsea primary, the high rapid charging hubs strategy has 2% or 4% increased HV TOTEX from the BU and TD models respectively, again being driven by CAPEX. The low managed charging sensitivity has negligible effect.

Being driven by CAPEX, these TOTEX impacts can be again be explained by the omission of LV new developments demand in the high rapid charging hubs runs:

- On Cribbs Causeway, the lack of en-route national network chargers in the scenario and the lack of LV new development demand has resulted in reduced Network TOTEX for the high rapid charging hubs strategy.
- On Dorchester St, the modelling of en-route national network chargers increased network TOTEX, this was mostly offset by the lack of LV new developments demand - resulting in little net change in TOTEX for the high rapid charging hubs strategy.
- On Nailsea, the upward impact of the en route national chargers was sufficient to outweigh the decrease in TOTEX from the lack of LV new development demand – resulting in a small net increase in TOTEX.

## 5.8. Whole Systems Net Present Cost

The nature of the Cost Benefit Analysis method means that significant impacts in some cost categories appear insignificant when summed into a whole systems Net Present Cost (NPC); these results indicate no significant change in whole systems NPC between the high on street residential charger strategy and the high rapid charging hubs strategy. The same is true of a high or low uptake of managed charging.

# 6. APPENDIX 1: Dorchester St significant results

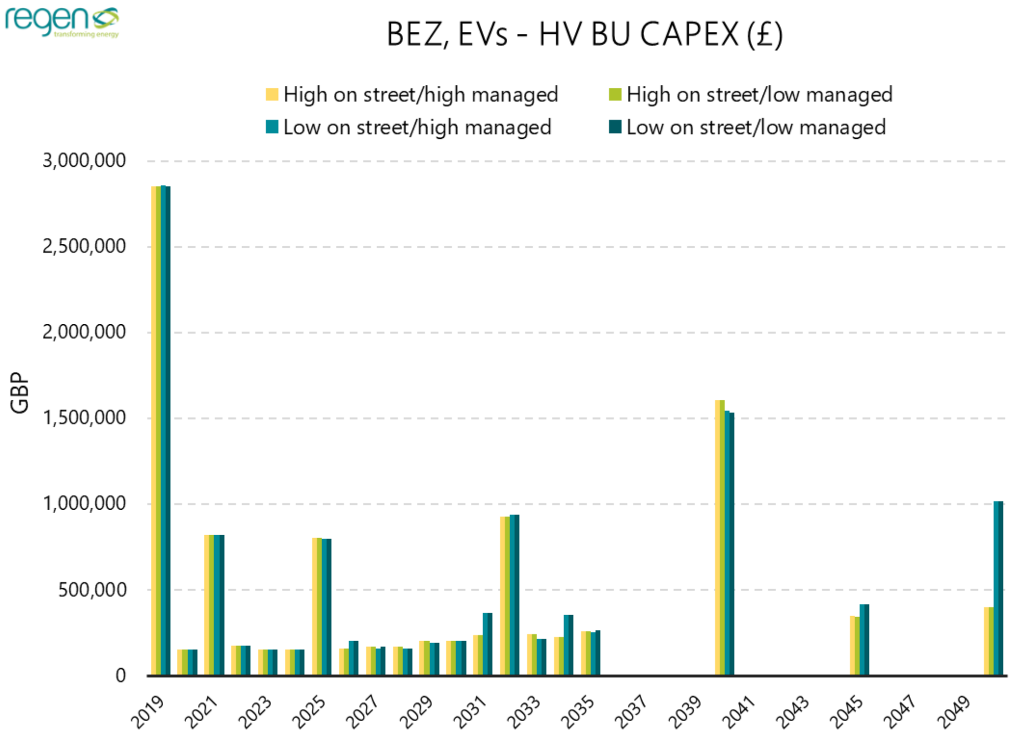



*Figure 6: Absolute HV CAPEX from bottom up analysis*

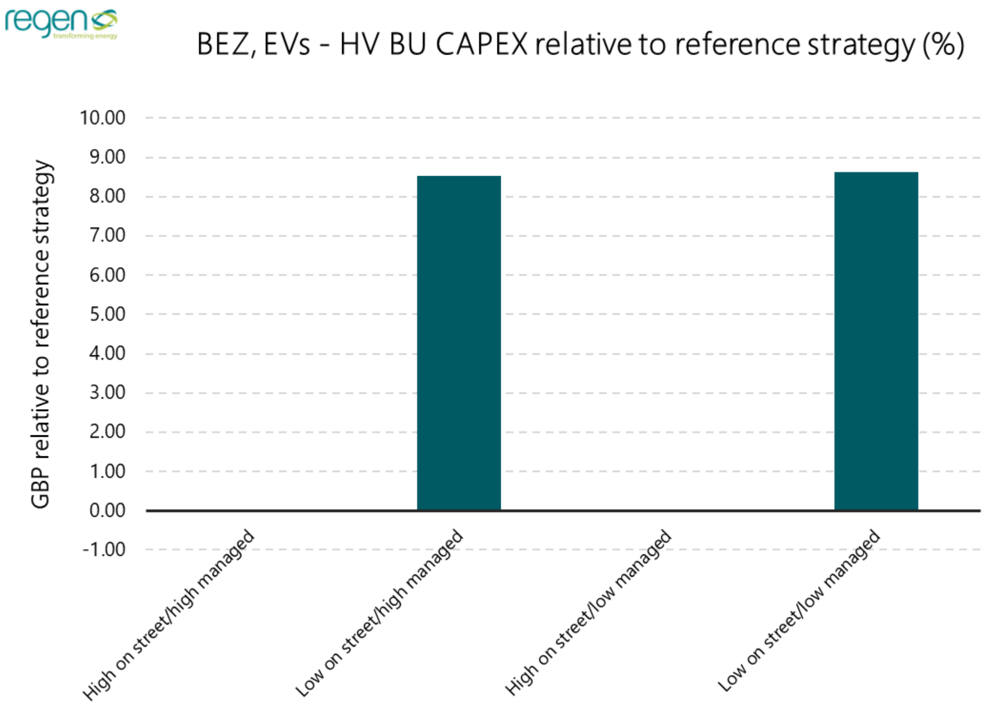



*Figure 7: Relative HV CAPEX from bottom up analysis*

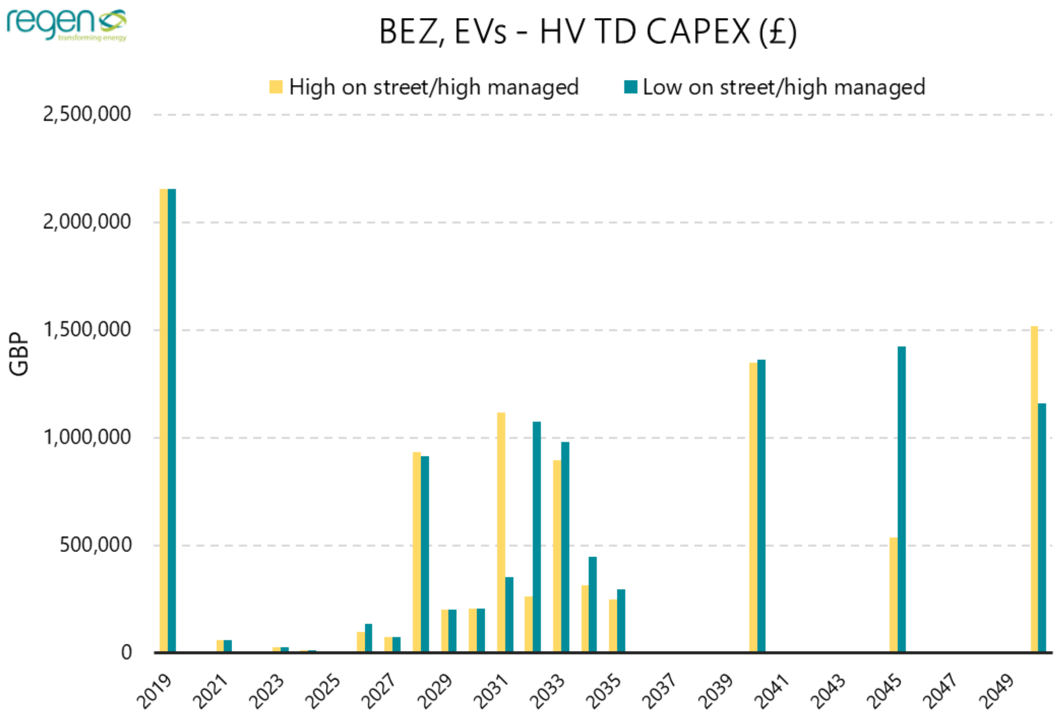



*Figure 8: Absolute HV CAPEX from top down analysis*

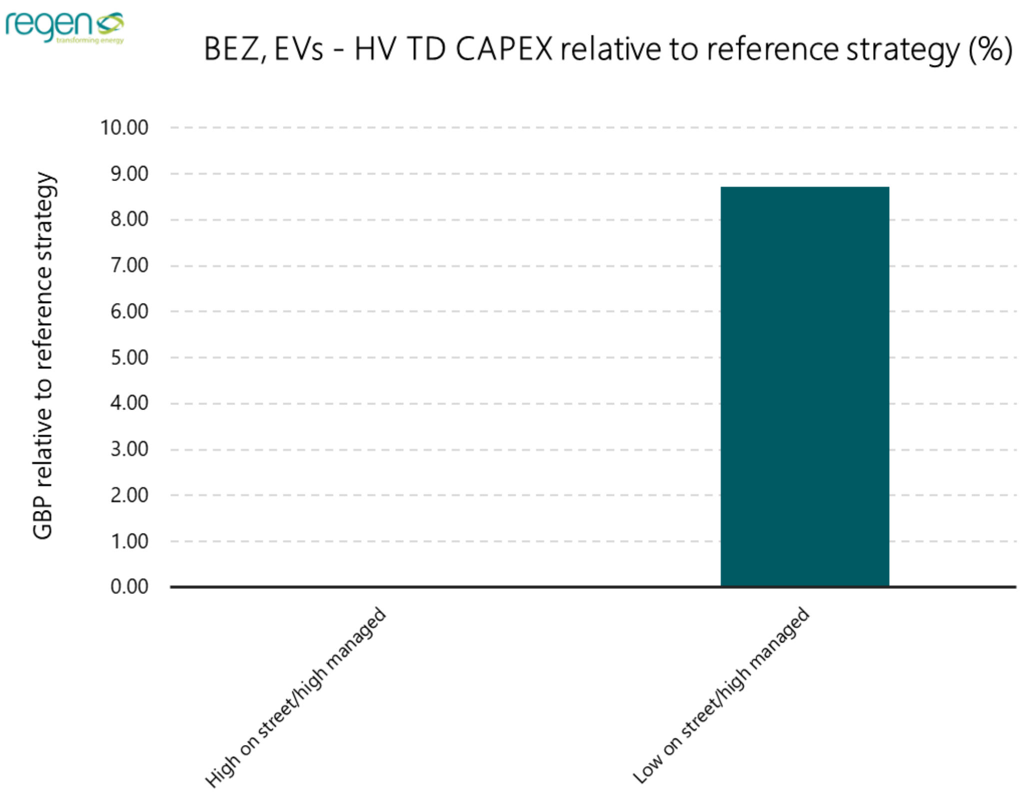



*Figure 9: Relative HV CAPEX from top down analysis*

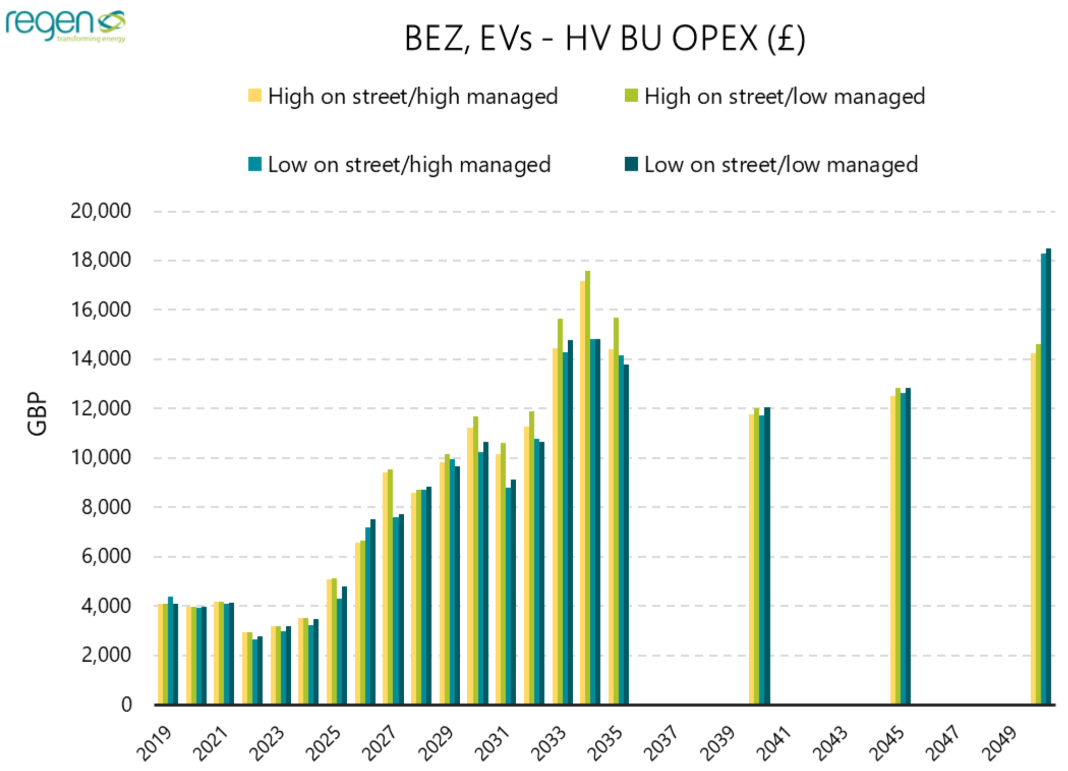



*Figure 10: Absolute HV OPEX from bottom up analysis*

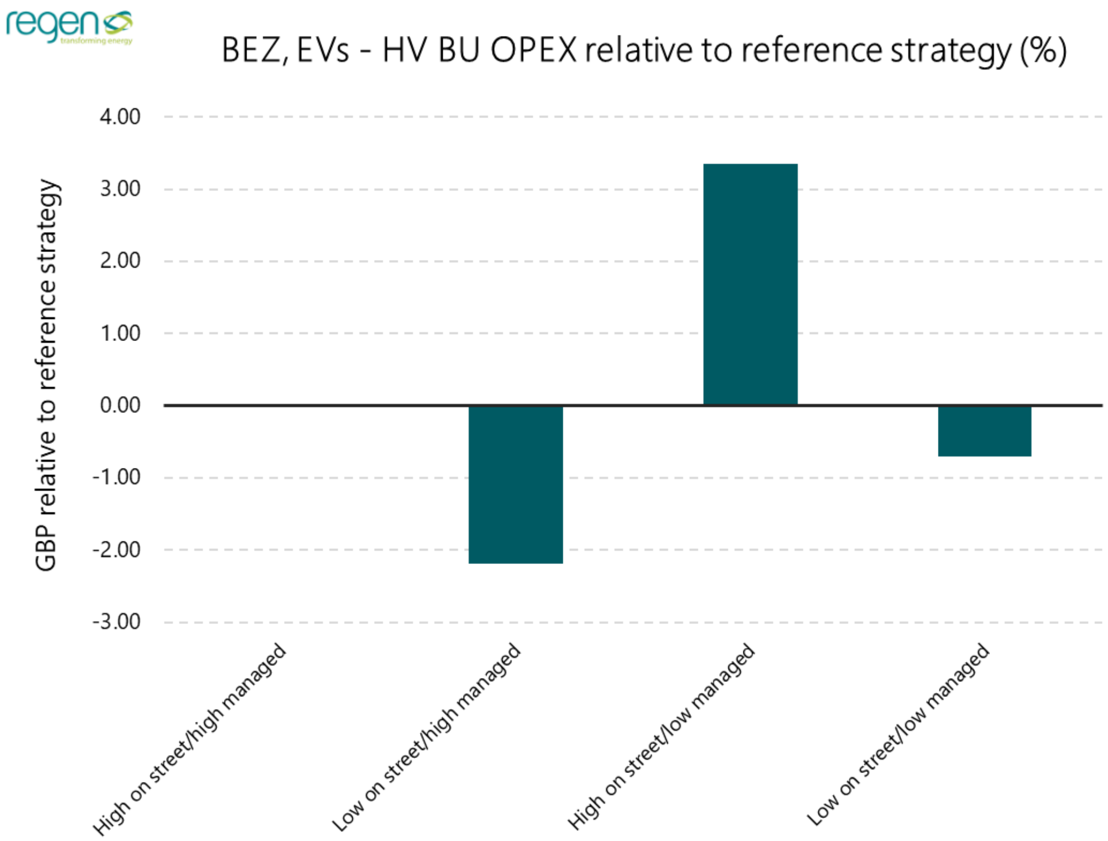



*Figure 11: Relative HV OPEX from bottom up analysis*

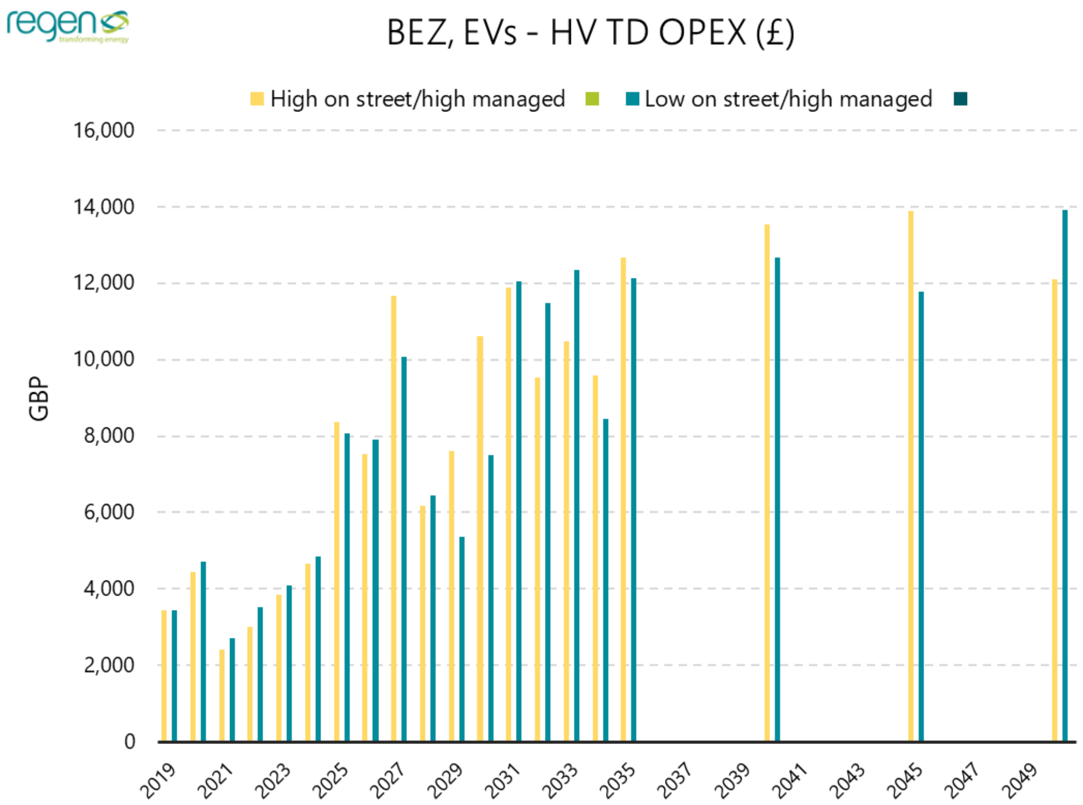



*Figure 12: Absolute HV OPEX from top down analysis*

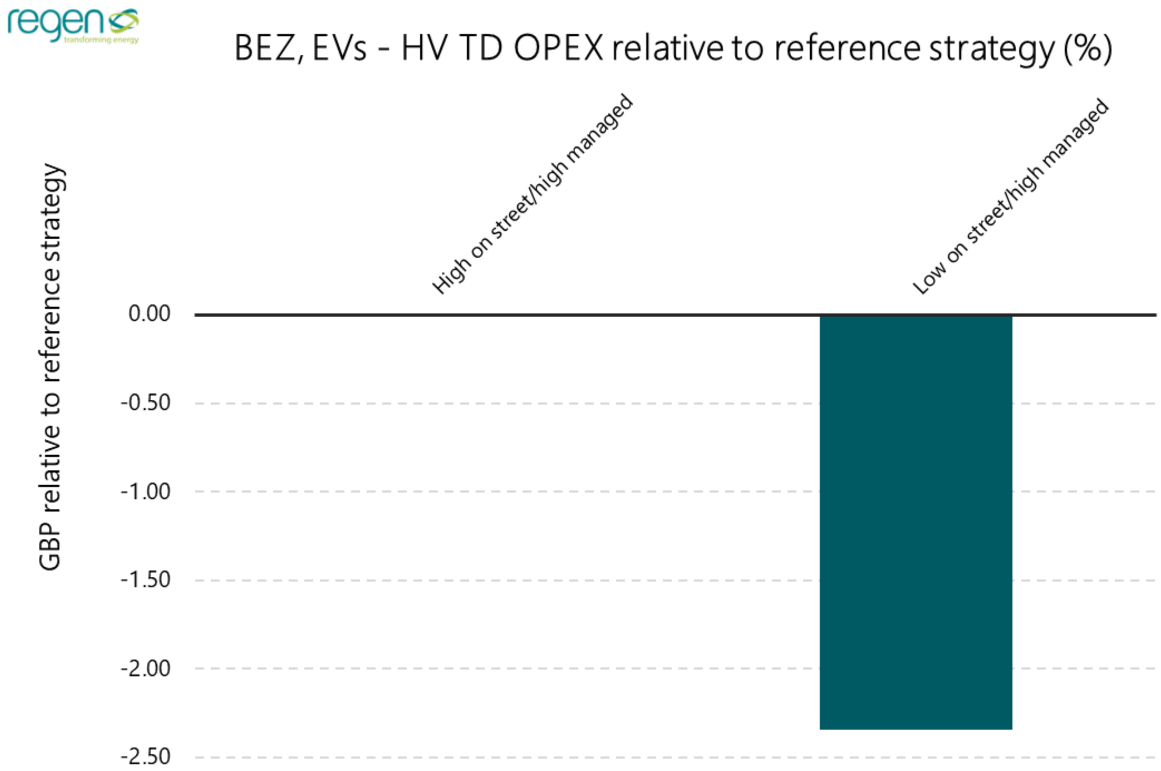



*Figure 13: Relative HV OPEX from top down analysis*

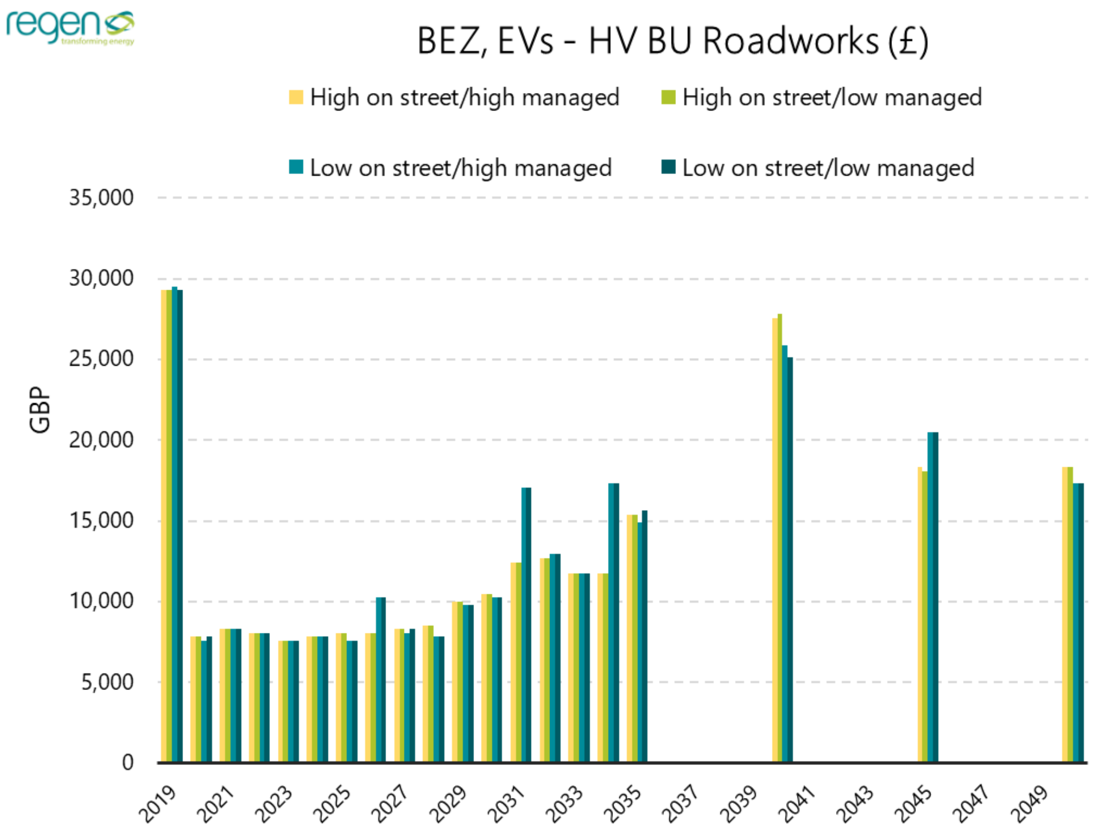



*Figure 14: Absolute HV Roadworks from bottom up analysis*

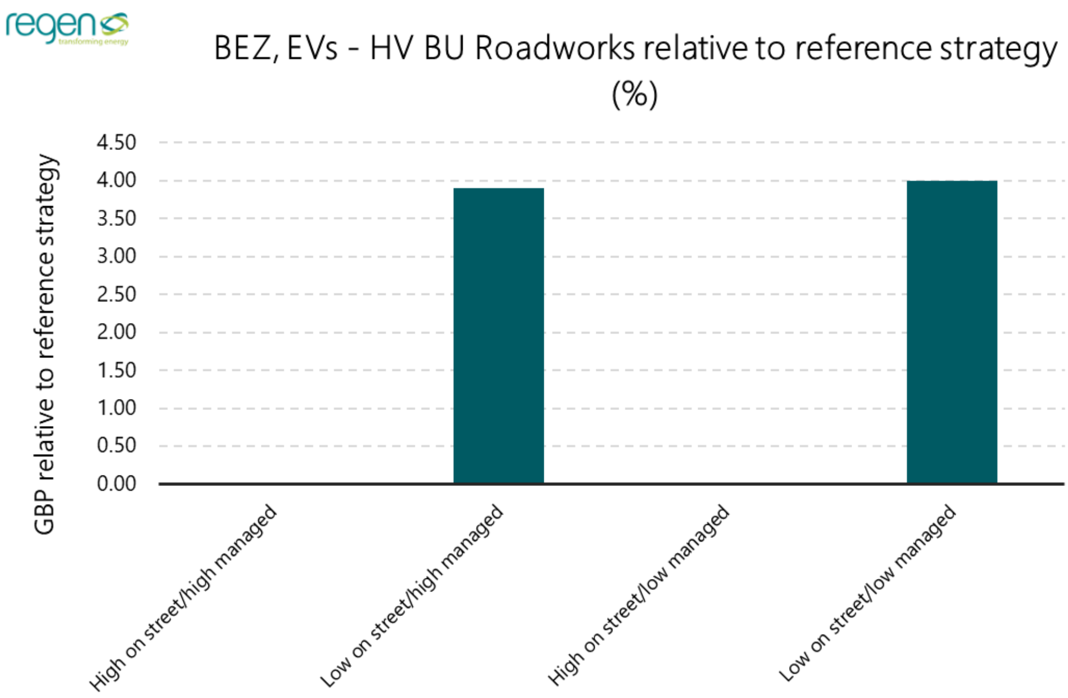



*Figure 15: Relative HV Roadworks from bottom up analysis*

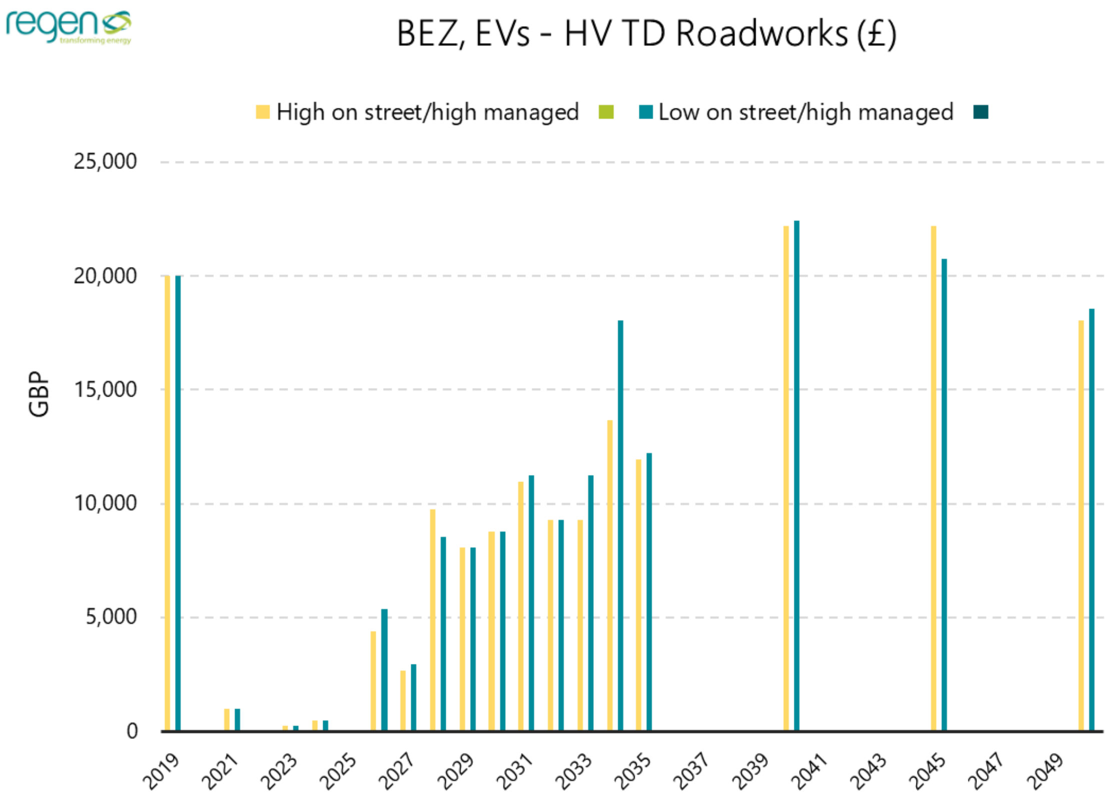



*Figure 16: Absolute HV Roadworks from top down analysis*

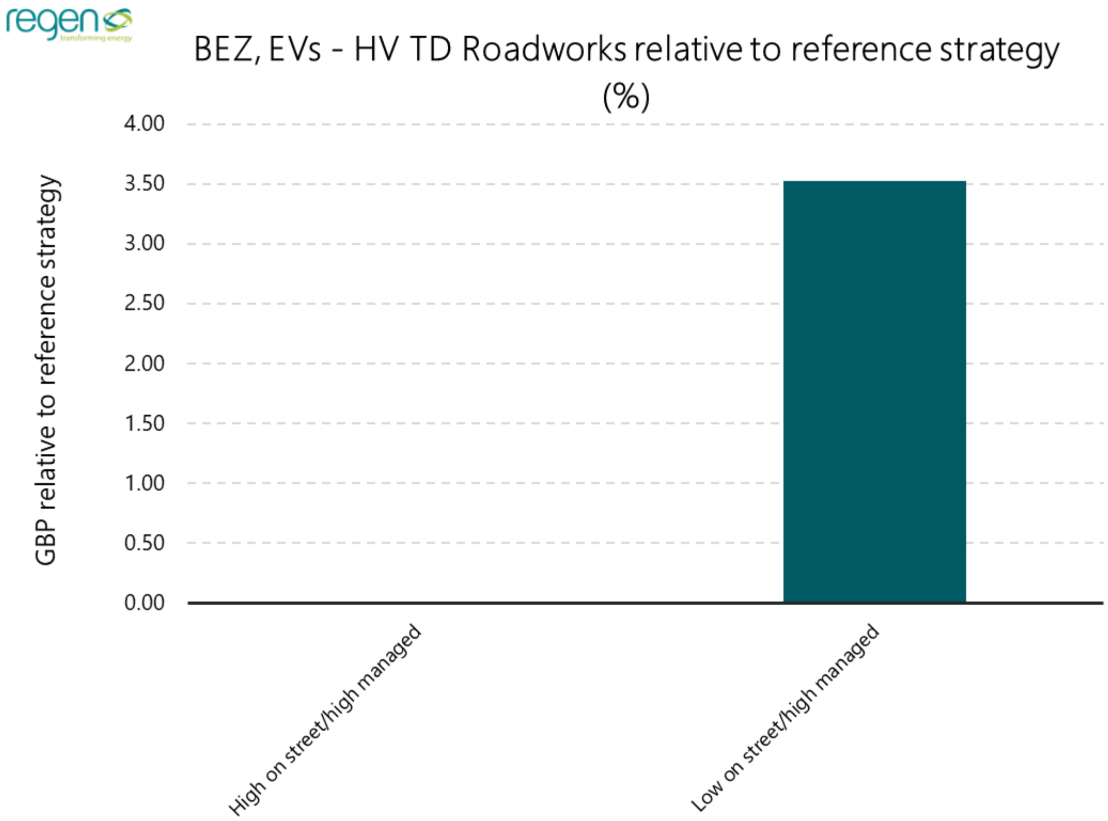



*Figure 17: Relative HV Roadworks from top down analysis*

# 7. APPENDIX 2: Cribbs Causeway significant results

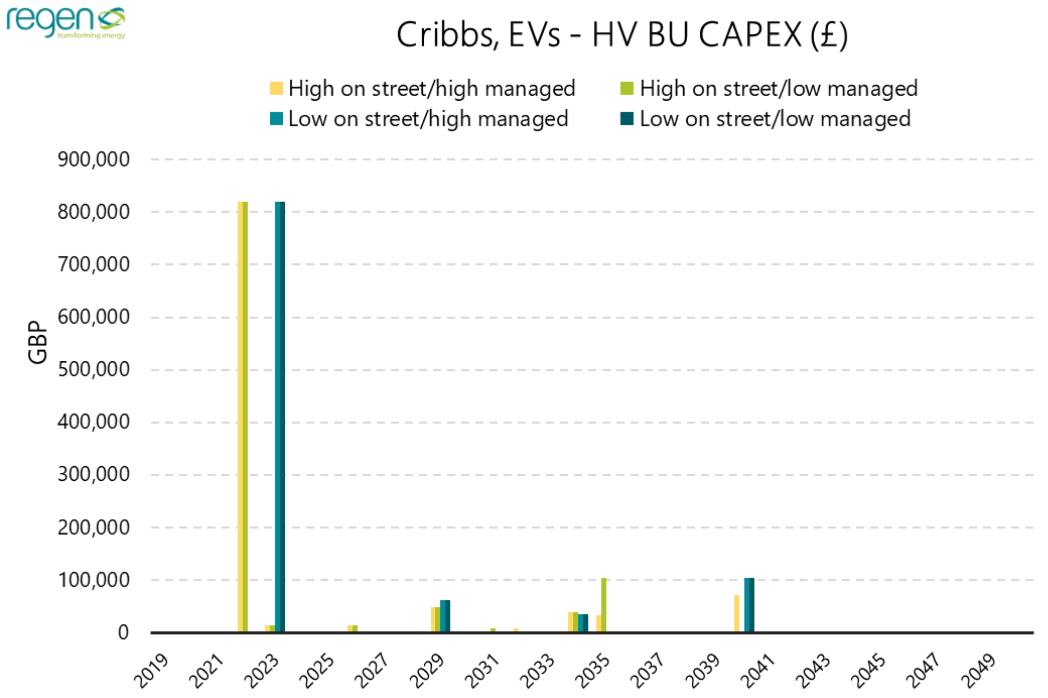



*Figure 18: Absolute HV CAPEX on the Cribbs Causeway primary from bottom up analysis*

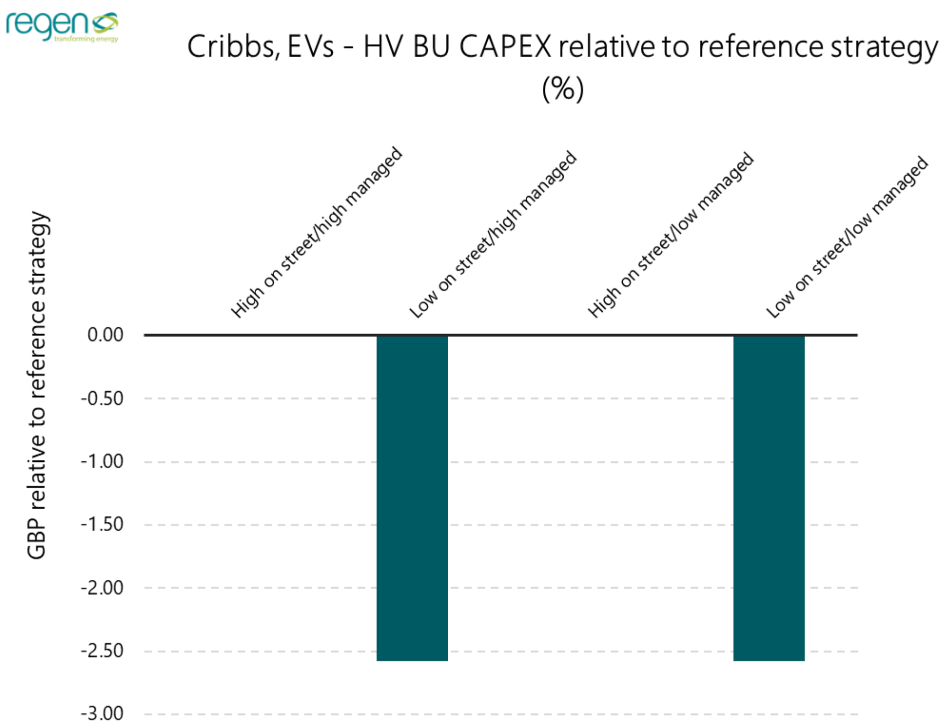



*Figure 19: Relative HV CAPEX on the Cribbs Causeway primary from bottom up analysis*

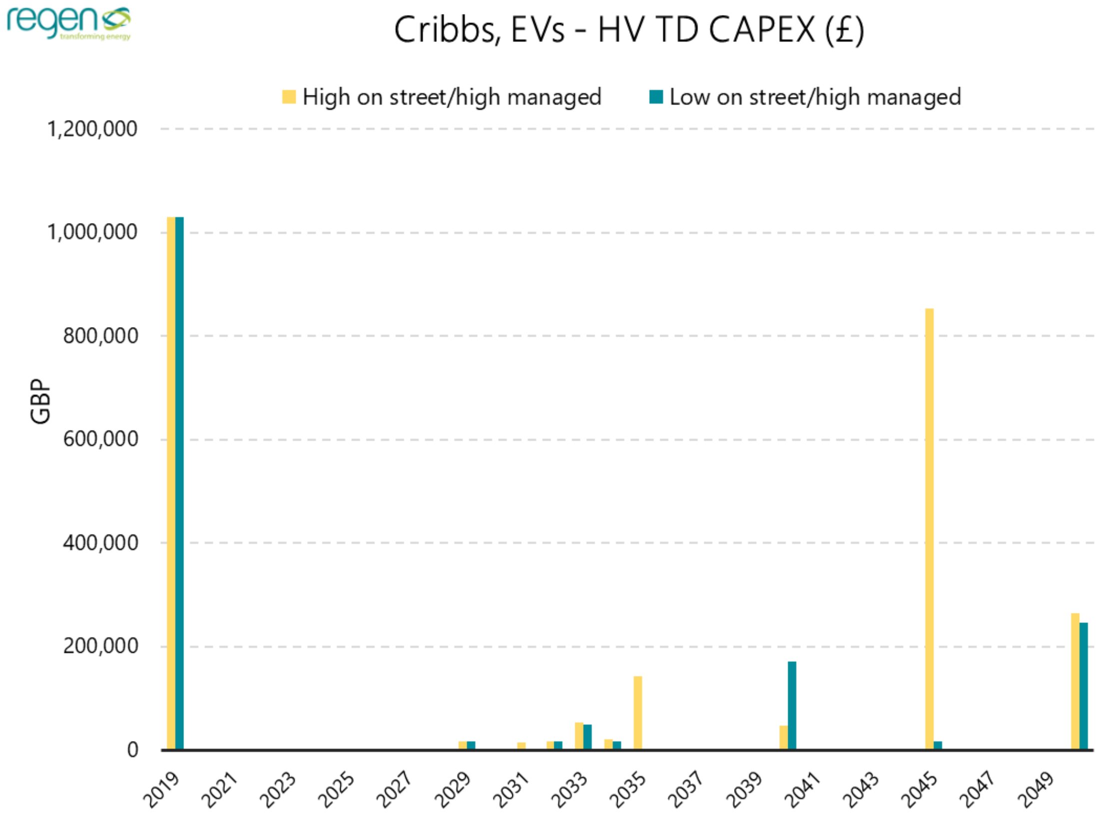



*Figure 20: Absolute HV CAPEX on the Cribbs Causeway primary from top down analysis*

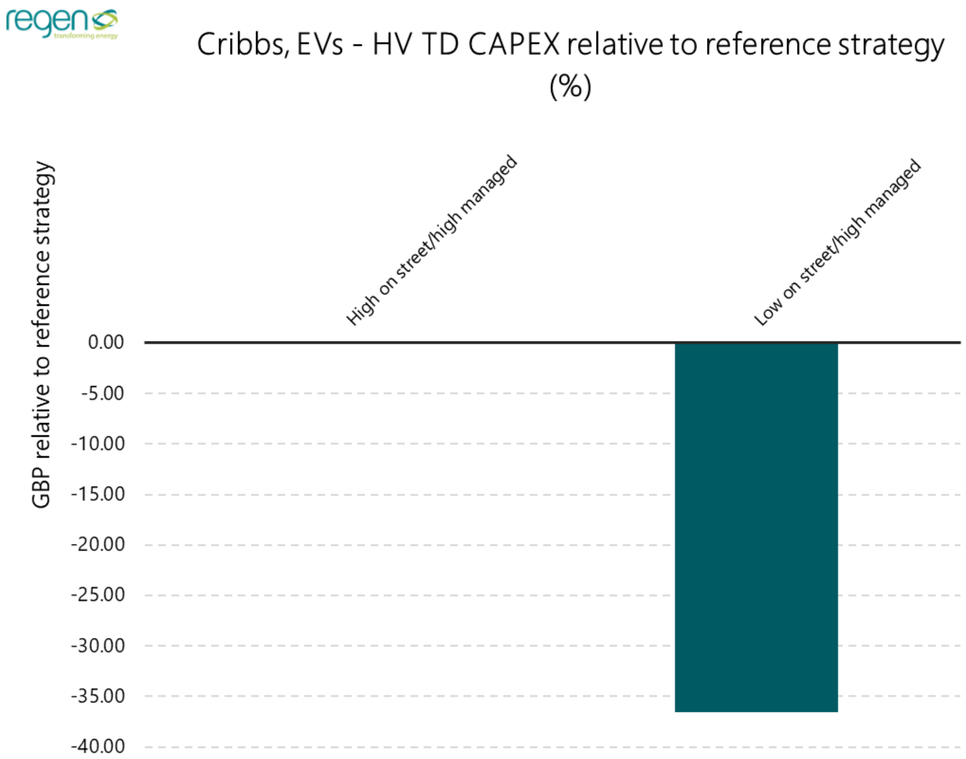



*Figure 21: Relative HV CAPEX on the Cribbs Causeway primary from top down analysis*

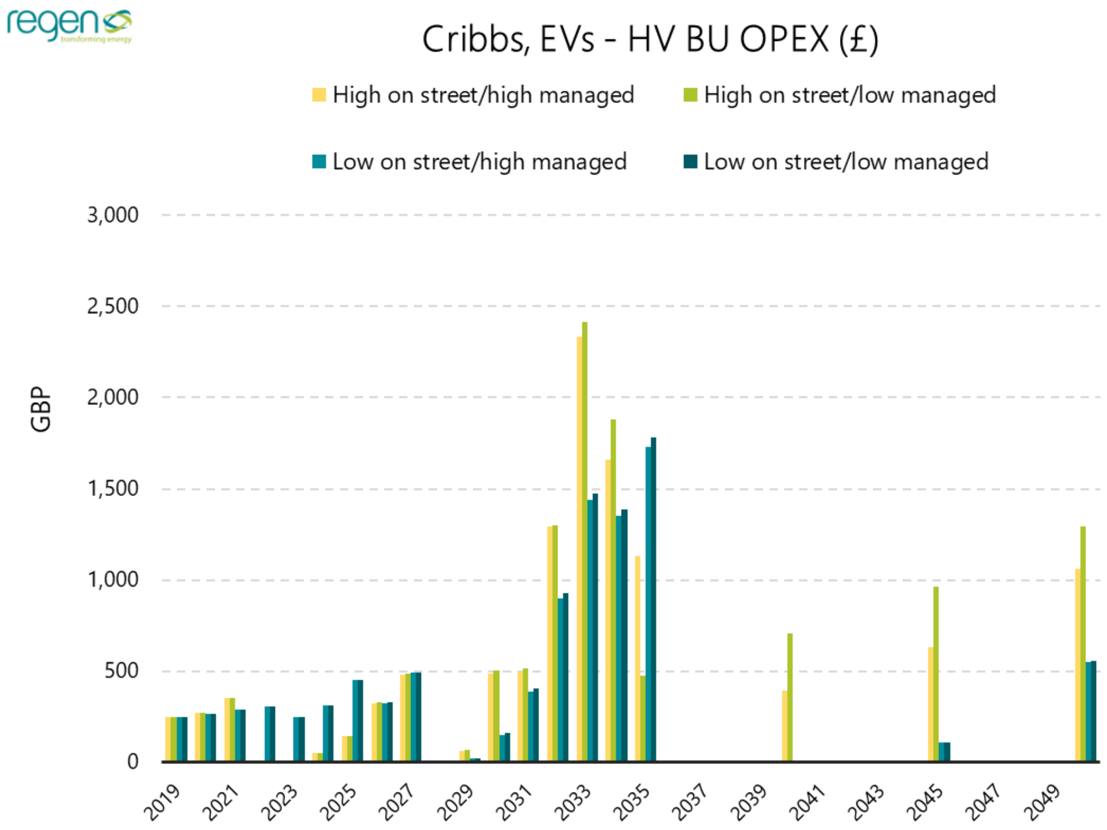



*Figure 22: Absolute HV OPEX on the Cribbs Causeway primary from bottom up analysis*

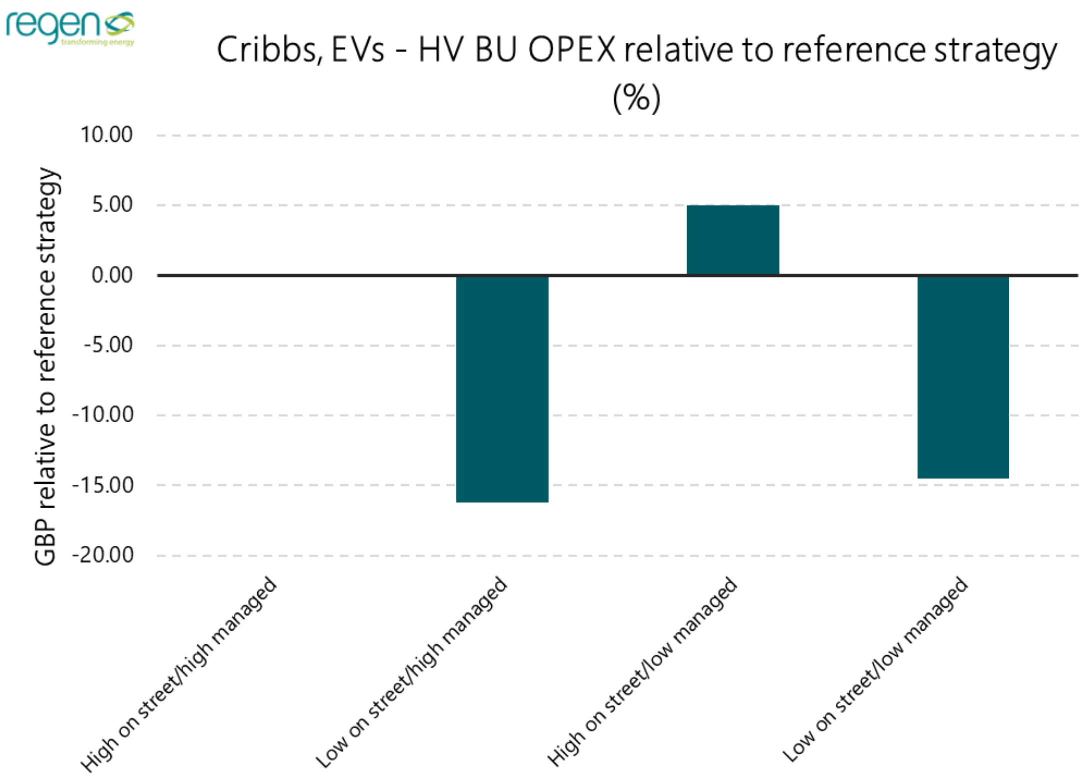



*Figure 23: Relative HV OPEX on the Cribbs Causeway primary from bottom up analysis*

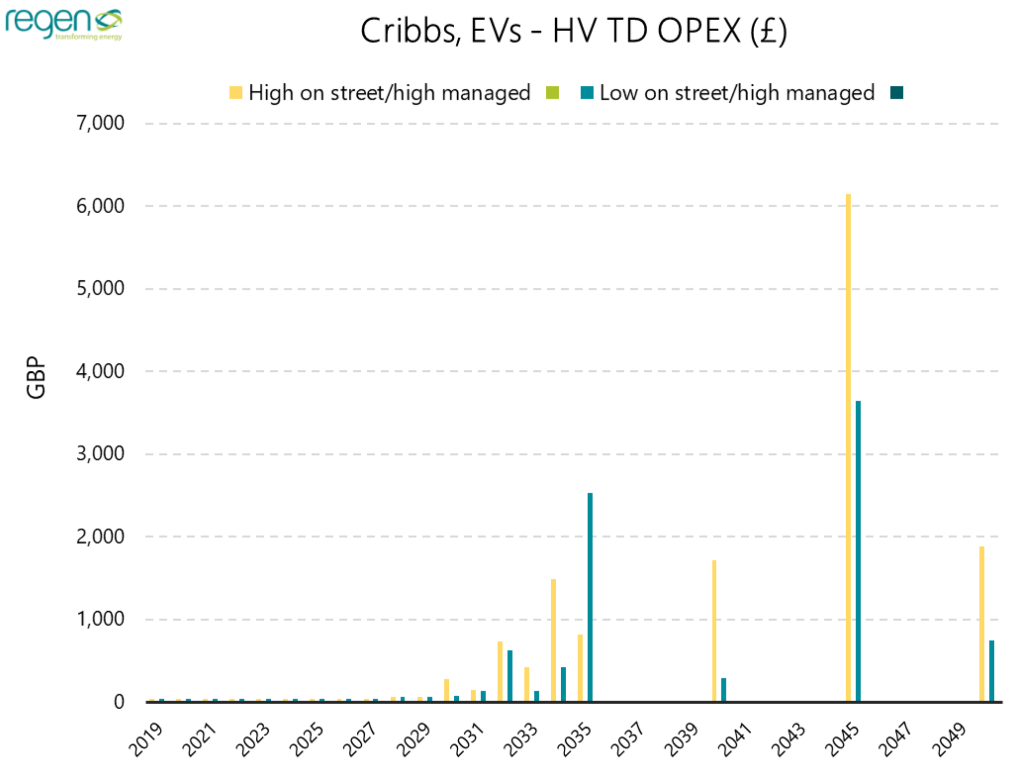



*Figure 24: Absolute HV OPEX on the Cribbs Causeway primary from top down analysis*

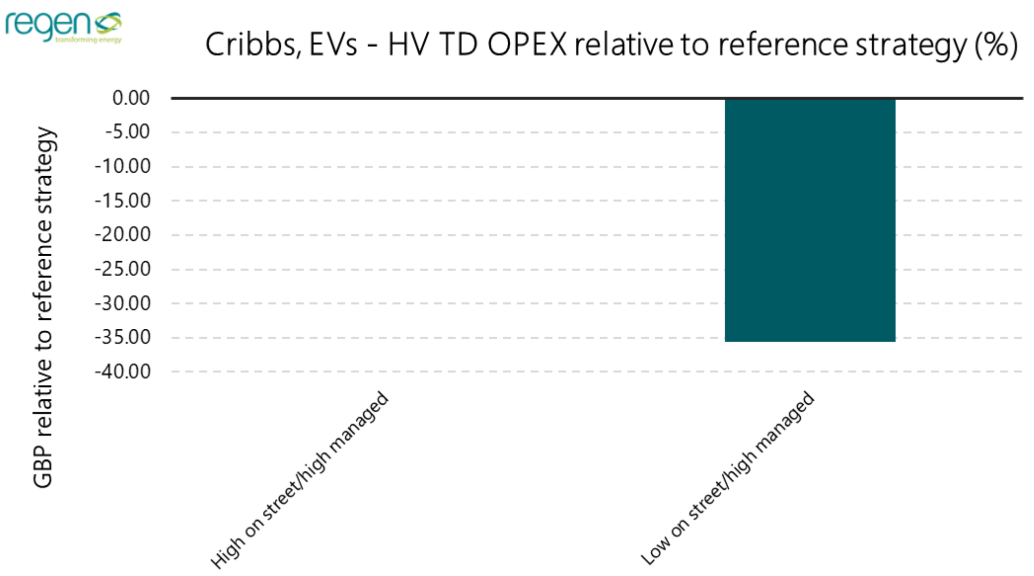



*Figure 25: Relative HV OPEX on the Cribbs Causeway primary from top down analysis*

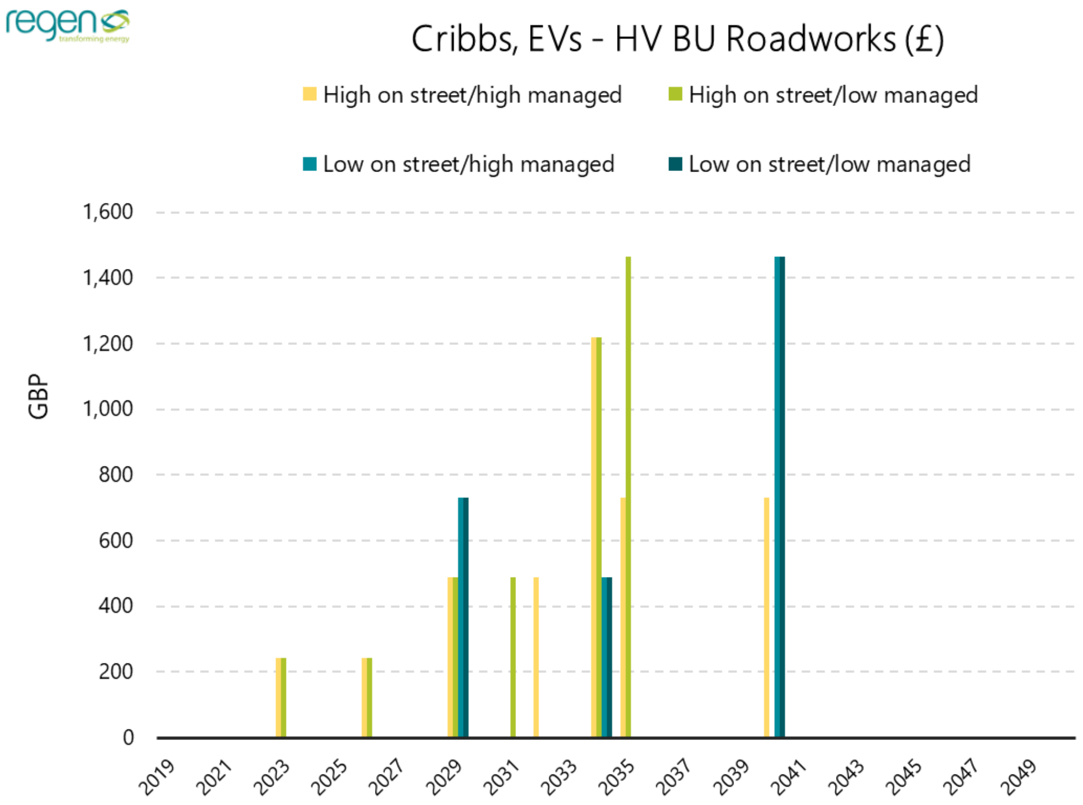



*Figure 26: Absolute HV roadworks on the Cribbs Causeway primary from bottom up analysis*

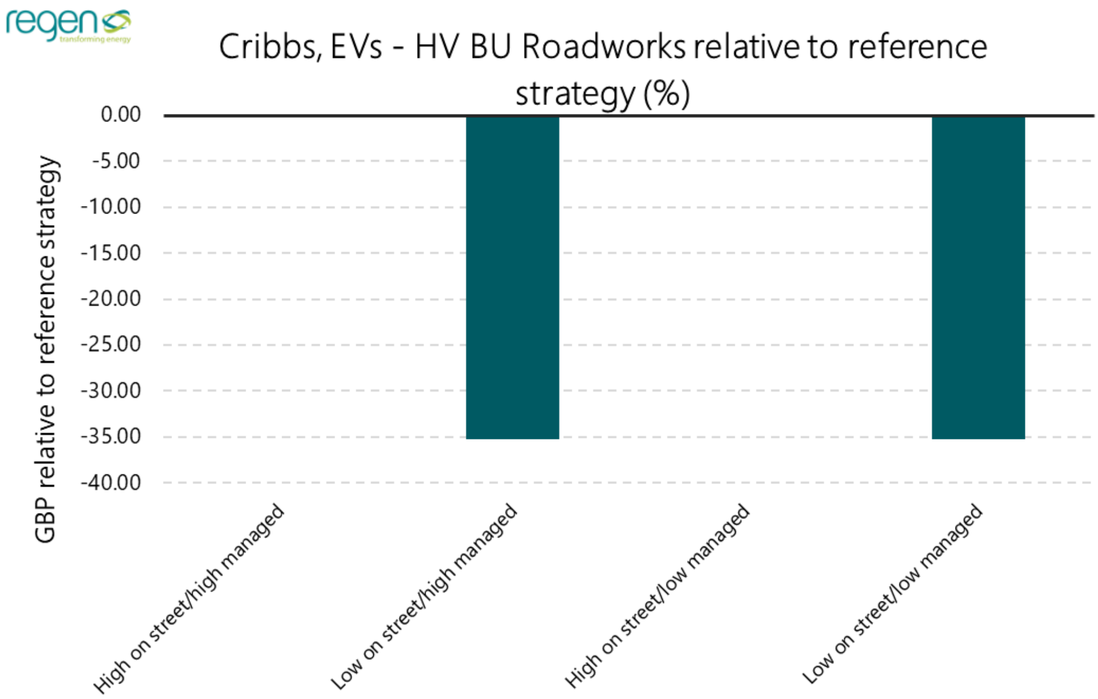



*Figure 27: Relative HV roadworks on the Cribbs Causeway primary from bottom up analysis*

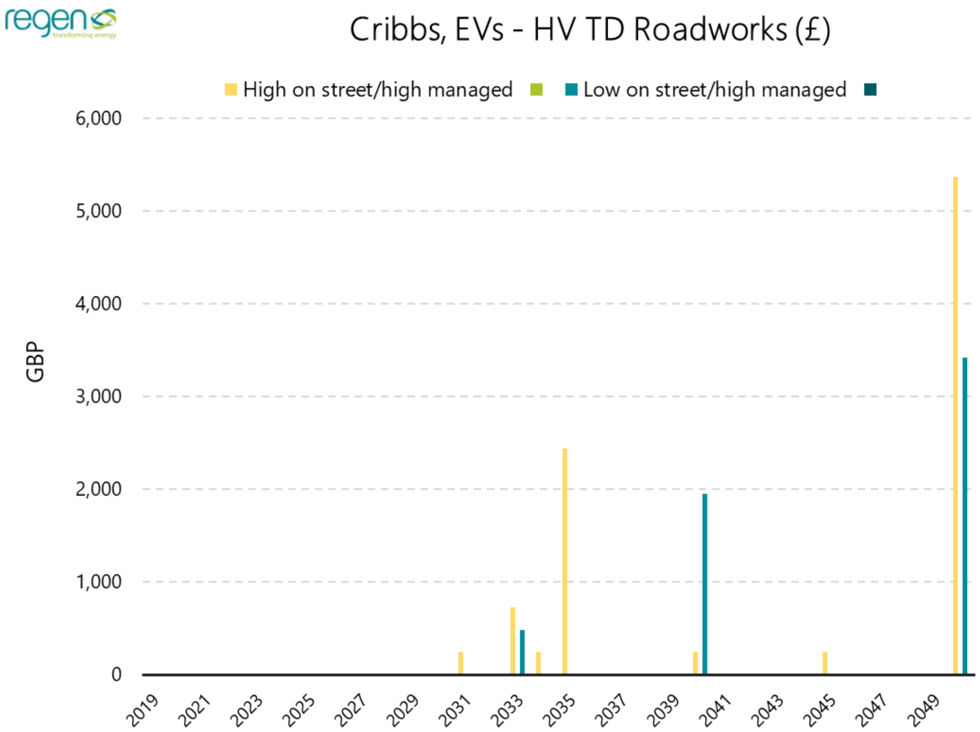



*Figure 28: Absolute HV roadworks on the Cribbs Causeway primary from top down analysis*

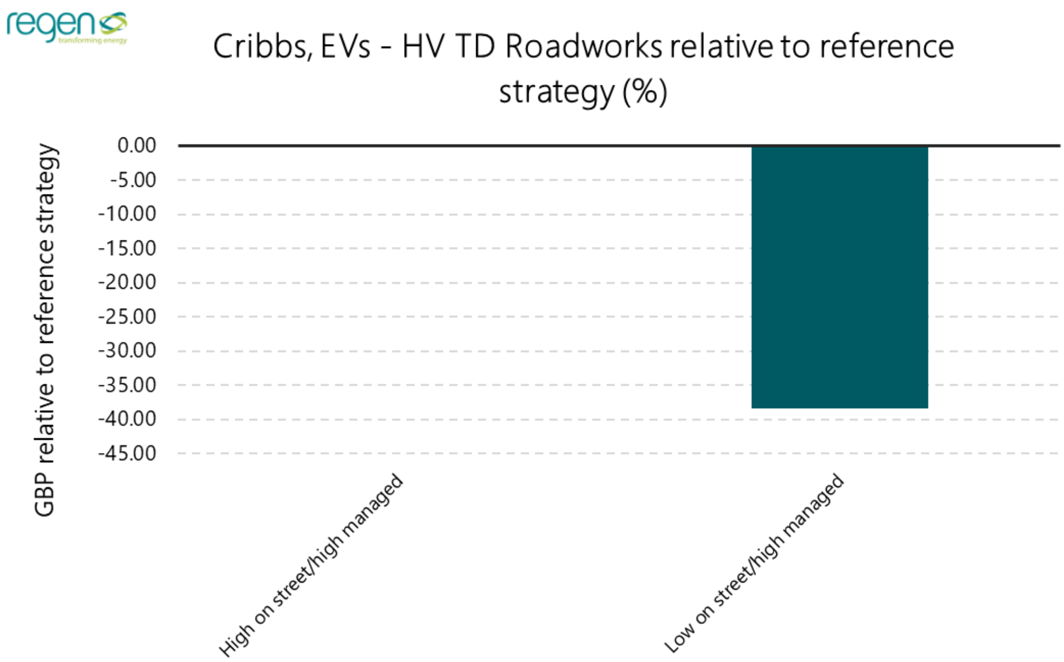



*Figure 29: Relative HV roadworks on the Cribbs Causeway primary from top down analysis*

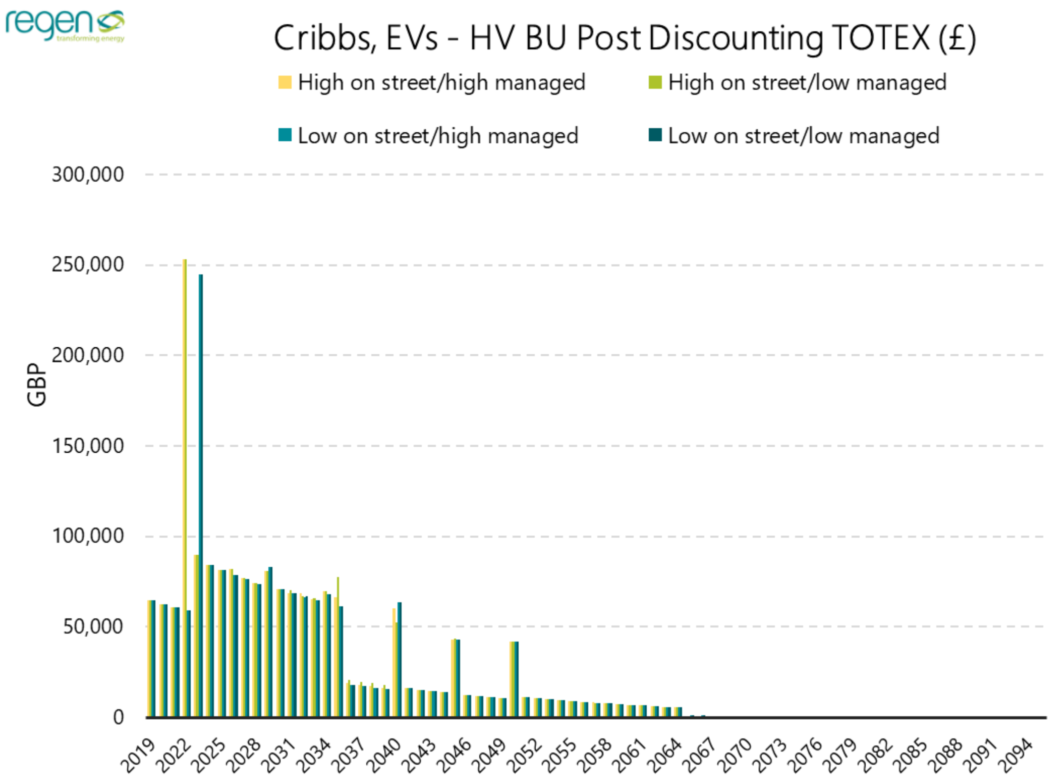



*Figure 30: Absolute HV TOTEX on the Cribbs Causeway primary from bottom up analysis*

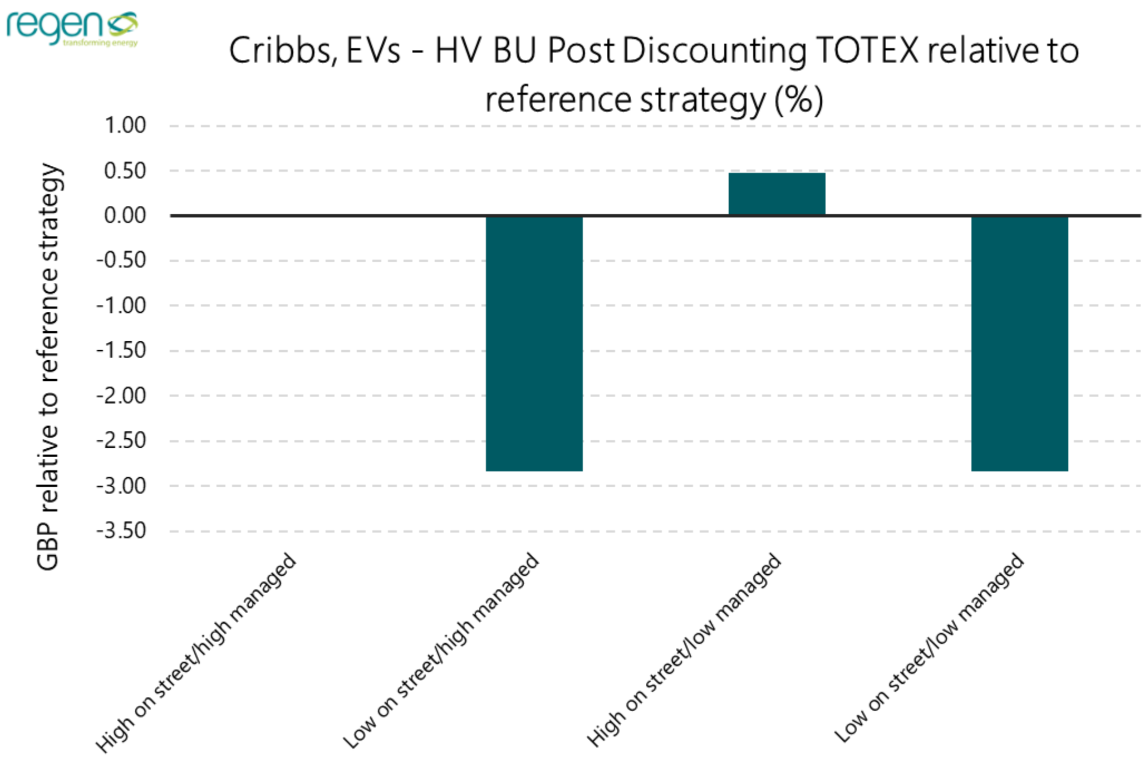



*Figure 31: Relative HV TOTEX on the Cribbs Causeway primary from bottom up analysis*

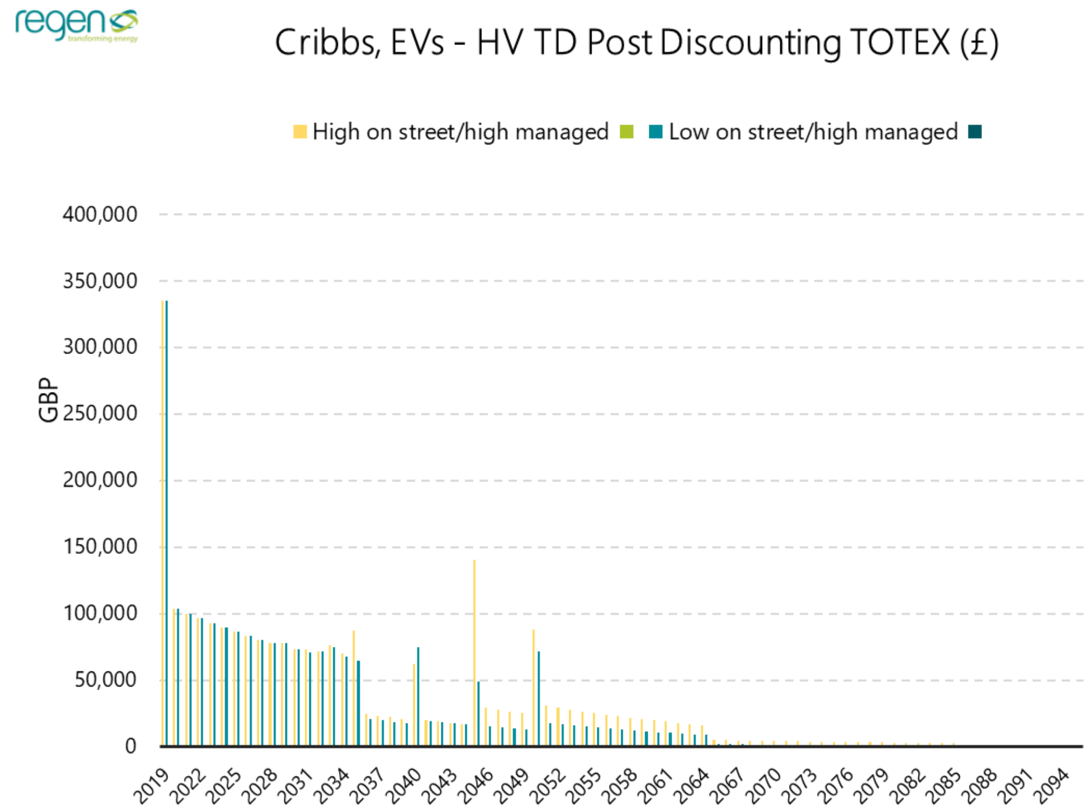



*Figure 32: Absolute HV TOTEX on the Cribbs Causeway primary from top down analysis*

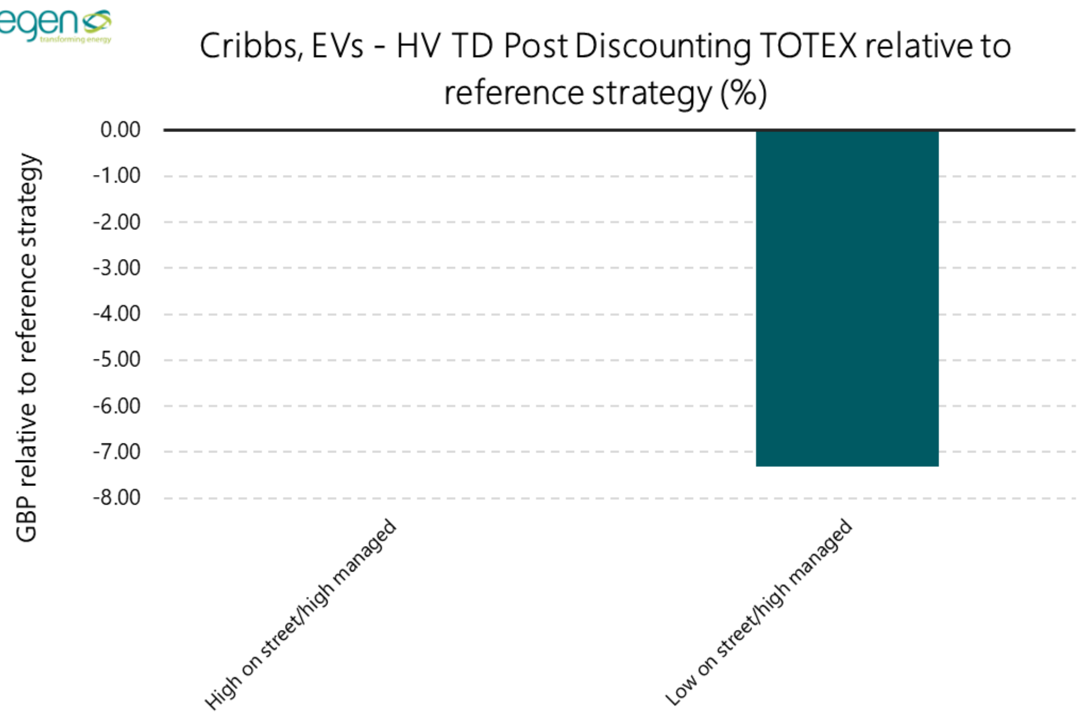



*Figure 33: Relative HV TOTEX on the Cribbs Causeway primary from top down analysis*

# 8. APPENDIX 3: Nailsea significant results

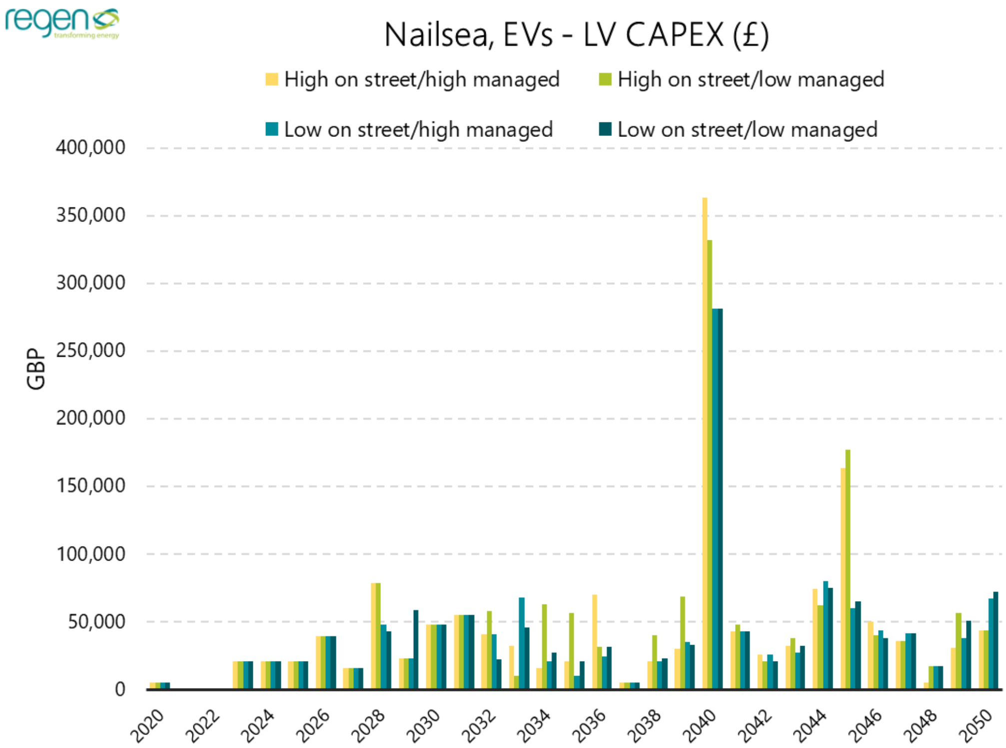



*Figure 34: Absolute LV CAPEX on the Nailsea primary*

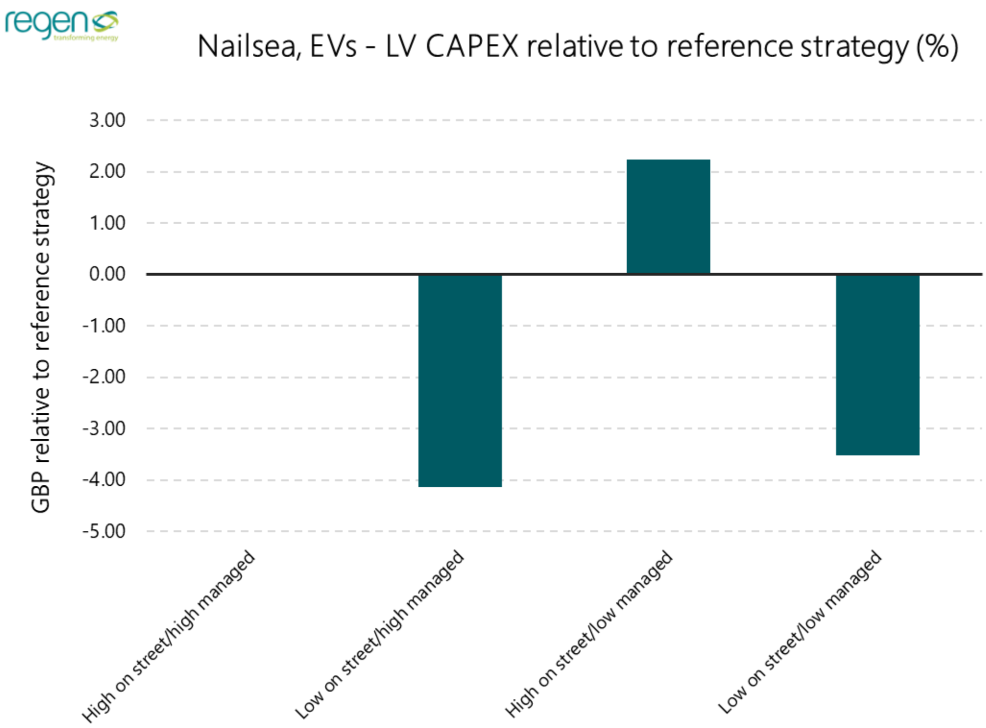



*Figure 35: Relative LV CAPEX on the Nailsea primary*

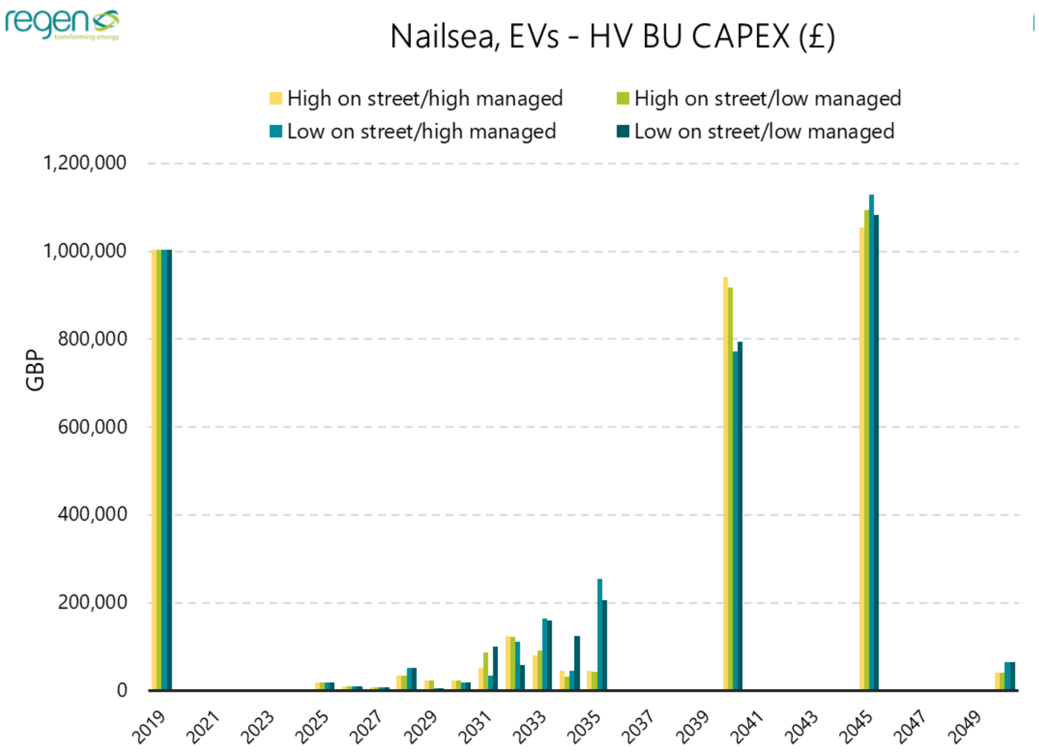



*Figure 36: Absolute HV CAPEX on the Nailsea primary from bottom up analysis*

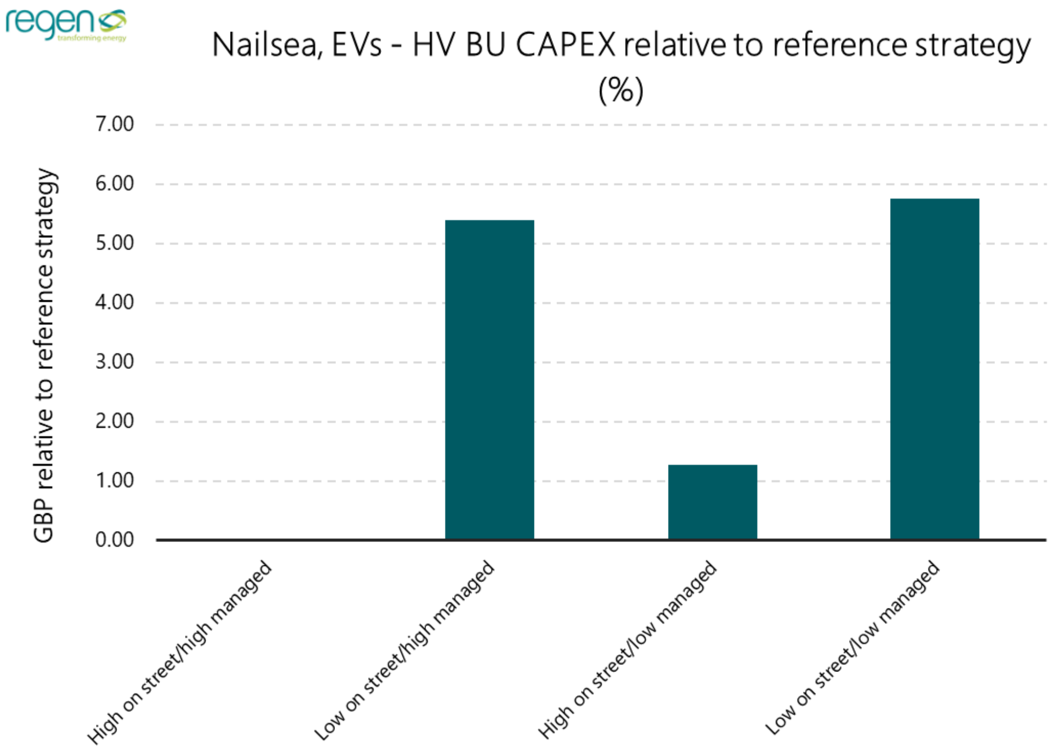



*Figure 37: Relative HV CAPEX on the Nailsea primary from bottom up analysis*

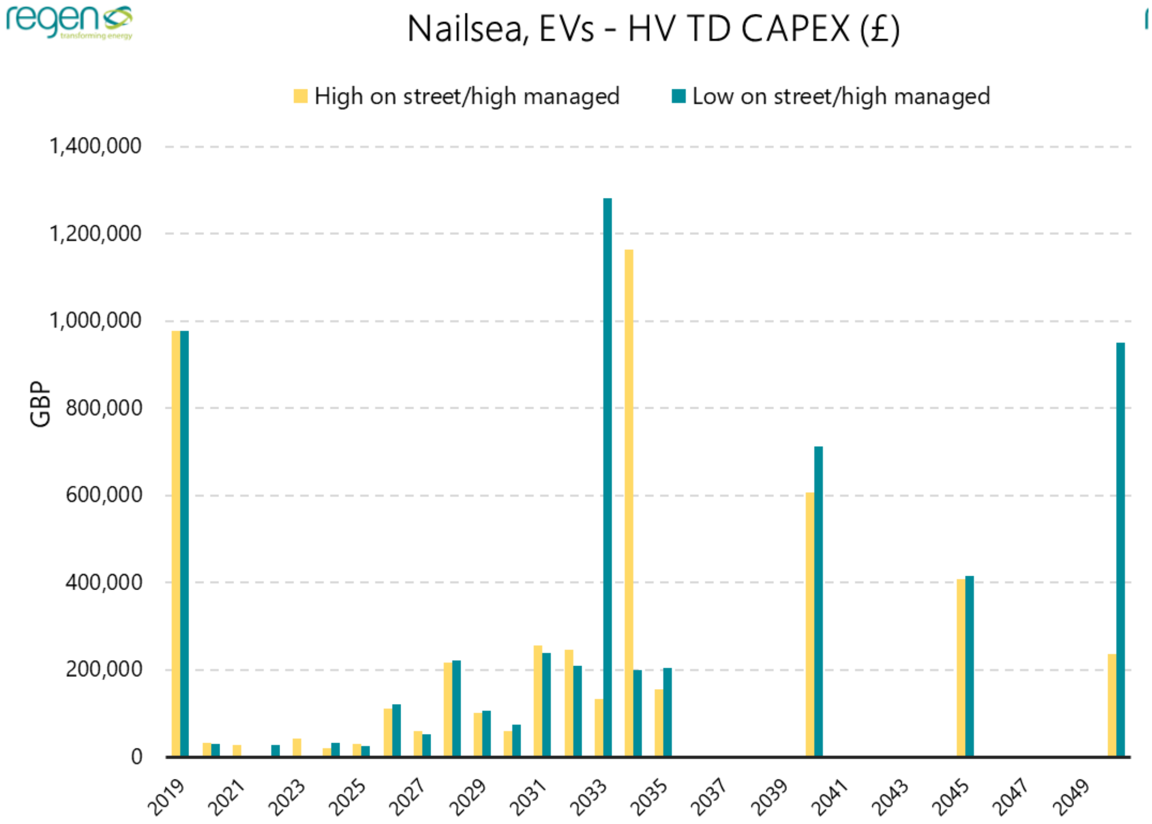



*Figure 38: Absolute HV CAPEX on the Nailsea primary from top down analysis*

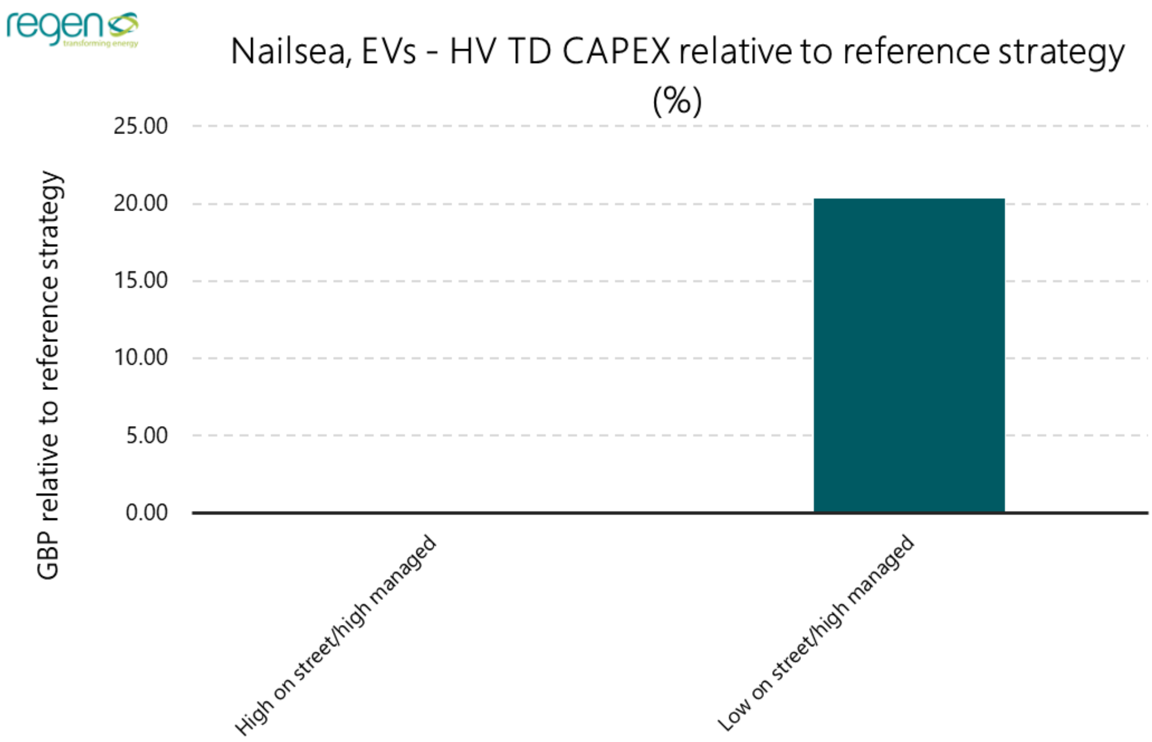



*Figure 39: Relative HV CAPEX on the Nailsea primary from top down analysis*

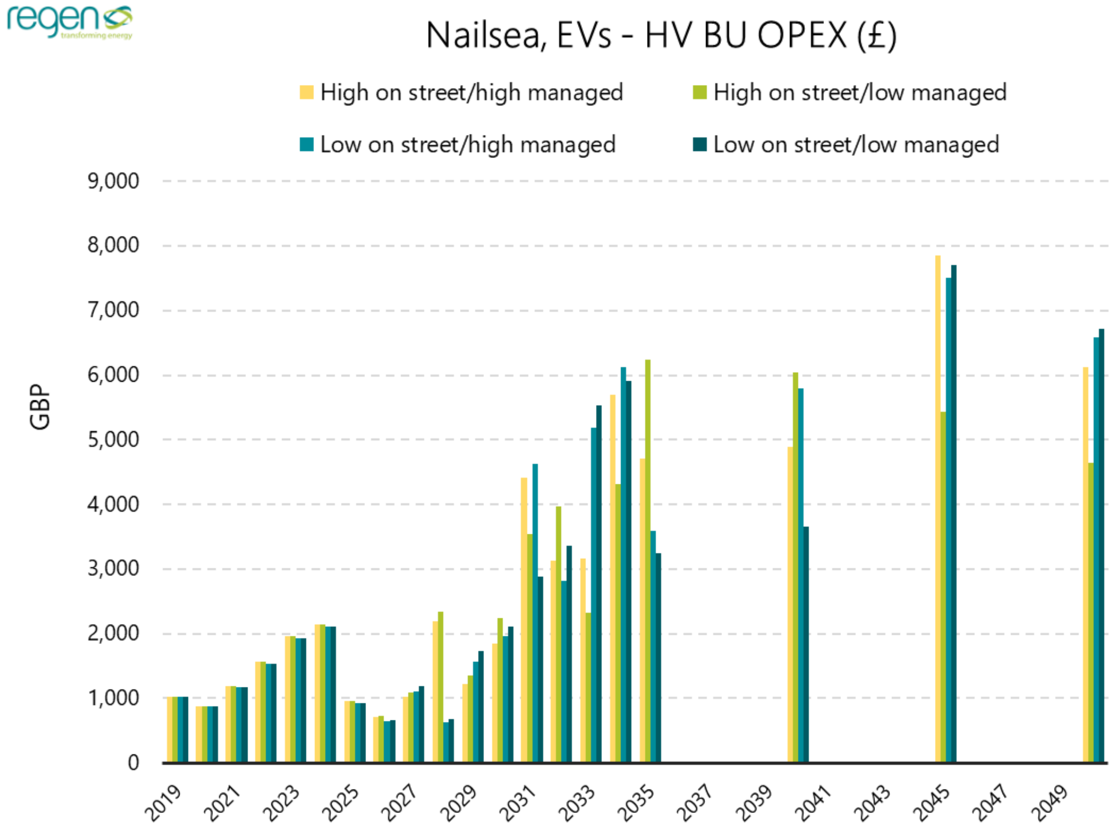



*Figure 40: Absolute HV OPEX on the Nailsea primary from bottom up analysis*

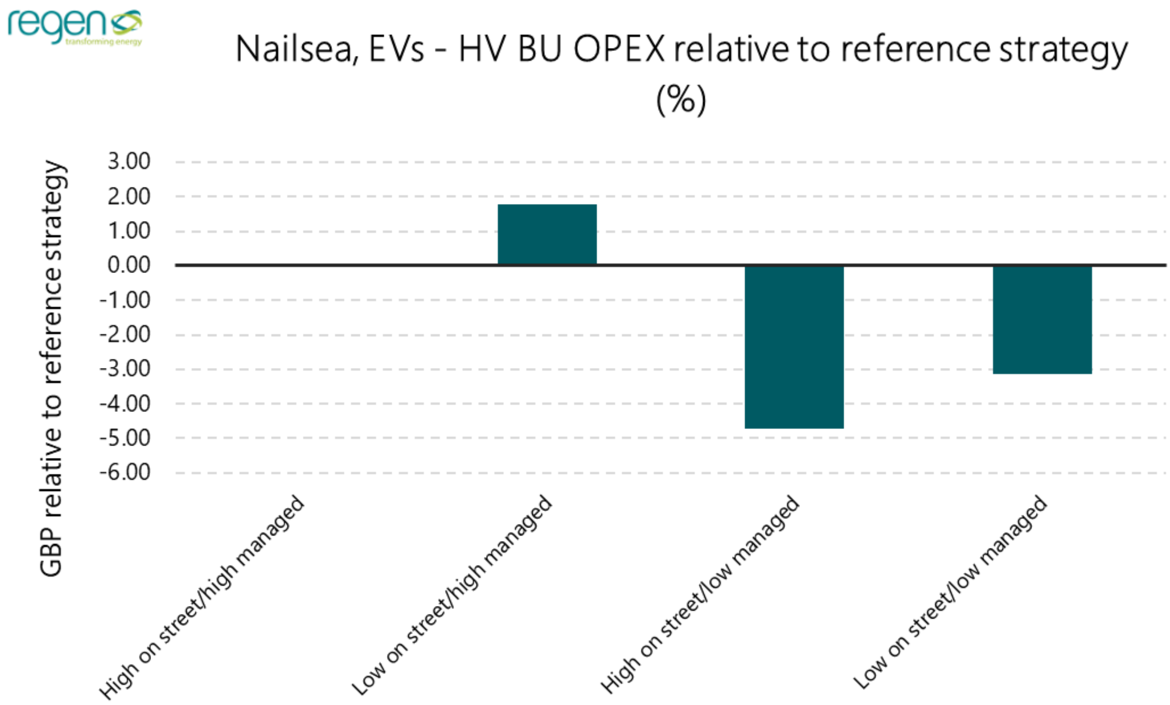



*Figure 41: Relative HV OPEX on the Nailsea primary from bottom up analysis*

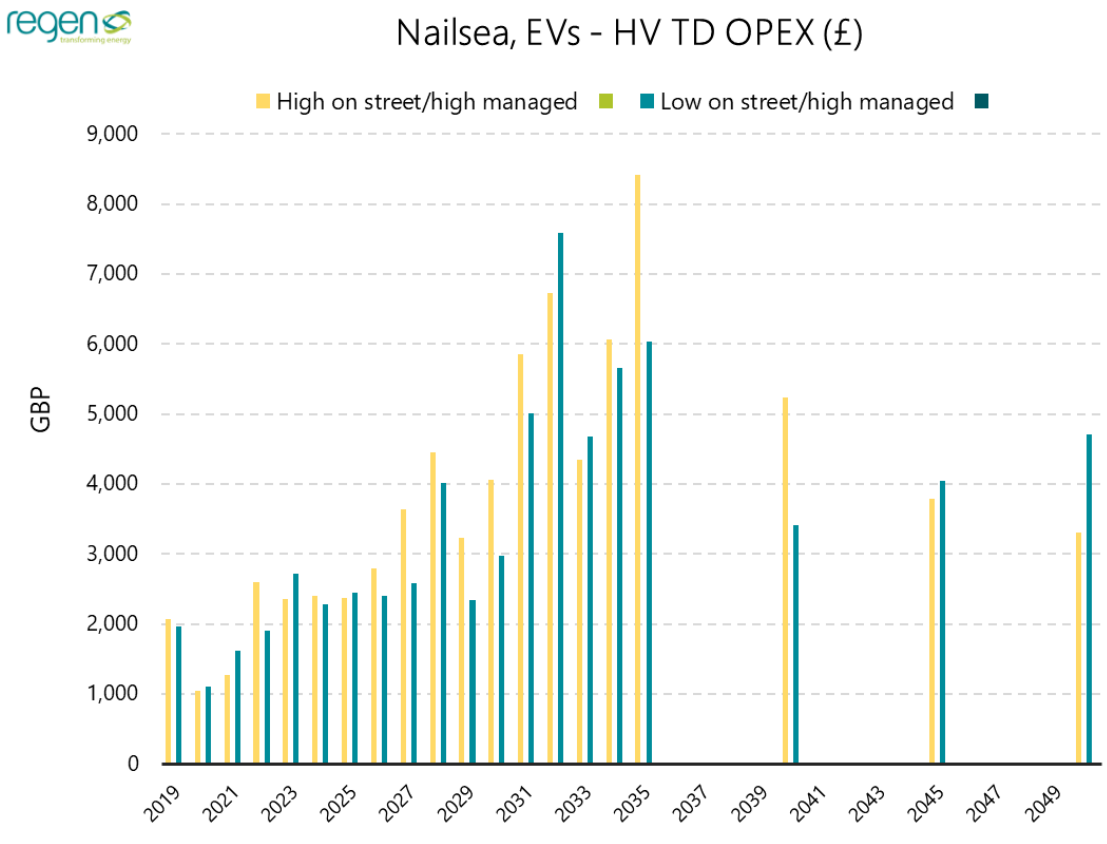



*Figure 42: Absolute HV OPEX on the Nailsea primary from top down analysis*

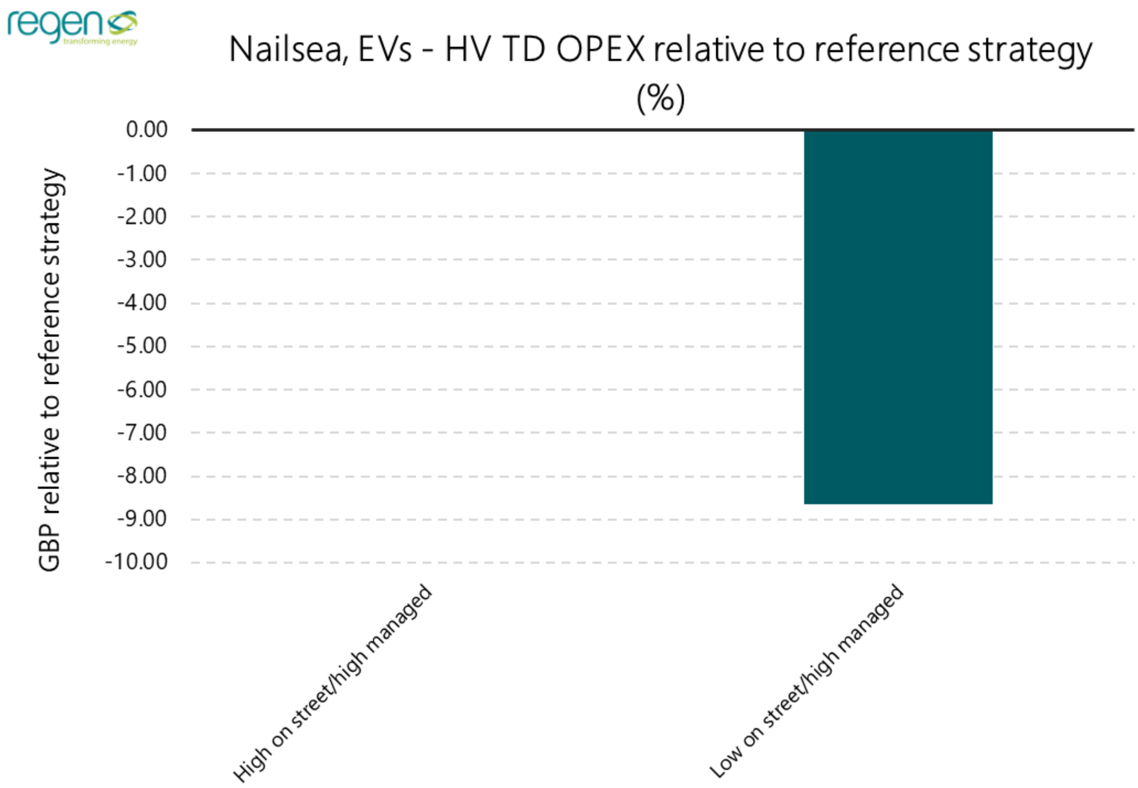



*Figure 43: Relative HV OPEX on the Nailsea primary from top down analysis*

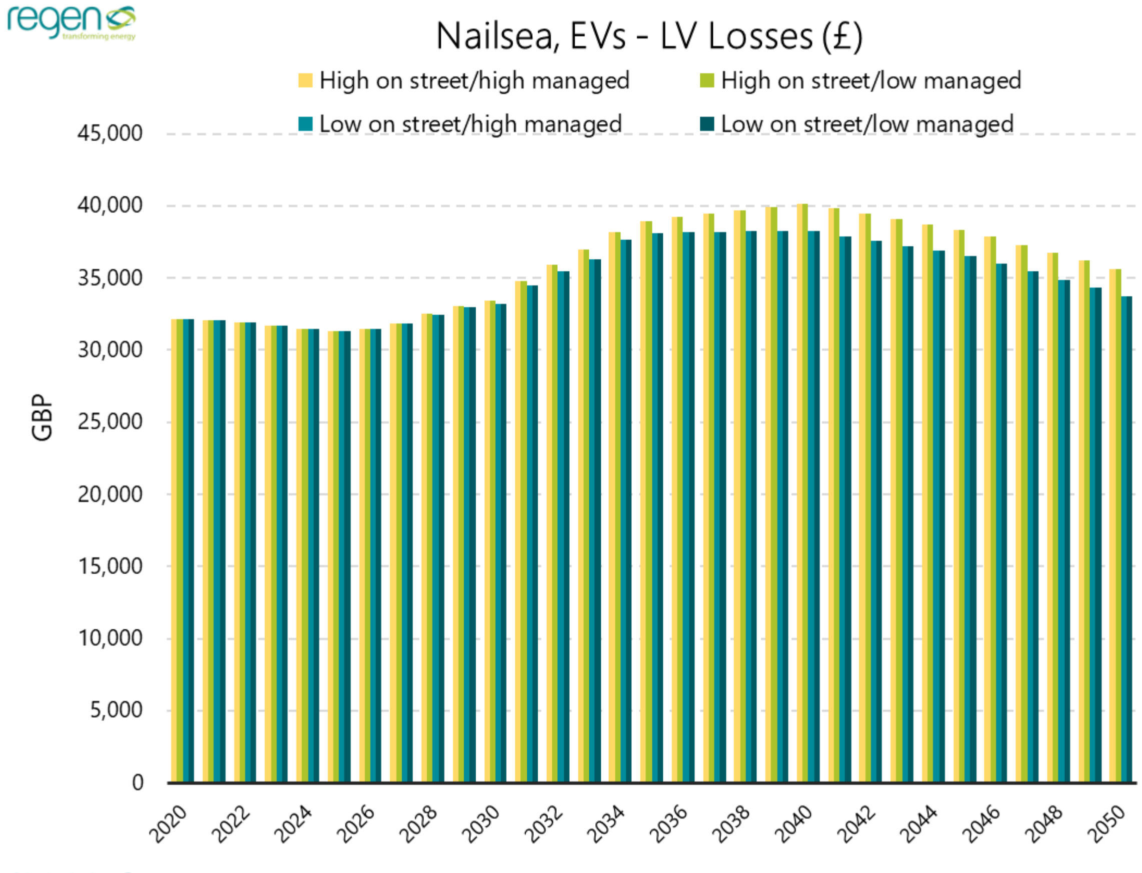



*Figure 44: Absolute LV losses on the Nailsea primary*

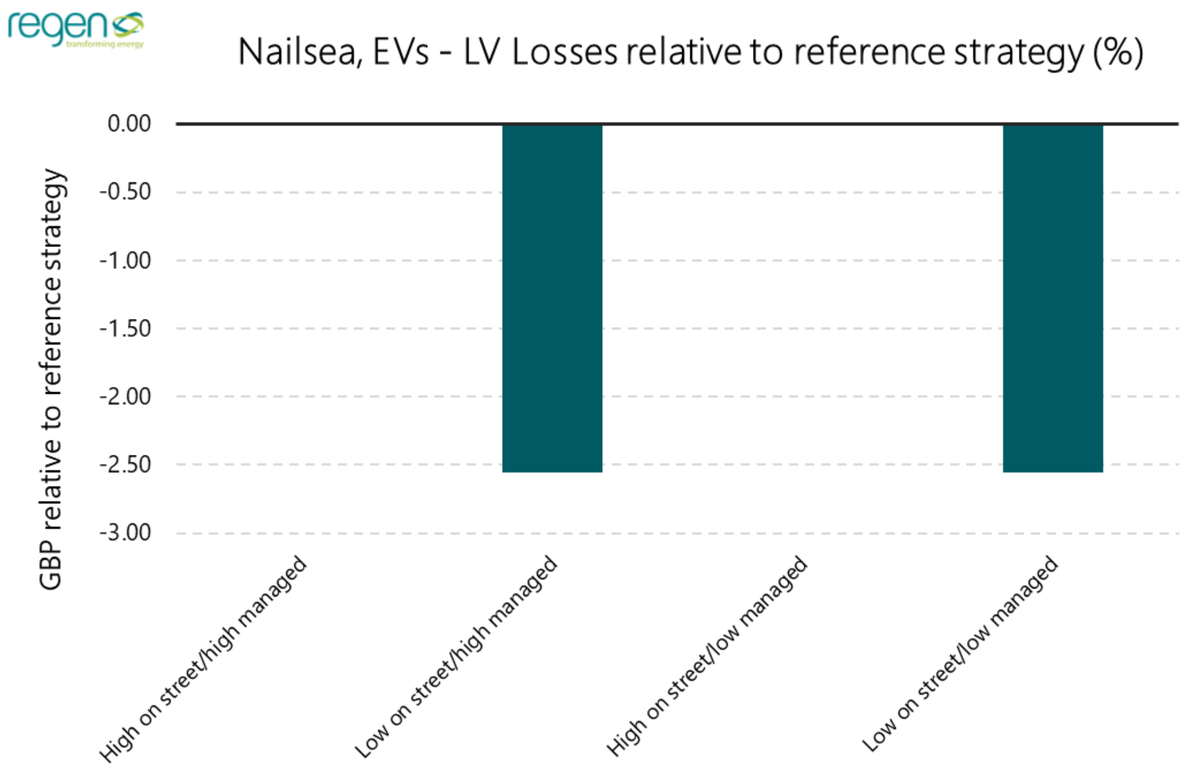



*Figure 45: Relative LV losses on the Nailsea primary*

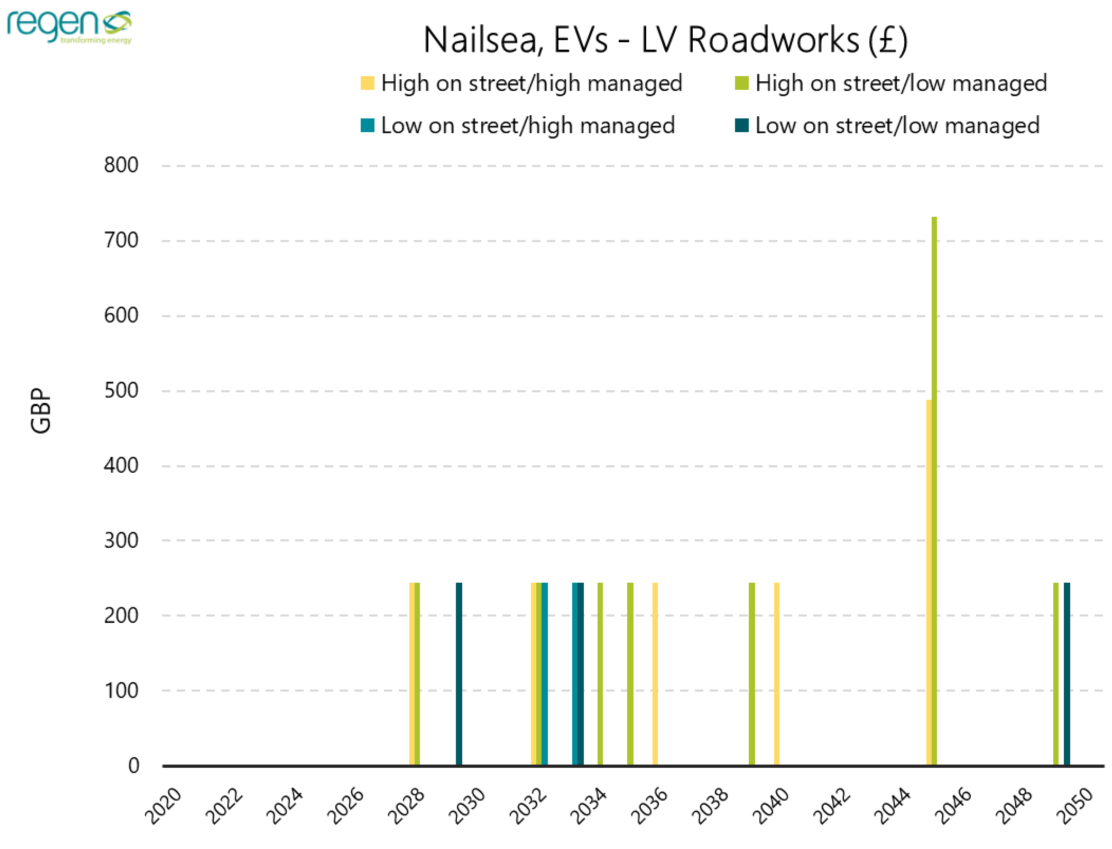



*Figure 46: Absolute LV roadworks on the Nailsea primary*

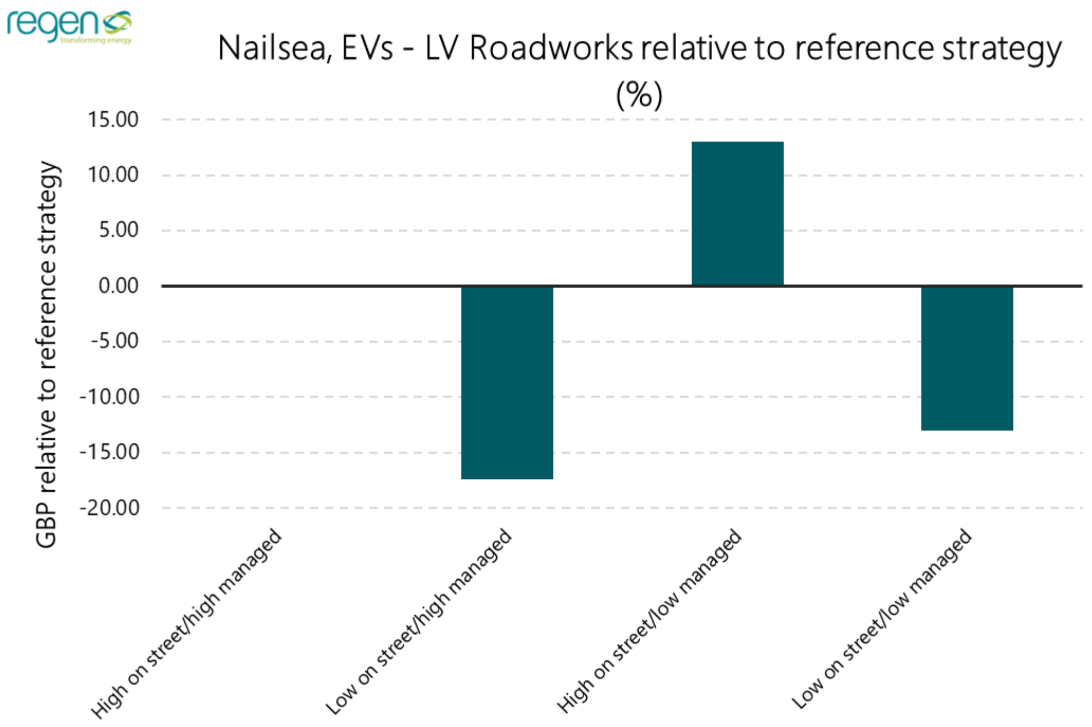



*Figure 47: Relative LV roadworks on the Nailsea primary*

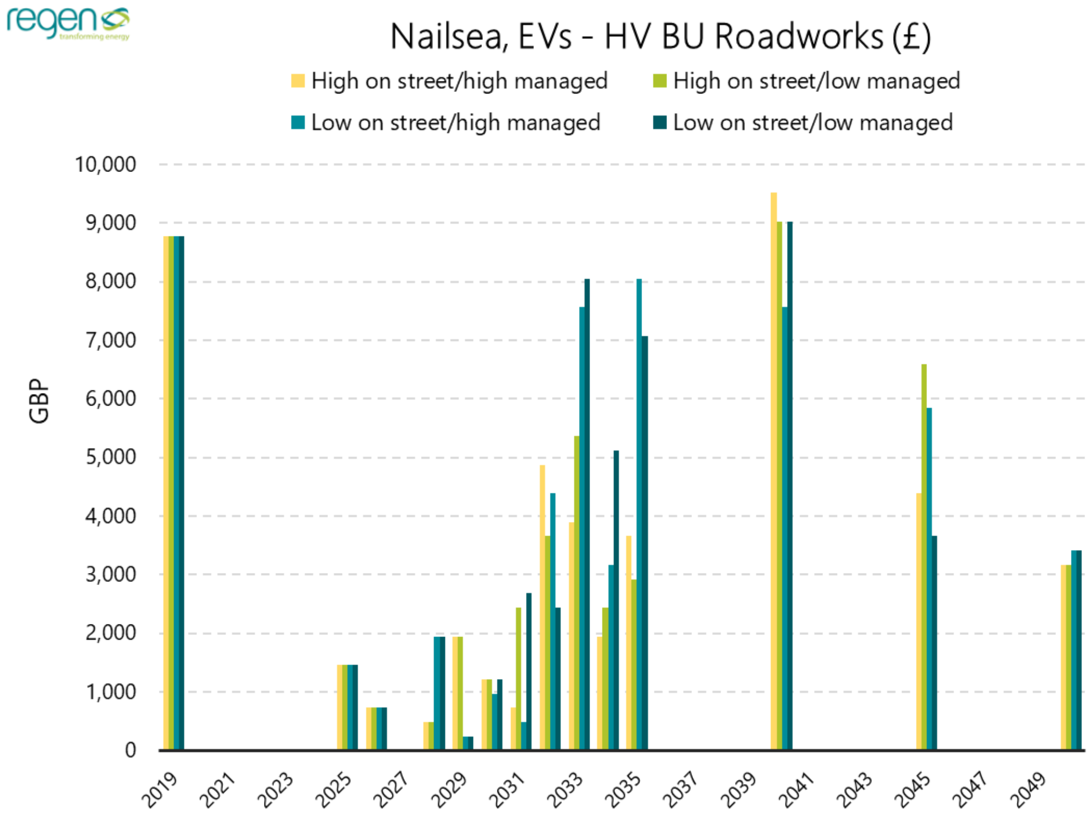



*Figure 48: Absolute HV roadworks on the Nailsea primary from bottom up analysis*

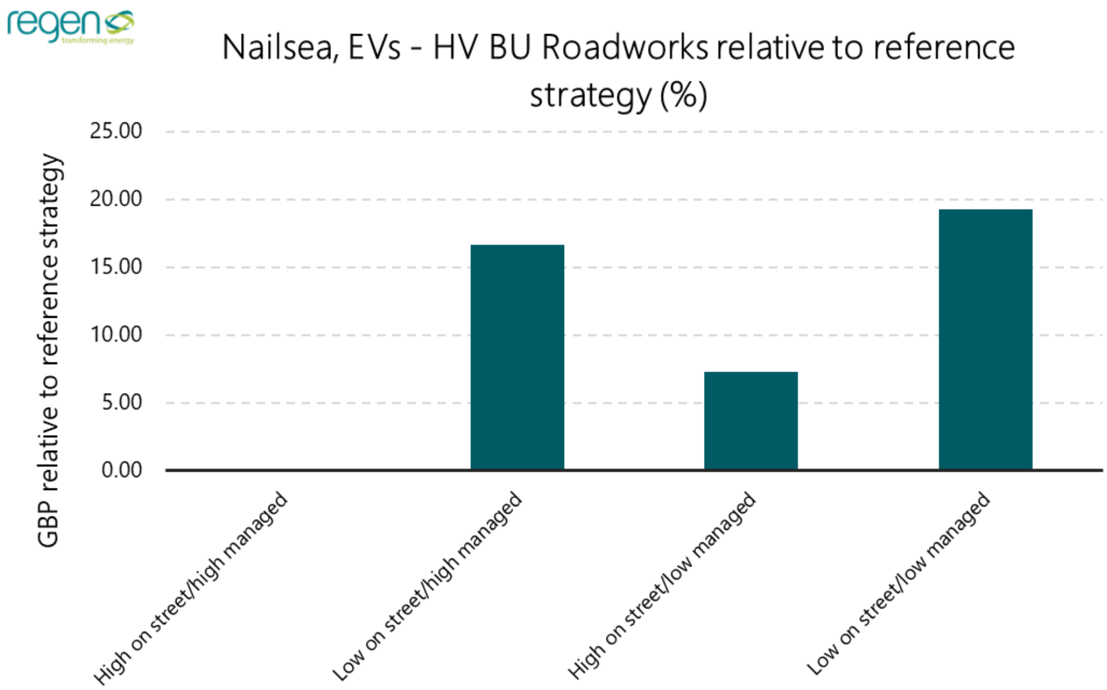



*Figure 49: Relative HV roadworks on the Nailsea primary from bottom up analysis*

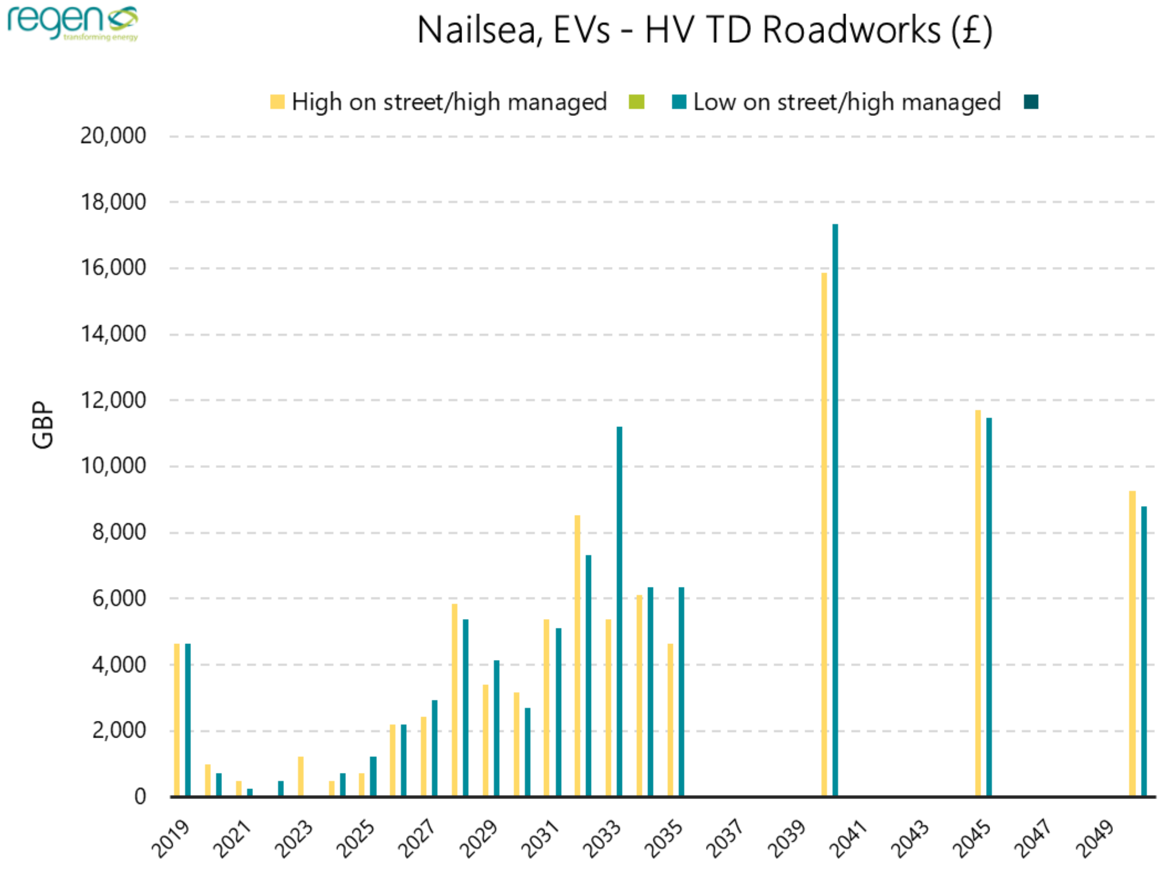



*Figure 50: Absolute HV roadworks on the Nailsea primary from top down analysis*

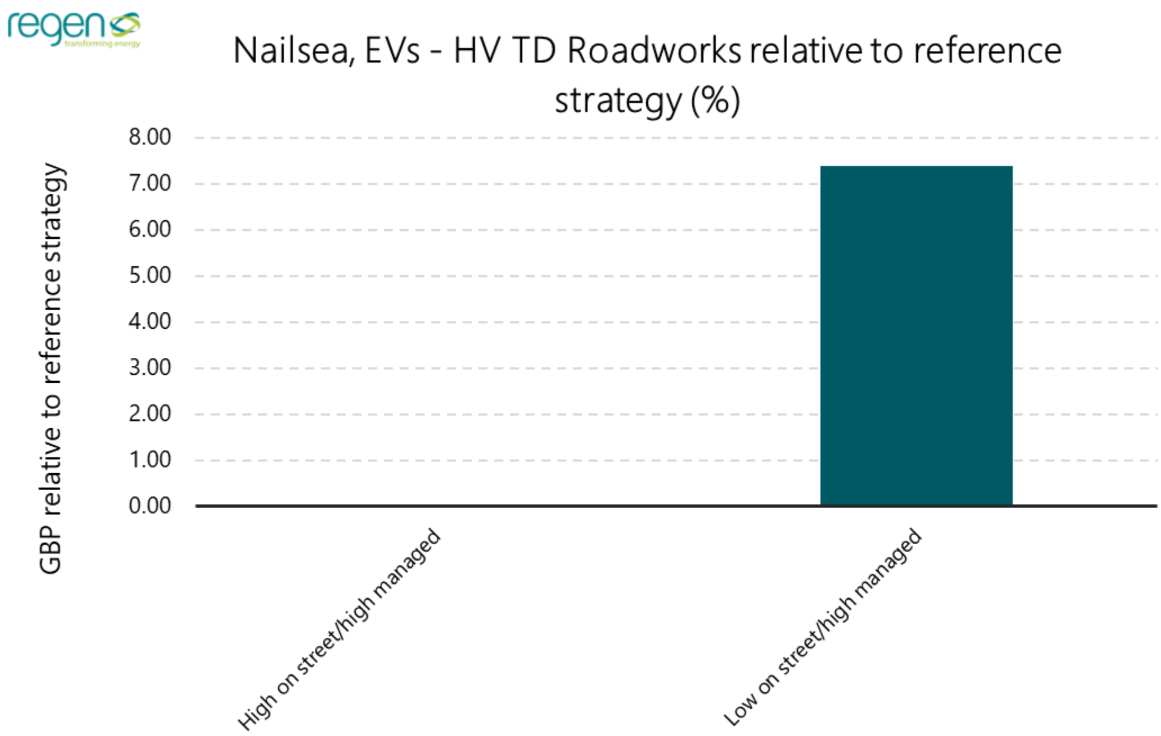



*Figure 51: Relative HV roadworks on the Nailsea primary from top down analysis*

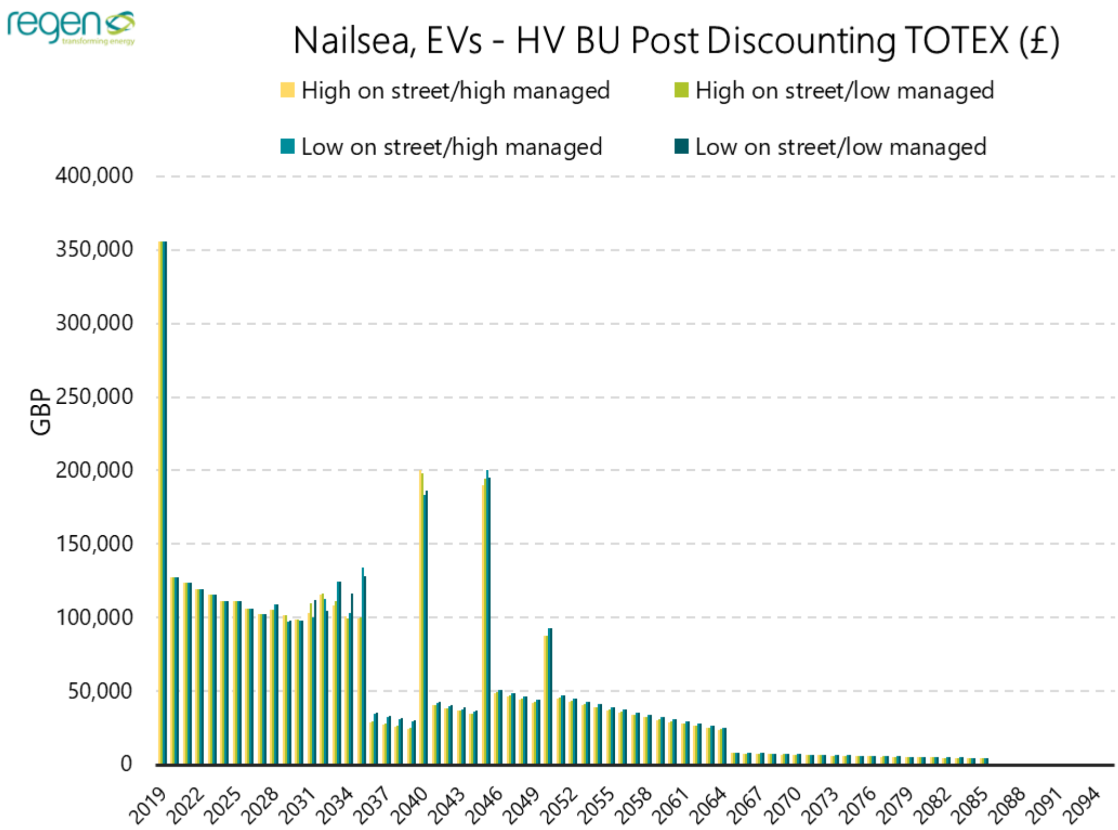



*Figure 52: Absolute HV TOTEX on the Nailsea primary from bottom up analysis*

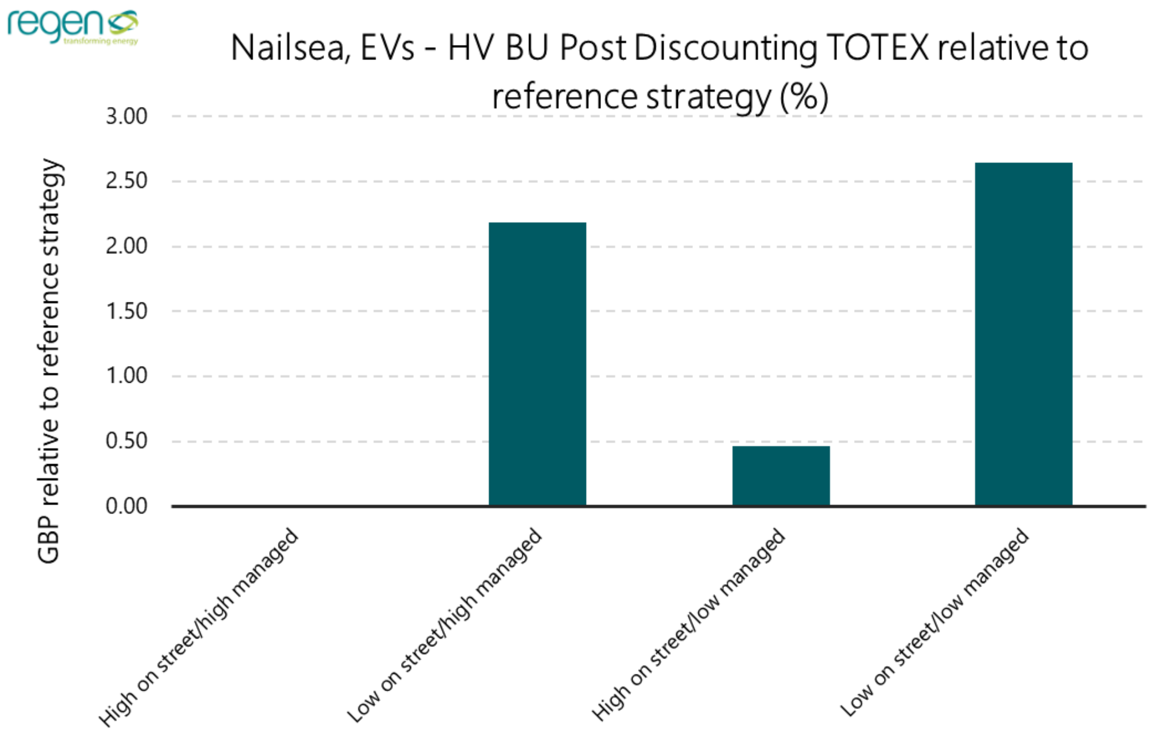



*Figure 53: Relative HV TOTEX on the Nailsea primary from bottom up analysis*

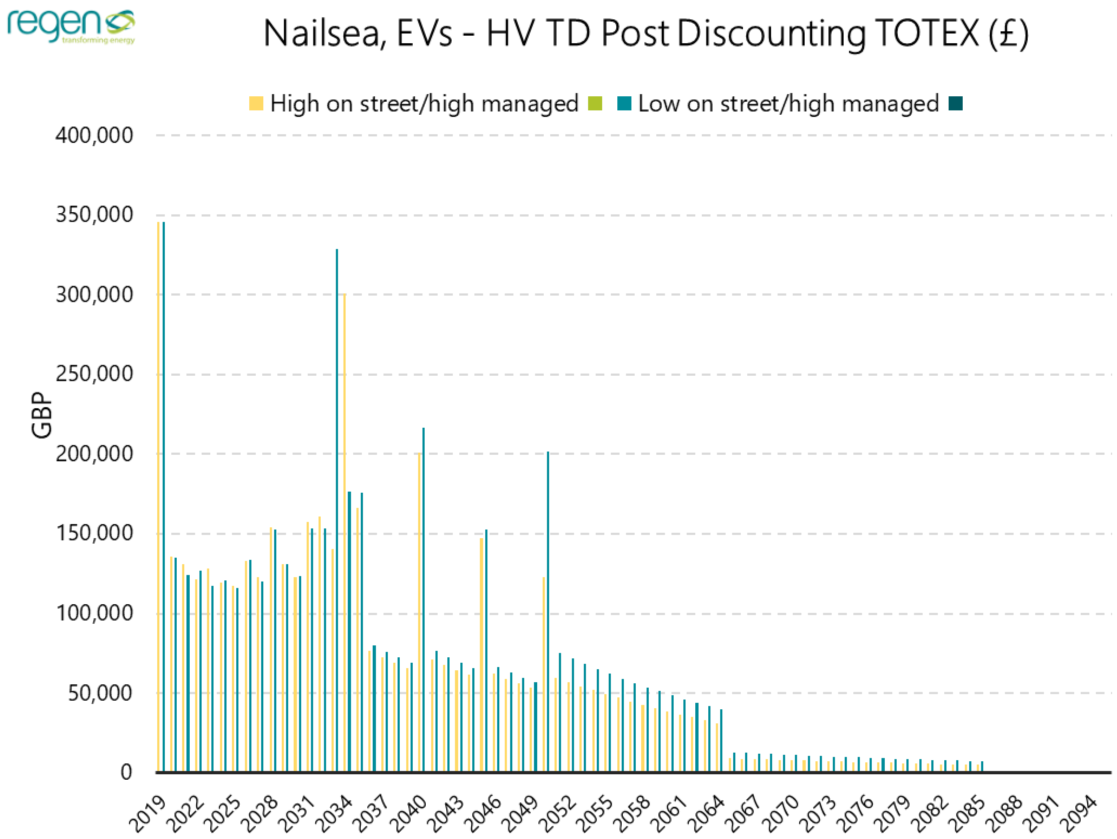



*Figure 54: Absolute HV TOTEX on the Nailsea primary from top down analysis*

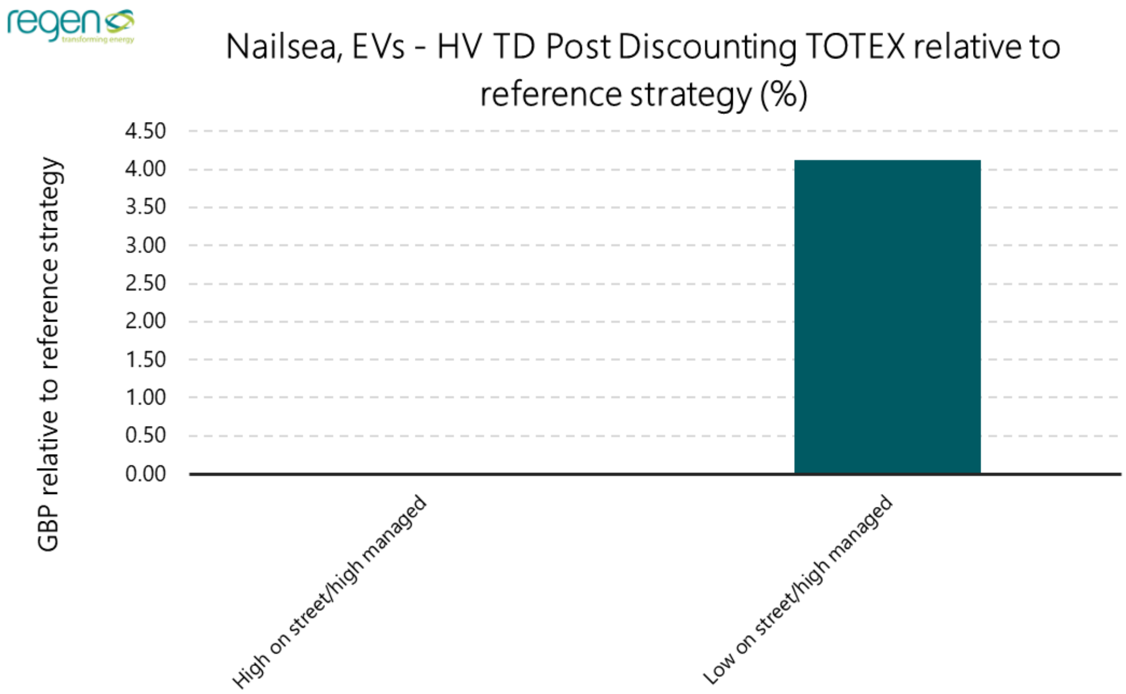



*Figure 55: Relative HV TOTEX on the Nailsea primary from top down analysis*

# 9. Appendix 4: EV charger costs to the Local Authority

As well as the network impact, the costs to the local authority of installing and operating EV chargers is considered in this use case. For this EPIC trial process, it is assumed that the local authority will be paying the full amount for the purchase, installation and operation of the chargers.

The charger classifications below, from WPD's DFES Customer Behaviour Assumptions report, will also be used to estimate Local Authority costs:

| Charger Grouping | WPD Charger Subtechnology |
|---|---|
| Residential | Domestic off-street |
| | Domestic on-street |
| Work | Fleet/Depot |
| | Workplace |
| Slow/Fast Public | En-route / local charging stations |
| | Car parks |
| | Destination |
| Rapid Public* | En-route national network |

*Figure 56: WPD DFES EV charger groupings and sub technologies*[2]

## 9.1. Residential (LV level, up to 7kW)

On-street domestic units on the LV level are assumed to be 7kW Fast Dual Type 2 units. The London EV infrastructure delivery plan[3] provides a CAPEX estimate of £4000-£6000 for this unit. The UK EV Supply Equipment Association, in their Procurement Guide[4], provides a CAPEX of £1700-£5000 (excluding VAT, Delivery and installation).

An additional datapoint is the government's On-Street Residential Scheme (ORCS). This is a grant provided by government to Local Authorities. It covers 75% of:

1. **Charge point hardware costs:** This includes the cost of the charge point units and any associated hardware (such as guard rails or barriers).
2. **Labour and installation costs:** This includes the costs associated with installing the hardware and civil engineering.

[2] https://www.westernpower.co.uk/downloads-view-reciteme/303103
[3] https://lruc.content.tfl.gov.uk/london-electric-vehicle-infrastructure-taskforce-delivery-plan.pdf
[4] https://www.r-e-a.net/wp-content/uploads/2020/03/Updated-UK-EVSE-Procurement-Guide.pdf

3. **Electrical connection costs and associated labour:** This includes the DNO cost, the labour involved in installing an electrical connection and associated civil engineering work (such as trenching).

Over a period of 4 years from 2017-2021, 1603 installations were completed at a grant cost of £5,236,664. This suggests an average installation cost to the Local Authority of £4355.

**A CAPEX of £4300 for a charging unit falls within the range of the above sources and aligns with this average value – it will be assumed for the EPIC trial run.**

## 9.2. Work Chargers

Though this category, containing Fleet/Depot and Workplace units is modelled on the HV network, they are likely to be of the same charger type as the residential on street units, and so have the same estimated CAPEX of £4300.

However, Element Energy in their 2022 report "Analysis of a Net Zero 2030 Target for Greater London"[5] have provided far lower estimates for the cost of workplace and depot chargers. A workplace charger (including installation) is estimated at £1058, while a depot ranges from £1000 for an LGV point - to £25,000 for an HGV and bus point.

**In the absence of clear plans for which type of workplace charger would be installed, the EPIC trial has assumed the value of £4300 as an average CAPEX for workplace chargers.**

## 9.3. Slow/Fast Public

These units are in the range of 3kW-22kW. CAPEX costs increase significantly with the power rating of the charger, from an estimated £1000 for a slow charger up to over £6k for fast chargers:

- The UK EV Supply Equipment Association outline a CAPEX range of £3000-£5000 (excluding VAT, delivery, and installation).
- The London EV Taskforce provide a range of £4000-£6000 for fast chargers.
- Element Energy provide an assumed cost of £6745 for a public charger.

**The assumed cost will be £5500 to reflect these increases and the likelihood that public charge points are likely to deploy in higher ratings going forward.**

## 9.4. Rapid Public

The UK EV Supply Equipment Association estimates these 43+ kW chargers to have a higher CAPEX of £15-25k for a dual unit, and £15-30k for a triple unit (excluding VAT, delivery, and installation). The London EV taskforce give a higher CAPEX of ~£50,000k and Element Energy assume £70,733 per charger in their 2020 model. **£65,000 will be assumed for this assessment.**

[5] https://www.london.gov.uk/sites/default/files/nz2030_element_energy.pdf

## 9.5. CAPEX reduction over time

There will be a natural reduction in CAPEX costs for charger deployment as technology and practices become more efficient. Element Energy have modelled this with annual percentage changes seen below, of note is the increase in rapid charger costs as higher rated chargers above 100kW are deployed at scale. With the rapid chargers in the EPIC trial having 350kW ratings throughout the period, this increase will not be modelled, the costs of a rapid charger will be assumed to decrease in line with the other charger types.

**Table 5.7 Relative cost reductions (and increases) over time. Note that rapid charge point costs increase over time as the share of 100 kW and above power ratings increases.**

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| Summarised cost curves | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|
| Home charge point | 100% | 88% | 75% | 75% | 75% | 75% | 75% |
| Workplace charge point | 100% | 85% | 71% | 71% | 71% | 71% | 71% |
| Public charge point | 100% | 91% | 81% | 81% | 81% | 81% | 81% |
| Rapid charge point | 100% | 108% | 112% | 115% | 115% | 116% | 116% |
| Hydrogen refuelling station | 100% | 100% | 100% | 100% | 100% | 100% | 100% |

*Figure 57: Annual assumed charger cost variation from Element Energy's "Analysis of a Net Zero 2030 Target for Greater London*[5]

## 9.6. OPEX

Higher rated rapid chargers can have significantly higher OPEX costs than slow or fast chargers. They are generally far more complex pieces of equipment with higher parts cost and requiring more skilled technicians to service. There is also more incentive for the operator to monitor and maintain them as the loss of income from a fault is much higher. Hence they are subject to more rigorous and regular checks.

The EV Charger Procurement Guide estimates an annal inspection cost of £100-£200 for a slow/fast charger and a £300 – £2300 annual inspection cost for a rapid charger.

ENGIE have used a figure of 250EUR/kW/year in an OPEX estimation for the 'Zero Carbon Rugeley' project. With a large deployment of EV charging infrastructure, ENGIE have a large evidence base to inform this assumption. The 250 EUR/kW/year figure results in annual OPEX of:

- £1477 for a 7kW charger
- £9073 for a 43kW charger

These values are significantly higher than the ranges given the EV Charger Procurement Guide. However, the ratio of slow/fast charger OPEX to rapid charger OPEX is similar, meaning the comparison between the two strategies is similar regardless of the choice of OPEX values. While a higher annual OPEX, more in line with the ENGIE figures was also tested, **the results below**

[6] https://www.london.gov.uk/sites/default/files/nz2030_element_energy.pdf

**assume lower annual OPEX values of £150 and £1300 for chargers below and above the 43kW rapid charging threshold.**

# 10. Results

Applying the CAPEX and OPEX costs outlined above to the deployment numbers modelled in the two strategies produces the following total costs by 2050 to the Local Authority:

*Table 3: Local Authority EV charger deployment costs.*

| Primary | LA CAPEX and OPEX to 2050 (GBP) | |
|---|---|---|
| | High on-street domestic | High rapid charging hubs |
| Nailsea | 2.3m | 1.7m (-26%) |
| Dorchester St | 5.1m (-4%) | 5.3m |
| Cribbs Causeway | 2.4m | 2.3m (-4%) |

In Nailsea and Cribbs Causeway, the reduced number of chargers in the high rapid charging hubs strategy results in lower overall costs, the increased cost per unit does not offset this saving. On Dorchester St, the primary with the most rapid chargers modelled, the cost of these rapid charging units does offset the savings from reduced overall charger numbers, meaning the high rapid charging strategy is the more expensive option.

To compare the costs to the Local Authority to deploy and maintain these two charging strategies on a per kilowatt of electricity delivered basis, a Levelised Cost of Electricity comparison has been completed. This has used charger utilisation rates from a WPD 'Net Zero' DFES scenario. By 2050 a rapid charger is assumed to be in use 39% of the time, while an on-street domestic unit is used 23% of the time.

*Table 4: WPD DFES 'Net Zero' charger utilisation assumptions*

| Scenario | Charger type | 2018 | 2019 | 2020 | 2021 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|---|---|---|
| Net Zero | Car parks | 0.5% | 2.1% | 3.3% | 4.6% | 14.0% | 15.9% | 17.8% | 19.6% | 21.5% |
| Net Zero | Destination | 1.0% | 1.0% | 1.9% | 2.8% | 11.0% | 13.3% | 15.5% | 17.8% | 20.0% |
| Net Zero | Domestic off-street no charger | 11.0% | 11.0% | 10.4% | 9.8% | 4.4% | 4.6% | 4.8% | 5.1% | 5.3% |
| Net Zero | Domestic off-street with charger | 3.1% | 3.1% | 3.2% | 3.3% | 4.0% | 4.0% | 4.0% | 4.0% | 4.00% |
| Net Zero | Domestic on-street | 5.0% | 6.0% | 7.5% | 8.9% | 21.0% | 21.6% | 22.2% | 22.8% | 23.4% |
| Net Zero | En-route / local charging stations | 5.7% | 8.0% | 10.3% | 12.6% | 31.3% | 33.2% | 35.1% | 37.1% | 39.0% |
| Net Zero | En-route national network | 5.1% | 5.1% | 7.7% | 10.3% | 33.5% | 35.6% | 37.7% | 39.9% | 42.0% |
| Net Zero | Fleet/Depot | 17.7% | 17.7% | 17.8% | 17.9% | 18.8% | 19.7% | 20.7% | 21.7% | 22.7% |
| Net Zero | Workplace | 8.0% | 8.0% | 9.2% | 10.5% | 22.0% | 23.7% | 25.3% | 27.0% | 28.6% |

*Table 5: Levelised cost of electricity delivered by the two charging strategies*

| **Primary** | Strategy LCOE by 2050 (GBP/kWh) | |
|---|---|---|
| | High on-street domestic | High rapid charging hubs |
| Nailsea | 0.025 | 0.012 (-52%) |
| Dorchester St | 0.014 | 0.010 (-28%) |
| Cribbs Causeway | 0.022 | 0.020 (-10%) |

The high rapid charging hubs strategy has the lower LCOE across all primaries. The largest saving is seen on the Nailsea Primary, with the high rapid charging hubs strategy delivering electricity at under half the LCOE of the high on-street strategy.

Dorchester St has the most EV chargers modelled, and while the overall cost of the strategy is higher, per kWh of electricity delivered, it is 28% cheaper.

In this assessment, the assumed utilisation of a domestic on-street unit is very similar to the public units. There is an argument for using a lower utilisation rate for the domestic on-street units, with the likelihood that residents will park for long periods of time at these units without charging. If this was the case, the LCOE assessment would be higher still for the high-on street strategy.

This result presents an interesting question to Local Authorities tasked with delivering EV charging infrastructure. While the main cost benefit analysis in this report has described increased disruption from roadworks due to a high rapid charging strategy, this approach may be able to achieve significantly lower LCOE, reducing costs of charging for customers, or allowing higher revenue to be collected by local authorities.