Project EPIC

Work Package 6:

Network investment results for Use Case 2: Energy Efficiency

Final Draft

EPIC

Energy Planning Integrated with Councils

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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
EAC	Estimated Annual Consumption
EE	Energy Efficiency

Abbreviation	Term
ENA	Energy Networks Association
EPIC	Energy Planning Integrated with Councils
ESA	Electricity Supply Area
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.
WECA	West of England Combined Authority
WP	Work Package
WPD	Western Power Distribution
WS CBA	Whole System Cost Benefit Analysis
WWU	Wales and West Utilities

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 WP3.

This document forms part of WP6 of the EPIC Trial. It describes the results of this whole systems cost benefits analysis for Use Case 2, assessing the impact on the network and society of varying degrees of energy efficiency measures deployed across domestic customers.

Table 1: The project EPIC Trial use cases

Use Case 1: EV charger deployment	Comparing the network impact two Electric Vehicle (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 customers.**
Use Case 3:	Exploring the impact of using the gas network and hybrid heat pumps to reduce peak electricity demand and electricity network costs.

Hybrid Heat pumps	
Use Case 4: Just in Time vs. Fit for Future	Comparing a BAU network upgrade to meet immediate demand growth, or an investment in upgraded assets to meet longer term future demand growth.
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 tested 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 tested 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. This report presents the results of the use-case cost benefit analysis and financial outcomes. 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 Network Investment Forecasting Tool (NIFT) and HV Network Assessment Tool (NAT) results reports which will be produced as part of WP5.

3. Key outcomes and conclusions

Local authorities may achieve energy efficiency improvements in a number of ways. For example, through funding/promotion of retrofit measures, or through investment in local authority housing stock or commercial premises. There is an ongoing discussion that networks may also benefit from energy efficiency measures, because they will reduce network loads, and there may therefore be a whole-system justification for networks directly, or more likely indirectly, supporting the deployment of energy efficiency measures.

This use case goes some way in quantifying the network and societal impact of taking such actions by modelling a reduction in demand across domestic customers. On three primaries, a ‘medium energy efficiency’ strategy is compared with the baseline, low energy efficiency, results. On the Cribbs Causeway primary, a ‘high energy efficiency’ strategy is also tested.

Across all three primaries that were modelled, medium or high energy efficiency strategies result in significant reductions in some individual network costs, such as HV CAPEX, OPEX and roadworks. For the most part, these carry through to cause significant (2-10%) savings on electricity network TOTEX out to 2050; in the case of Nailsea, a large CAPEX saving results in a 13% HV TOTEX saving by 2050. This large saving reflects the inclusion or omission of large investments in the modelling, i.e. highly expensive primary transformers being replaced or not being replaced. This shows that the electricity network benefits of energy efficiency will vary according to the degree of spare capacity at a primary substation and the ability of energy efficiency to negate the impact of other LCTs being deployed. This in turn suggests that while there will always be some benefit to the electricity network, the scale of the benefit will vary between primary substations.

Differences between Bottom Up and Top Down modelling were expected. Bottom Up modelling in the NIFT models heat pumps as separate entities and therefore reflects the impact of building fabric improvements as a reduced Estimated Annual Consumption (EAC) for the customer's heat pump. The Top Down methodology makes percentage split assumptions in order to model the energy reductions which are likely to be less accurate.

A reduction in electricity network related roadworks is also captured, with up to 30% reductions in the in the societal cost of roadworks for the high energy efficiency strategy.

These results support the view that electricity networks and local authorities can plan energy efficiency in the knowledge that additional demand reduction will deliver additional network and societal benefit.

3.1. Limitations of the modelling

1) The nature of the Cost Benefit Analysis method 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 medium and high Energy Efficiency (EE) strategies 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.

   While in this use case, some significant network TOTEX impacts are captured, when whole systems NPC is considered, only the Nailsea primary sees a significant whole system saving of 2.5% for the medium EE strategy. The other primaries see whole system savings below 2%.

2) The expected impact of energy efficiency measures in reducing electricity demand and so the

associated cost of carbon emissions was not captured significantly in these results. This can be explained by modelling assumptions:

Relative to the Low EE strategy, a 7.7% reduction in total demand to 2050 from profile classes 1 and 2 was modelled for the medium EE strategy, increasing to 10.3% for the High EE strategy. These reductions were not large enough to have a significant impact on emissions once a reducing grid carbon factor was also assumed.

3) This use case was principally intended to investigate the network benefits of energy efficiency. As a result, the whole systems cost assessed here is missing key impacts which were outside the scope of this use case. Principle among these is reduced gas demand for heating; medium and high energy efficiency strategies would likely result in significant savings. The omission of gas network impacts from this whole systems CBA is discussed in this report (section 4.1.2) and within wider project EPIC deliverables. However, it is worth noting that energy efficiency would likely have benefits in the event of widespread hydrogen rollout, in that as well as minimising network impacts, the scale of production and storage assets could be minimised.

4) The costs of undertaking policies to achieve improved energy efficiency outcomes would have to be understood to undertake an improved cost benefit analysis. There will be a point at which additional investment in energy efficiency would exceed the systems savings it delivers. For example, heat pumps require an EPC-C rating to operate efficiently; investing in the efficiency of homes to raise them to this standard would enable efficient heat pump operation and would therefore be expected to result in a long term system saving. However, it may be that additional investment required to raise homes up to EPC-A, would not result in net system saving. These diminishing returns on investment would need to be better understood by networks in order to refine any future energy efficiency investment strategies.

5) The use case modelled the impact of set percentage levels of demand reduction without being able to determine what energy efficiency interventions would be required to achieve those levels. Modelling the impact of different interventions correctly requires details of the existing building stock, interventions already applied, existing heating system efficiencies etc. that was not in the scope of the EPIC trial. However future work to develop tools to determine the cost effectiveness of energy efficiency measures are being undertaken as part of WPD's DEFENDER[1] project.

[1] https://smarter.energynetworks.org/projects/nia_wpd_065/

4. Project EPIC background

The aim of the EPIC project is to develop an energy 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.

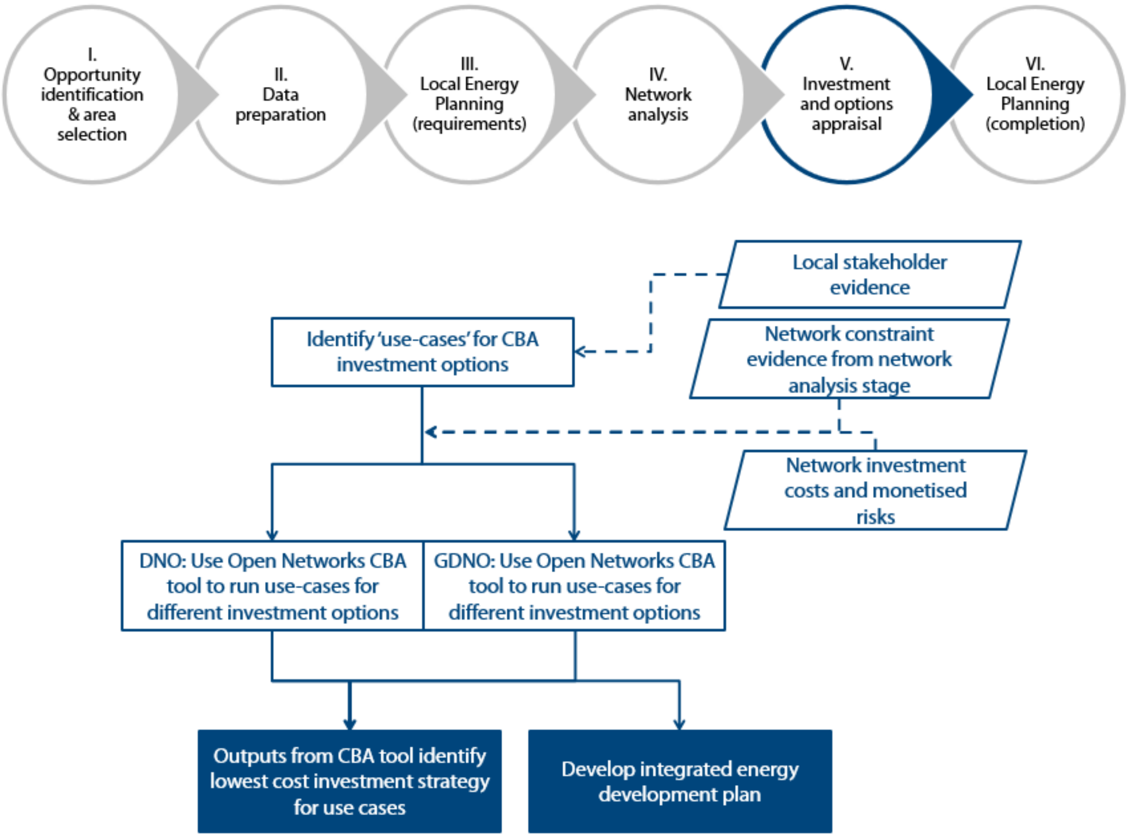

Figure 1: The EPIC Trial Planning Process.

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 network modelling tool used by 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. This is certainly true in the case of energy efficiency as in the early years of the scenarios, domestic heating will be dominated by gas boilers and so energy efficiency will act to reduce gas consumption, overall and at evening peaks, but will have less impact on electricity consumption. While customers will certainly benefit from reduced gas consumption (especially with the unusually high prices seen in mid-2022) because this reduced consumption does not lead to reduced network investment costs, the benefits for the energy efficiency use case are not expected to be dramatic. The impact of better energy efficiency from building fabric improvements is expected to be more significant as customers switch to heat pumps in later years of the scenarios, but the CBA tool will tend to put less emphasis on savings occurring later than those in earlier years which would be expected to result in relatively low levels of benefit.

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. 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:

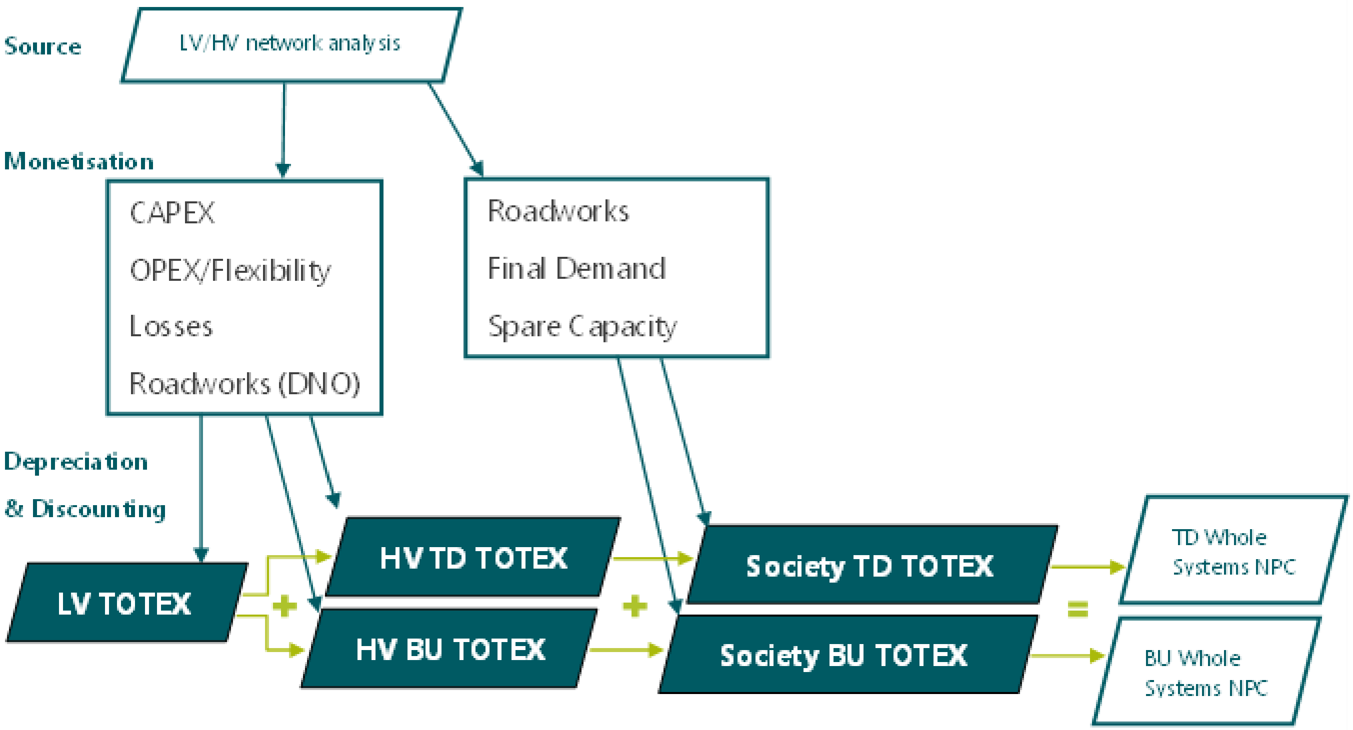

Figure 3: The processes involved in generating results from the WS CBA tool.

The diagram also illustrates how Top Down (TD) and Bottom Up (BU) analysis[2] 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.

[2] 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.

5. Results – Use Case 2: Energy Efficiency

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. 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. Examining all specific results and trends in detail has not been possible and so results are discussed where specific information has been available.

This Use Case assesses the impact on the network and society of a varying degree of energy efficiency (EE) measures leading to demand reductions across the HV and LV networks. These demand reductions are modelled on the HV and LV networks for both existing and new developments:

Table 2: HV Network, demand assumptions for existing developments

Low EE	Baseline DFES projected demand for all profile classes.
Medium EE	7.7% drop in demand from profile class 1-4 customers by 2050
High EE (only Cribbs Causeway)	10% drop in demand from profile class 1-4 customers by 2050

Table 3: LV Network, example demand reduction for existing developments

Low EE	Annual energy consumption for class 1 customer was 90% the 2019 value in 2050
Medium EE	Annual energy consumption for class 1 customer was 80% the 2019 value in 2050
High EE (only Cribbs Causeway)	Annual energy consumption for class 1 customer was 70% the 2019 value in 2050

Table 4: LV Network, demand assumptions for new developments

Profile	Scaled by	Low Energy Efficiency (Base)	Medium Energy Efficiency	High Energy Efficiency
Domestic – Class 1 (non-electrically heated)	Annual Energy Consumption (single value)	1320 kWh	880 kWh	770 kWh

Profile	Scaled by	Low Energy Efficiency (Base)	Medium Energy Efficiency	High Energy Efficiency
Domestic Class 2 (includes electric storage heating)	Annual Energy Consumption (day and night values)	Day = 841 kWh Night = 771 kWh	Day = 555 kWh Night = 526 kWh	Day = 496 kWh Night = 386 kWh
Class 3	Annual Energy Consumption (single value)	14,384 kWh	10,416 kWh	8,111 kWh
Class 7 and Class 8	Maximum Power Demand	91 kW	86 kW	81 kW
Solar PV	Maximum Power Output	3.6 kW	3.6 kW	3.6 kW
Domestic Energy Storage	Inverter Rating	0.5 kW	0.5 kW	0.5 kW
Heat Pump	Annual Energy Consumption (single value)	1,000 kWh	670 kWh	500 kWh
Off-street EV Charger	Annual Energy Consumption, varying from 2019 to 2035 based on assumed improvements in EV efficiency[3]	2019 = 2,658 kWh (Electric Nation baseline consumption) 2030 = 2,406 kWh 2050 = 2,259kWh		

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 "Low EE" variation**, and **percentage increases or savings** for the **"Medium EE"** and **"High EE"** strategy will be reported.

[3] Figure 47. Distribution Future Energy Scenarios 2020. Available from : https://www.westernpower.co.uk/downloads-view-reciteme/303103 Accessed January 2022

Table 5: The energy efficiency strategies being tested in Use Case 2 and the impacts discussed in this report.

Strategy	Strategy 1: **Low EE** (reference strategy)	Strategy 2: **Medium EE**	Strategy 3: **High EE** (only Cribbs Causeway primary)
Reporting:	N/A - Reference strategy	% change in costs/benefits	% change in costs/benefits

Table 3, below, illustrates the relative impact of the medium or high EE deployment 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. Even greater impacts, over 50%, are indicated by black cells. What is immediately clear is the regularity of marginal or small impacts, and the small incidence 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 (inc. High EE)																		
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 BU	WHOLE SYSTEM TD
Dorchester St							
Cribbs Causeway (inc. High EE)							
Nailsea							

Less than 2% difference in costs between strategies
2 - 10% difference in costs between strategies
Over 10% difference in costs between strategies
Over 50% 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. Additional explanation is given for those costs where a 50% or greater variation is observed.

5.1. CAPEX

5.1.1. Dorchester St

The medium EE strategy results in a 6% decrease in LV CAPEX over the low EE strategy. The impact is reduced on the HV network, with a 3.5% decrease from bottom up analysis, and a marginal 1.2% decrease from top down analysis.

This is the expected trend, with peak demand reduction leading to reduced network upgrade requirements. There is greater impact seen on the LV network because, whilst demand reductions were assumed for profile classes 1-4 (domestic customers), not enough was known about the demand reductions which could feasibly be delivered by energy efficiency on class 5-8 customers (commercial/industrial) to assume any value. As domestic customers make up a larger portion of LV network demand than HV demand, the LV network is more impacted by the assumed demand reduction.

5.1.2. Cribbs Causeway

On this primary, the medium EE strategy has less impact on LV and HV network CAPEX, with marginal impact on LV CAPEX and a maximum 2.5% impact on HV CAPEX if a top down approach is used.

The High EE strategy which is tested on this primary does have greater impact on the LV network, with 2.5% savings in LV CAPEX. However, the high EE strategy delivers significant 35% savings on the HV network if a top down approach is used.

5.1.3. Nailsea

The medium EE strategy results in a 3.5% decrease in LV CAPEX over the low EE strategy. In contrast to the other primaries, there is a large 50% saving in HV CAPEX if a BU approach is used:

This is due to the medium EE strategy preventing the need split a feeder in 2040 and preventing the need to upgrade a primary transformer in 2045:

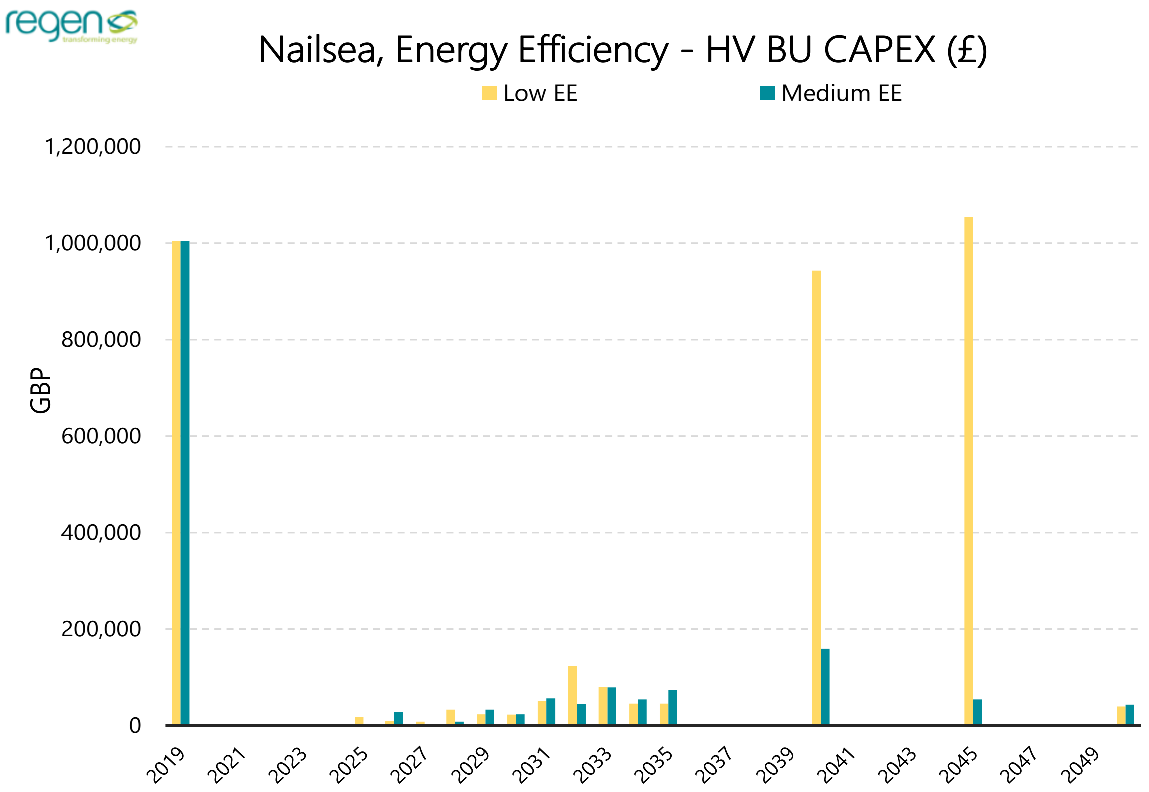

Figure 4: HV CAPEX on the Cribbs Causeway primary out to 2050, from bottom up analysis

This impact is not seen in top down analysis, with very similar annual investments leading to a 3% saving in total CAPEX for the medium EE strategy.

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.

5.2.1. Dorchester St

There are very similar impacts on OPEX between the networks on this primary. The LV and HV results all show a 4-5% reduction in OPEX resulting from the medium EE strategy. This is in contrast to CAPEX, where a greater reduction on the LV network was seen, suggesting more smart solutions were deployed.

5.2.2. Cribbs Causeway

On this primary, the LV results are counter intuitive, with 5% increased OPEX for the medium EE strategy and a lower, 4% increase for the High EE strategy.

The HV results are also unusual. If a bottom up approach is used, the medium EE strategy has marginal upward impact on HV OPEX and the High EE strategy delivers 9% savings.

From the top down analysis, the effects are far more significant, with a 35% and 45% saving in HV OPEX from the medium and high EE strategy respectively.

These result have not been explained conclusively. However, the root of them may lie in Cribbs Causeway having a very low assumed uptake of low carbon technologies, fewer customers or a different mix of smart solutions being deployed in this instance.

5.2.3. Nailsea

LV OPEX is not impacted significantly by the Medium EE strategy – a 1.8% saving. However, on the HV network, as with CAPEX on this primary, the bottom up approach leads to a large, 20% saving for the Medium EE strategy. The top down approach also has a reduced, 8%, saving,

5.3. Losses

5.3.1. Dorchester St.

Losses have been modelled as a portion of final demand on the LV and HV networks. In reducing peak demand, the Medium EE strategy does lead to reduced losses, however the impact is small, only 3.5% on the LV network and less than one percent on the HV side.

5.3.2. Cribbs Causeway

There is no significant impact on losses between the low, medium and high energy efficiency strategies.

5.3.3. Nailsea

On this primary there is a larger impact on the LV network, with a 7% saving for the medium EE strategy. However on the HV side the savings are minimal, less than 2%.

5.4. Roadworks

5.4.1. Dorchester St

The LV network sees the most benefit from the medium EE strategy, with 14% reduced roadworks costs.

The HV network sees 8% reduced roadworks from bottom up analysis, but only 2.5% if the top down approach is taken.

This is an intuitive result, linking to the reduced number of CAPEX interventions for this strategy and the greater CAPEX impact on the LV network.

5.4.2. Cribbs Causeway

The medium EE strategy has no impact on LV roadworks, this is in line with its marginal impact on LV CAPEX. However, it does result in a reduced number of interventions being required on the HV network, leading to a 30-35% drop in the cost of HV roadworks.

The High EE strategy does lead to slightly reduced LV roadworks, however it does not save additional HV roadworks over the medium EE strategy.

5.4.3. Nailsea

Compared to the other primaries, there is a larger impact on LV roadworks in Nailsea, a 20% reduction for the Medium EE strategy. This is interesting because Nailsea has a smaller LV CAPEX saving than Dorchester St, but a larger LV roadworks reduction. This is due to Nailsea primary having longer feeders on average than Dorchester St, 291m compared to 254m.

This 20% reduction is also seen on the HV network from bottom up analysis. This corresponds to the large (50%) CAPEX saving seen on the HV network.

5.5. Emissions (Final Demand)

The expected impact of energy efficiency measures in reducing electricity demand and so the associated societal cost of carbon emissions was not captured significantly in these results. This can be explained by modelling assumptions.

Relative to the Low EE strategy, a 7.7% reduction in total demand to 2050 from profile classes 1 and 2 was modelled for the medium EE strategy, increasing to 10.3% for the High EE strategy. These reductions were not large enough to have a significant impact on emissions once a reducing grid carbon factor was also assumed. In addition, no reductions in demand were assumed for profile classes 5 – 8 (I&C customers) this further dampened the impact of the medium and high EE strategies.

Dorchester St sees 0.45% reductions, Cribbs Causeway 0.29% (& 0.35% for high EE) and Nailsea 0.8%. The reducing grid carbon factor does contribute to these low figures; If a fixed carbon factor is assumed, the result for Nailsea would be a 1.8% decrease.

It is worth noting that despite these marginal impacts, the monetisation method applied to emissions (based on the social cost of carbon) leads to high absolute cost differentials when viewed against the other cost categories. For example for the High EE strategy on Cribbs Causeway, a 0.34% reduction in emissions represents a £200k saving to society. In comparison, a 35% saving in HV CAPEX represents a £900k saving to the network.

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 - significant (over 2%) impacts

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 benefits being delivered through reduced roadworks.

5.7.1. Dorchester St

The LV and HV networks have TOTEX impacts which are very similar, 2.5-3.5% savings from the medium EE strategy if the bottom up approach is taken. Top down analysis leads to reduced HV TOTEX impact due to reduced CAPEX and roadworks impact. No significant impacts on societal TOTEX were captured in this set of results.

5.7.2. Cribbs Causeway

The LV TOTEX result is of highly marginal value, but the trend is unexpected, with the medium EE strategy having higher TOTEX than the low EE strategy, this is driven by the OPEX result discussed above. The high EE strategy results in CAPEX savings which outweigh this impact, and as a result it has the (marginally) lowest TOTEX

On the HV network and through bottom up analysis, the TOTEX result is interesting and demonstrates the impact of the depreciation and discounting treatment. While there is marginal change in total CAPEX between strategies, the timing of the CAPEX investments has resulted in the high EE strategy having the highest TOTEX.

As shown in Figure 5, below, the dominant CAPEX investments in each strategy are separated by 3-4 years. The High EE investment comes first, in 2019, followed by the low and medium EE strategies in 2022 and 2023. Depreciation treatment spreads 70% of capitalised costs over the asset lifetime of 45 years, these future costs are then discounted at a rate of 3.5%. (See WP3 for detail on financial treatment). Therefore, as the high EE investment comes earlier, its impact on post depreciation and discounting TOTEX is greater, leading to a 6% increase on the low EE strategy.

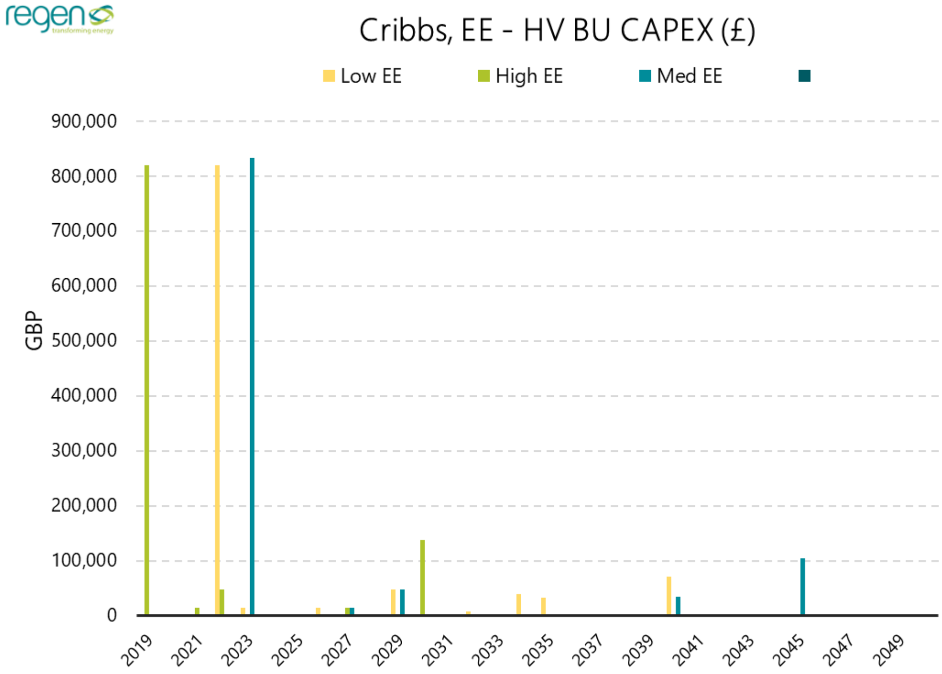

Figure 5: HV CAPEX on the Cribbs Causeway primary out to 2050, from bottom up analysis.

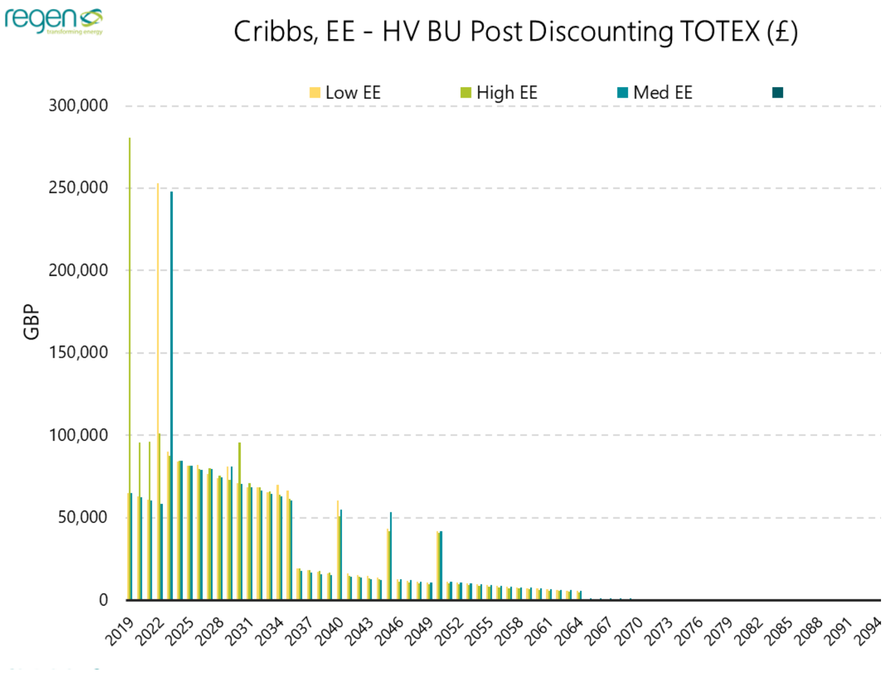

Figure 6: HV TOTEX on the Cribbs causeway primary out to 2050, from bottom up analysis.

5.7.3. Nailsea

On the LV network, the medium EE strategy results in 2% TOTEX savings, this is driven (relatively evenly) by CAPEX, OPEX and losses savings.

Bottom up analysis results in a 13% saving in HV network TOTEX, this is primarily due to the large (50%) CAPEX saving. Top Down analysis leads to insignificant savings for medium EE.

Marginal reductions in emissions and increases in spare capacity have resulted in a marginal saving in overall societal costs for the medium EE strategy, despite savings in roadworks.

5.8. Whole Systems

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); Only the Nailsea primary sees a whole systems impact of above 2% (a 2.5% saving for the medium EE strategy, if bottom up analysis is used). This is driven by reductions in HV network costs, which are, again, primarily due to CAPEX savings.

6. APPENDIX 1: Dorchester St significant results

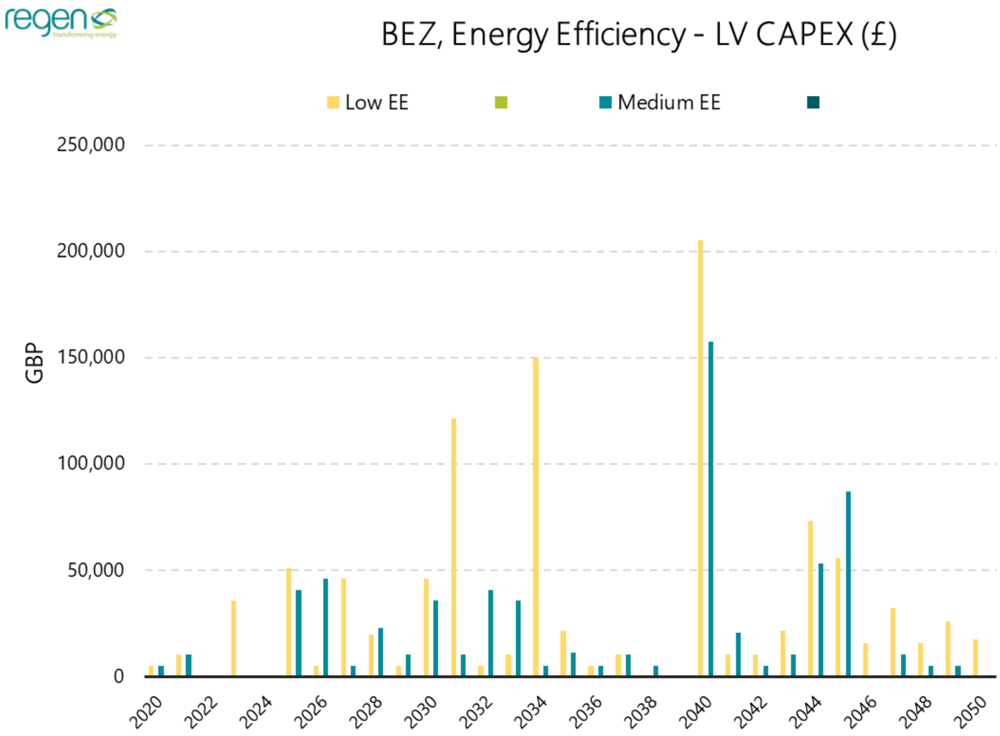

Figure 7: Annual LV CAPEX by year to 2050 on the Dorchester St primary

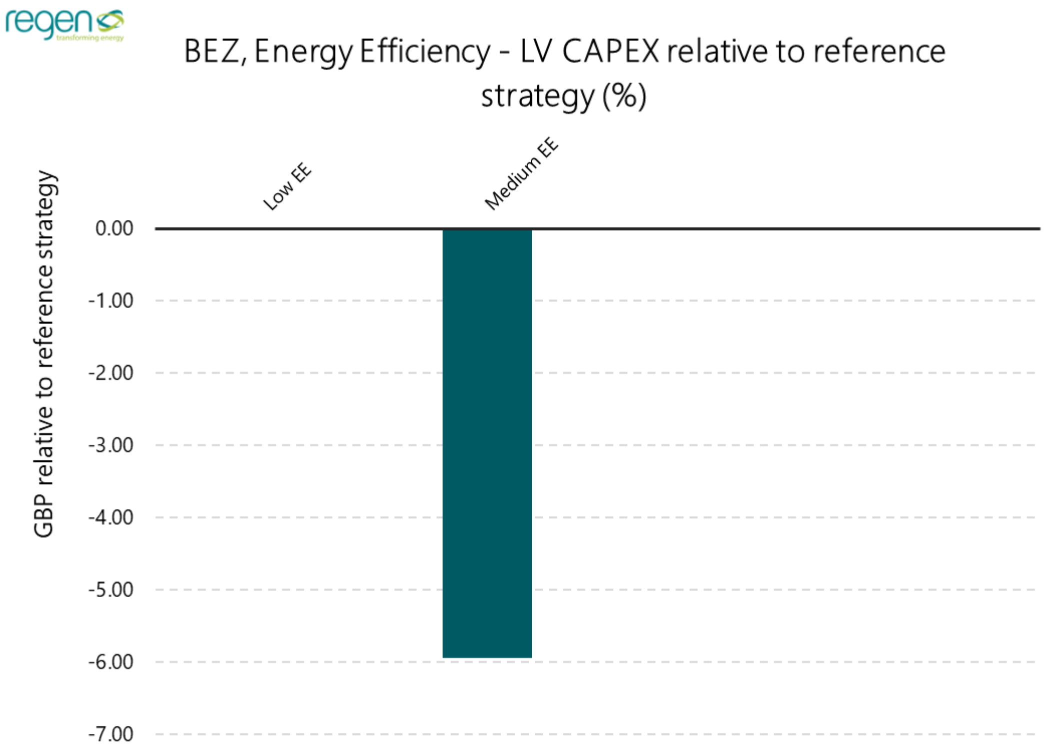

Figure 8: Total LV CAPEX on the Dorchester St primary relative to the Low EE strategy

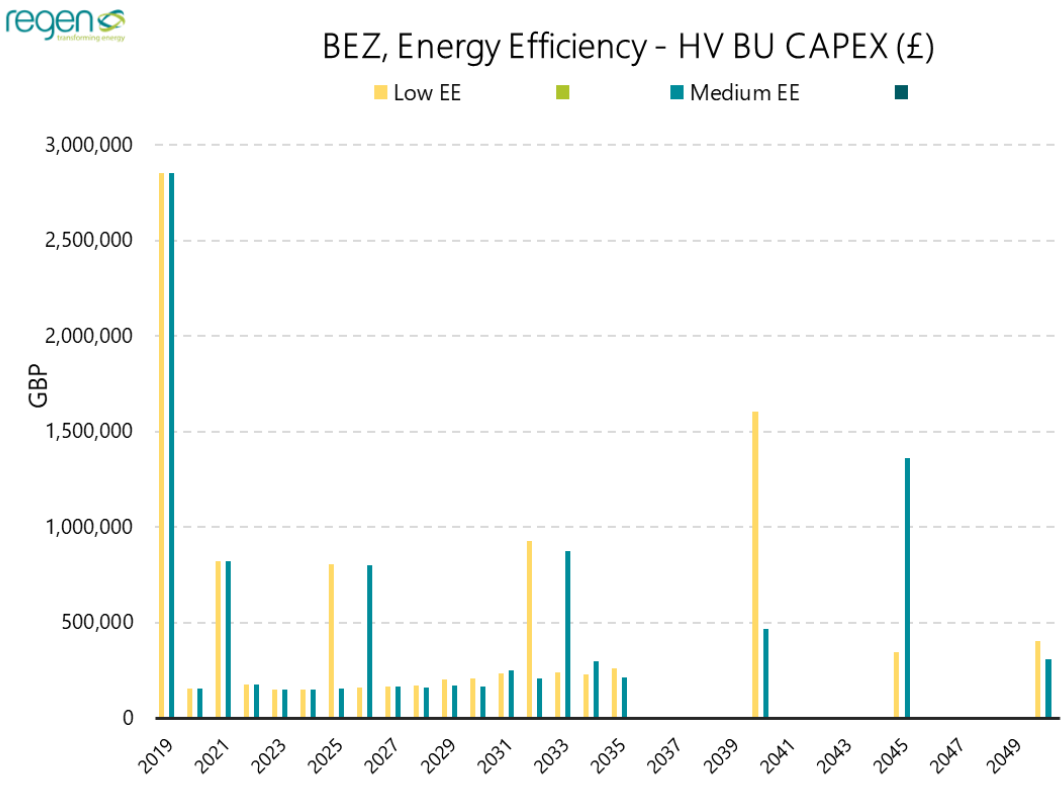

Figure 9: Annual HV CAPEX by year to 2050 on the Dorchester St primary, from bottom up analysis

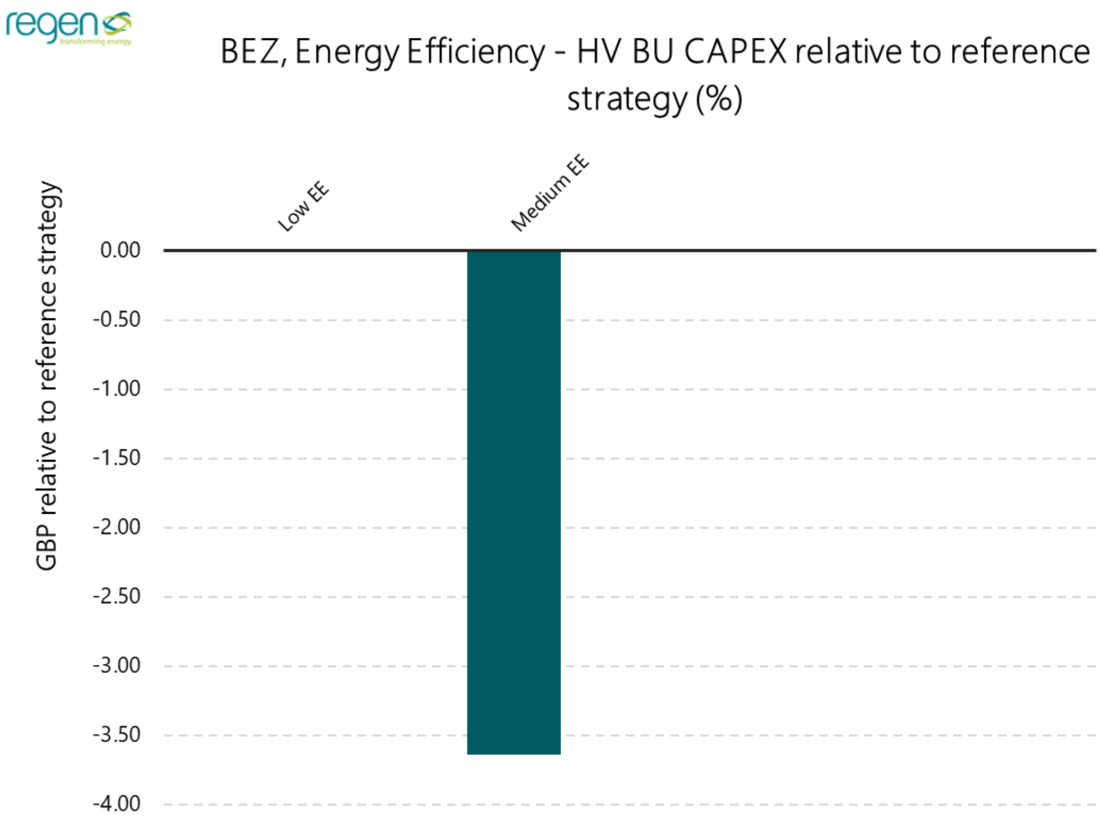

Figure 10: Total HV CAPEX on the Dorchester St primary relative to the Low EE strategy

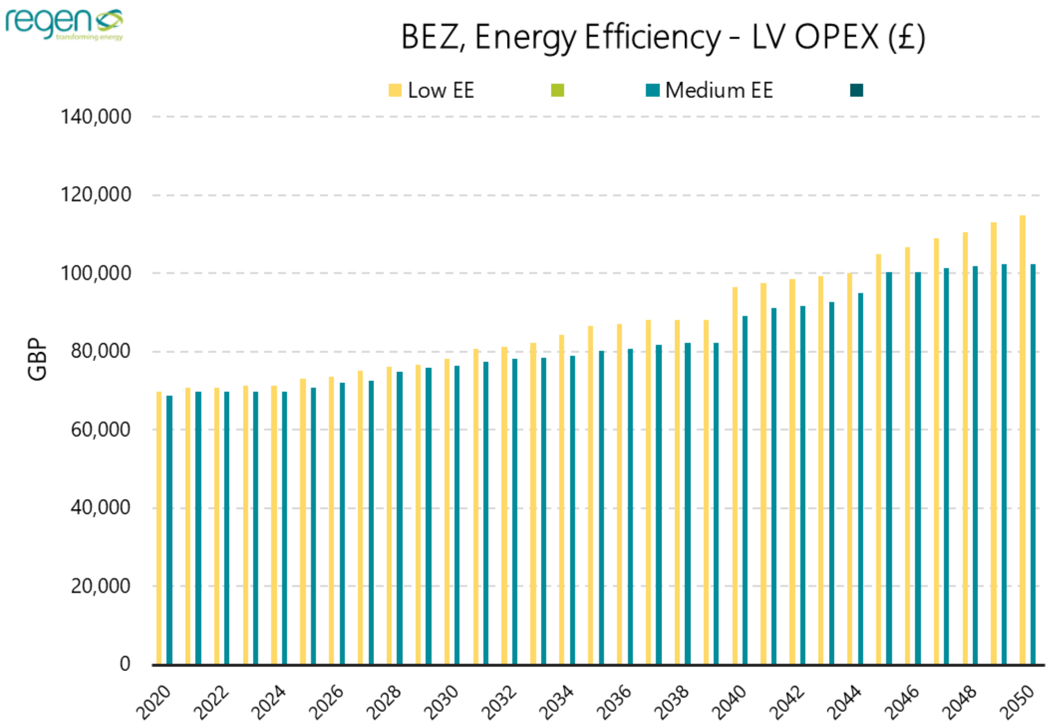

Figure 11: Annual LV OPEX by year to 2050 on the Dorchester St primary

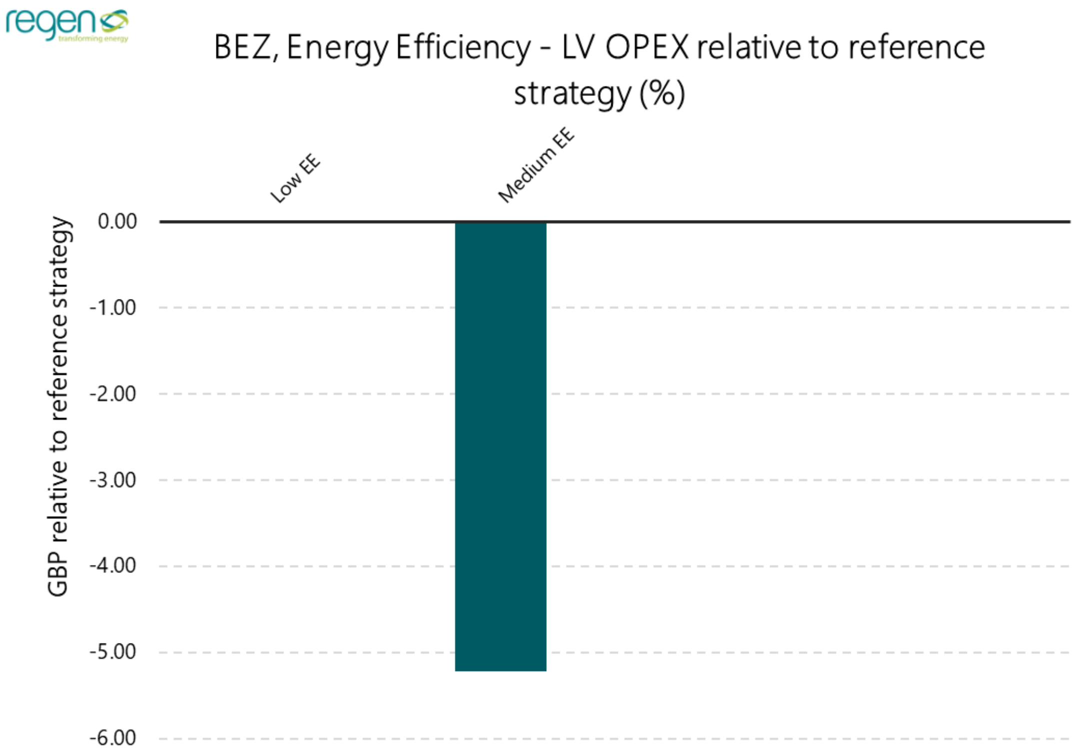

Figure 12: Total LV OPEX on the Dorchester St primary relative to the Low EE strategy

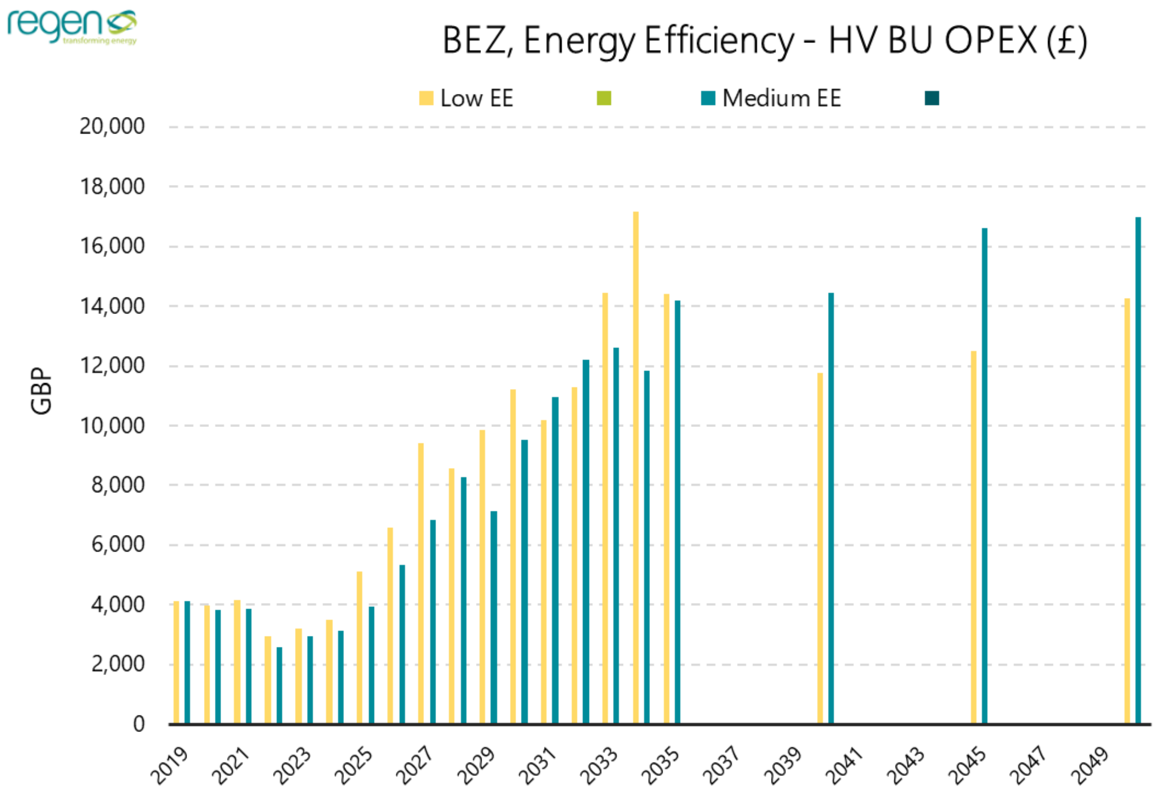

Figure 13: Annual HV OPEX by year to 2050 on the Dorchester St primary, from bottom up analysis

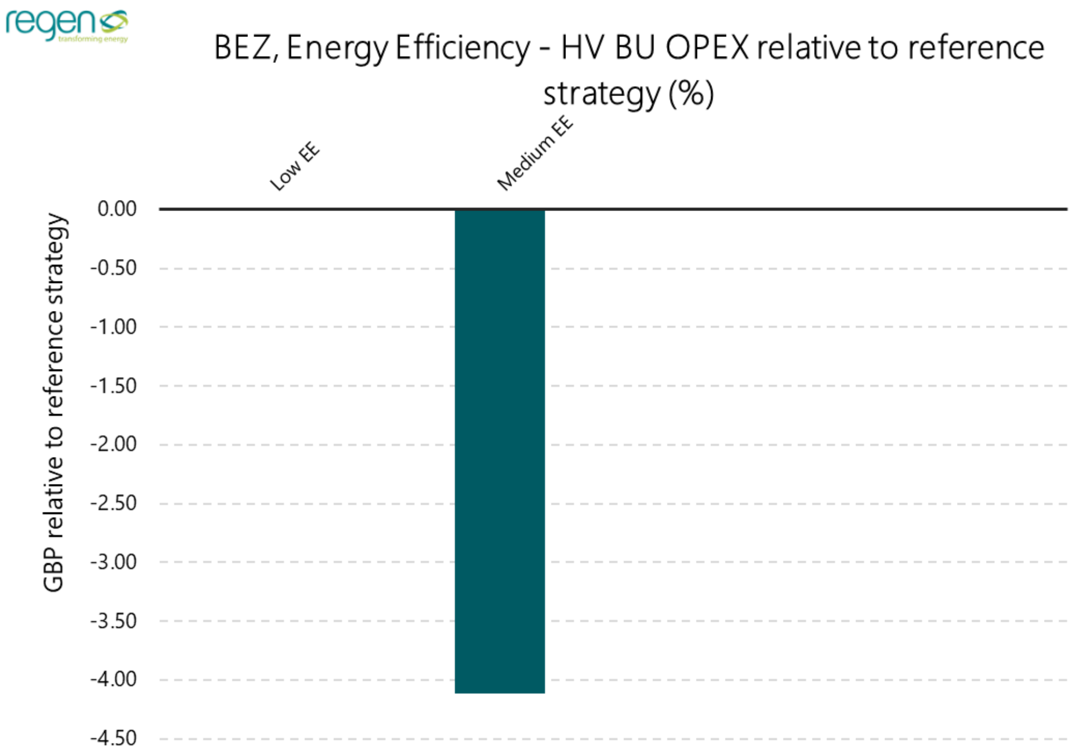

Figure 14: Total HV OPEX on the Dorchester St primary relative to the Low EE strategy, from bottom up analysis

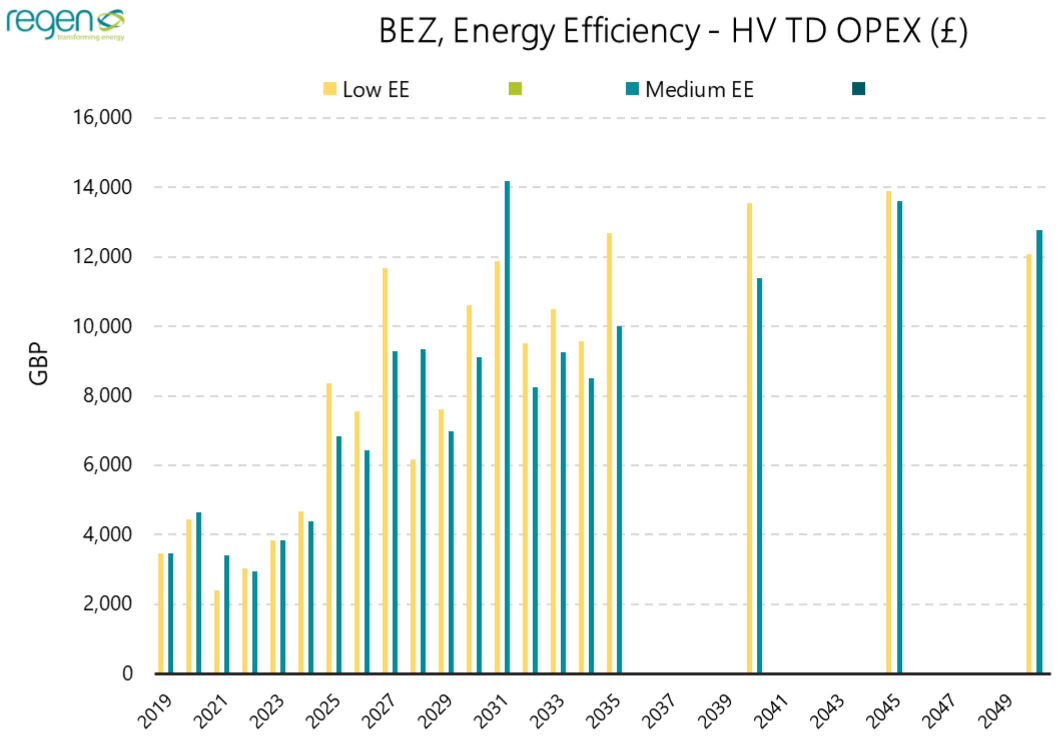

Figure 15: Annual HV OPEX by year to 2050 on the Dorchester St primary, from top down analysis

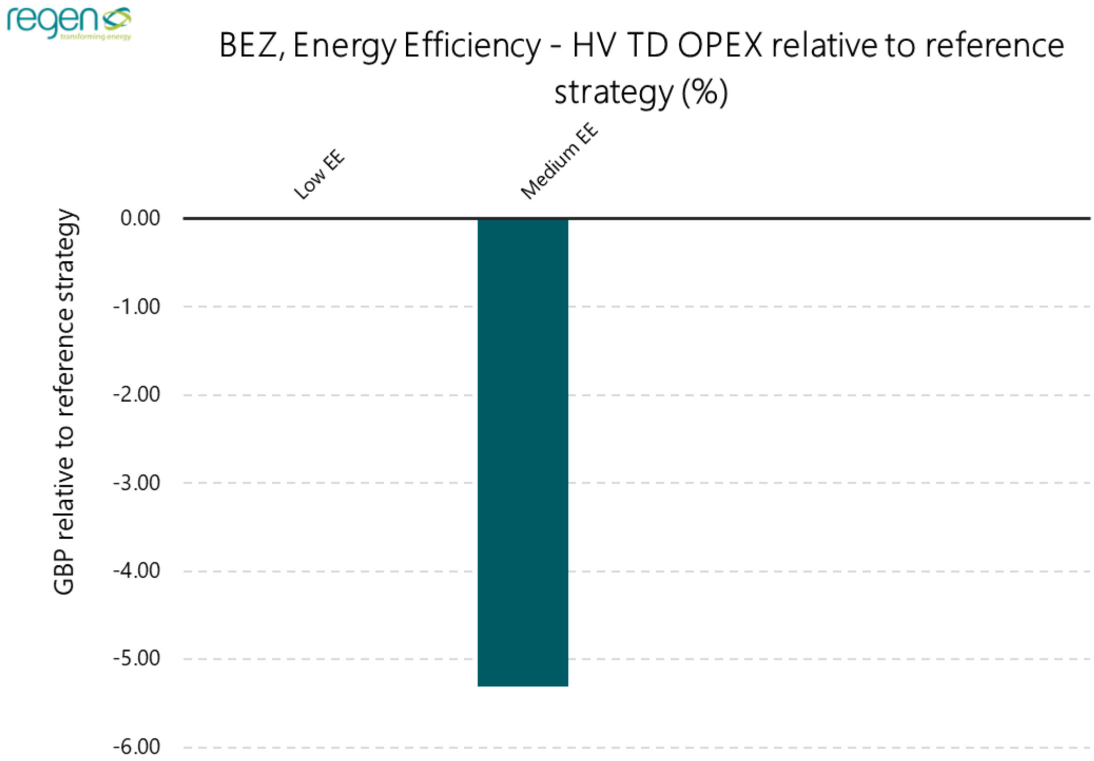

Figure 16: Total HV OPEX on the Dorchester St primary relative to the Low EE strategy, from top down analysis

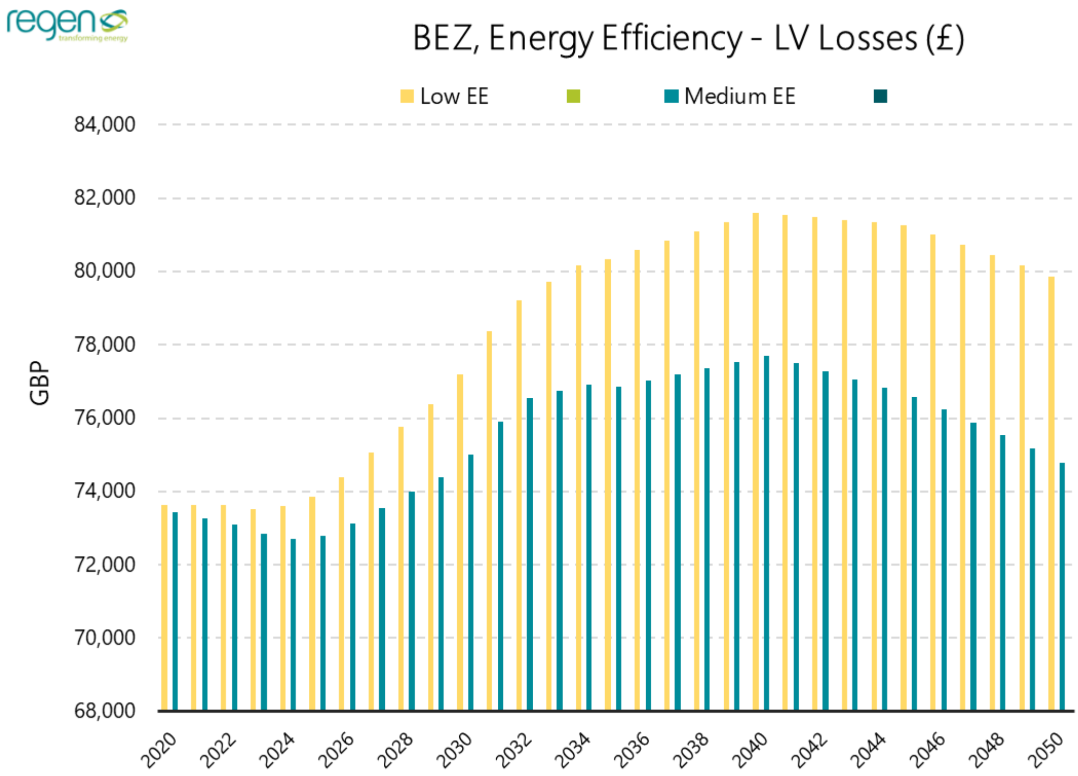

Figure 17: Annual LV losses by year to 2050 on the Dorchester St primary

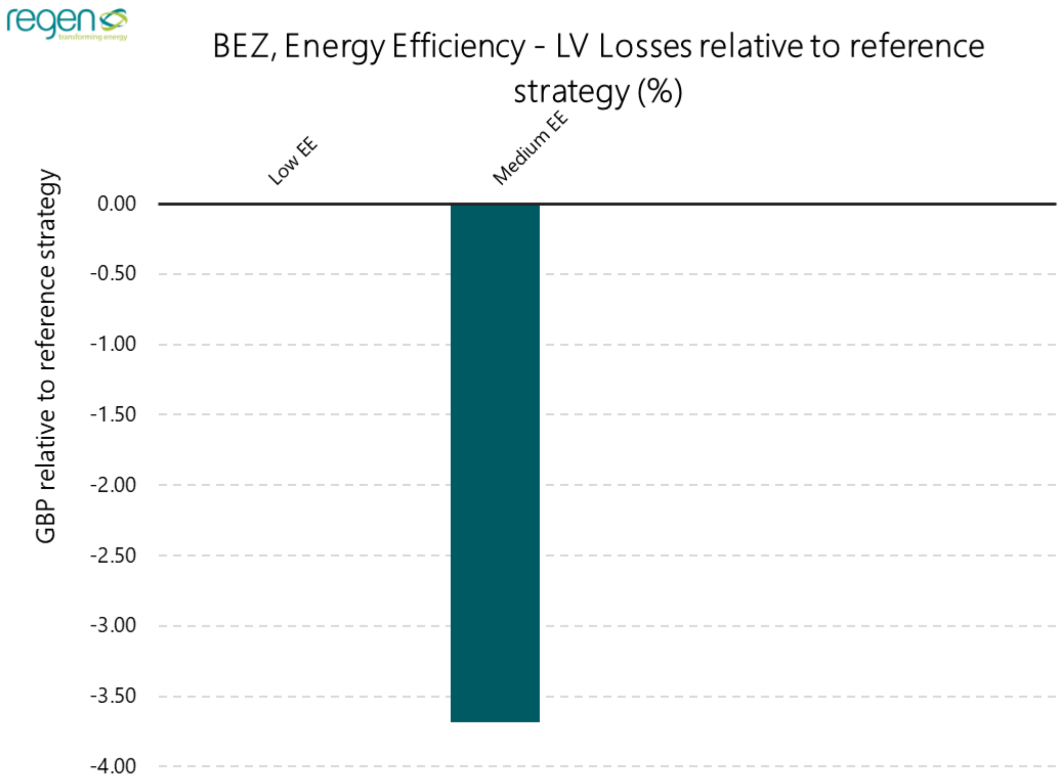

Figure 18: Total LV losses on the Dorchester St primary relative to the Low EE strategy

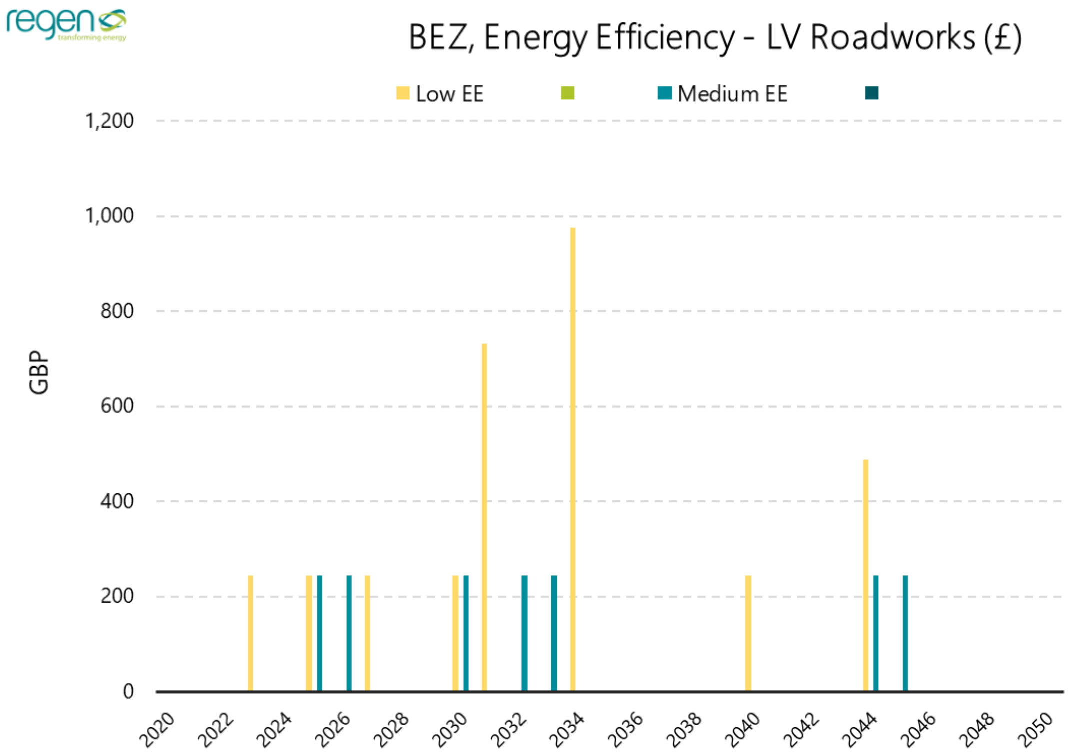

Figure 19: Annual LV roadworks by year to 2050 on the Dorchester St primary

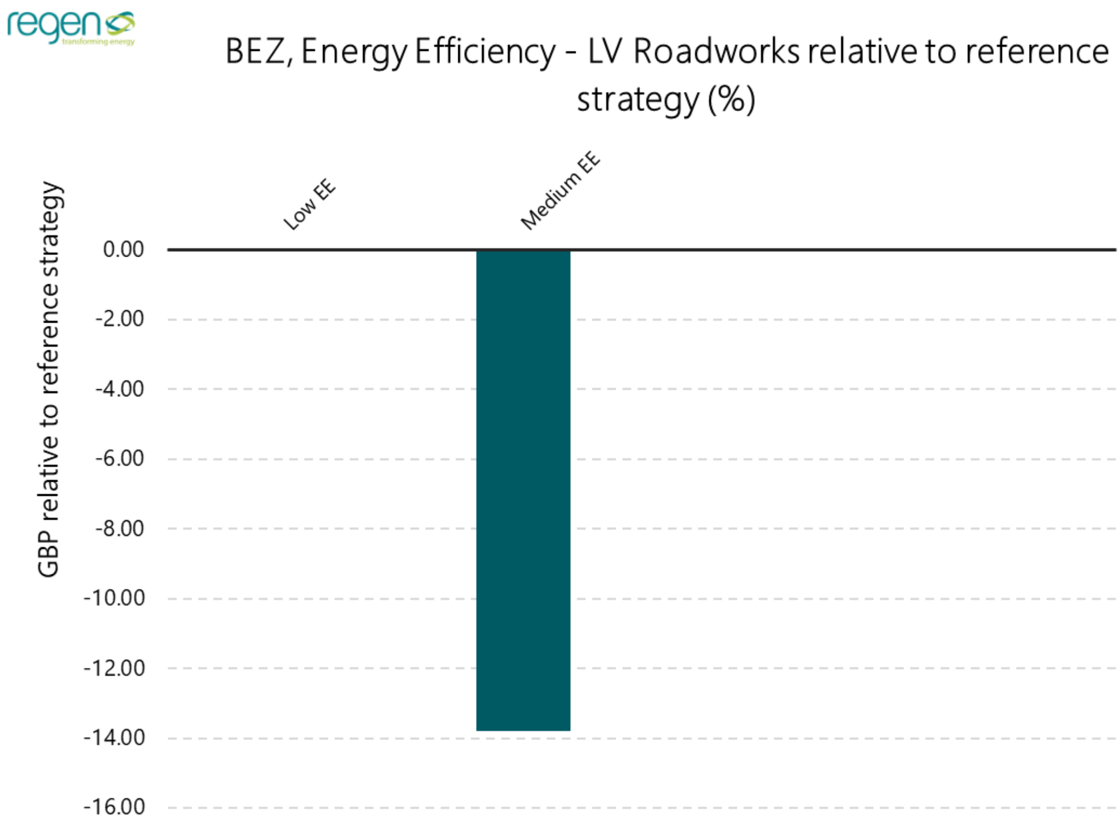

Figure 20: Total LV roadworks on the Dorchester St primary relative to the Low EE strateg

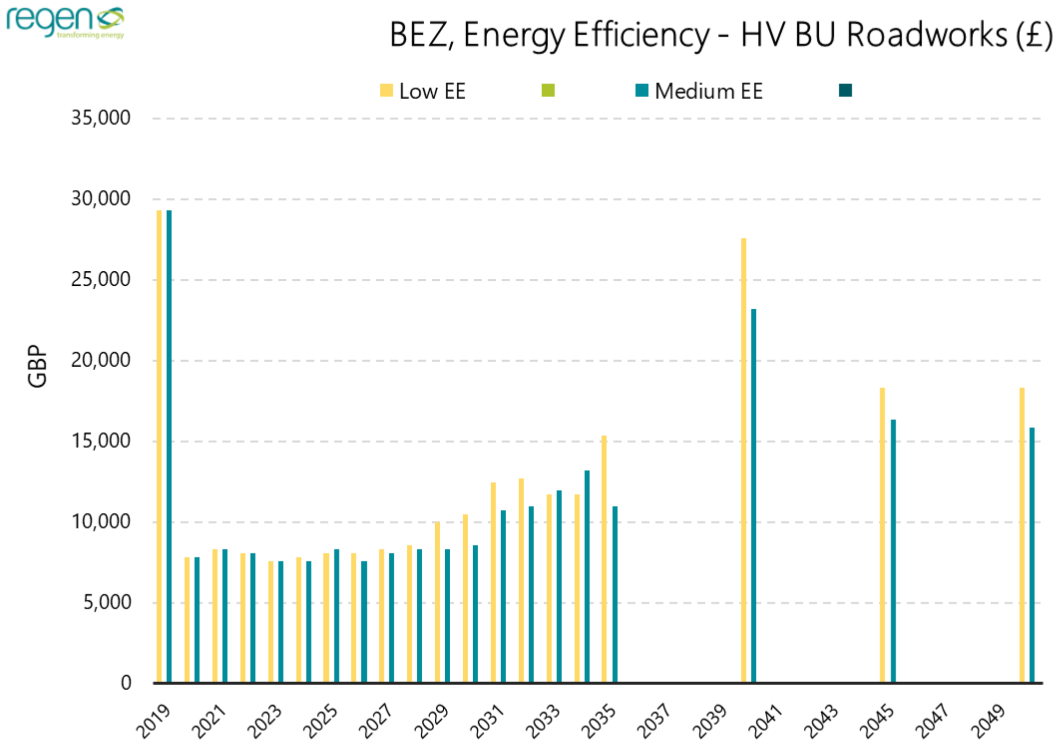

Figure 21: Annual HV roadworks by year to 2050 on the Dorchester St primary, from bottom up analysis

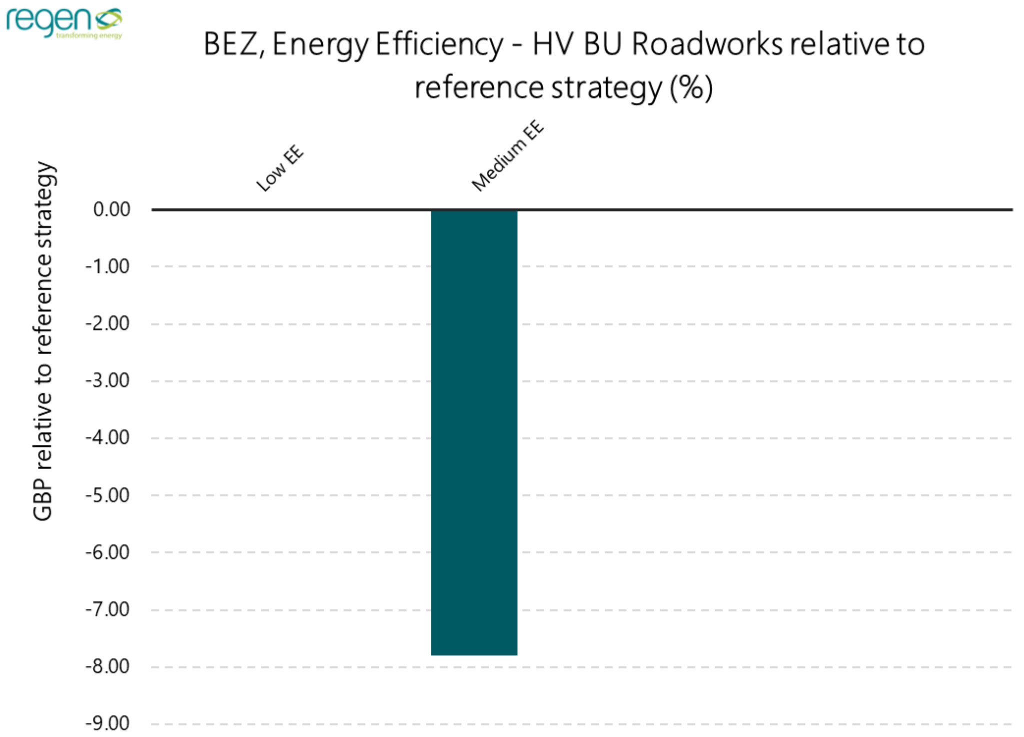

Figure 22: Total HV roadworks on the Dorchester St primary relative to the Low EE strategy, from bottom up analysis

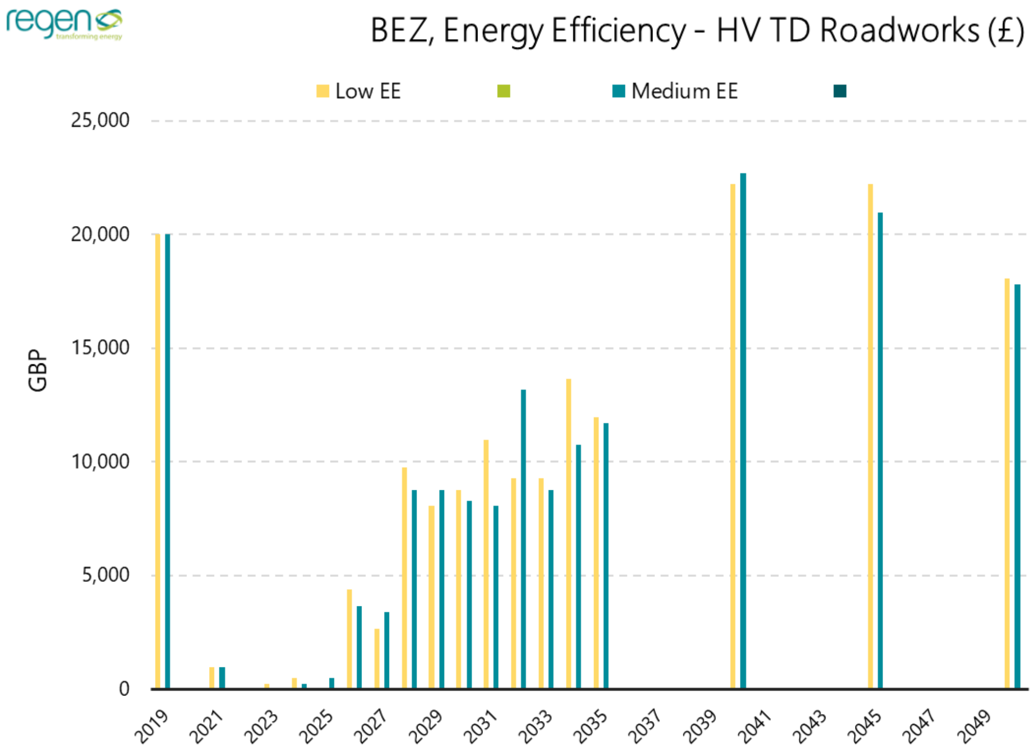

Figure 23: Annual HV roadworks by year to 2050 on the Dorchester St primary, from top down analysis

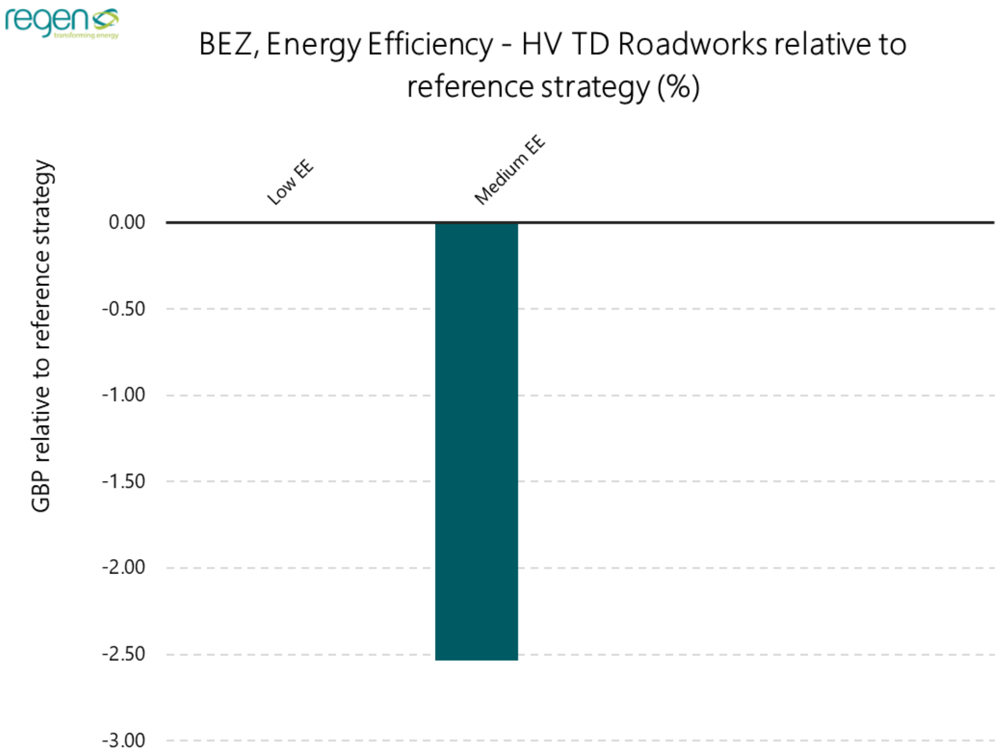

Figure 24: Total HV roadworks on the Dorchester St primary relative to the Low EE strategy, from top down analysis

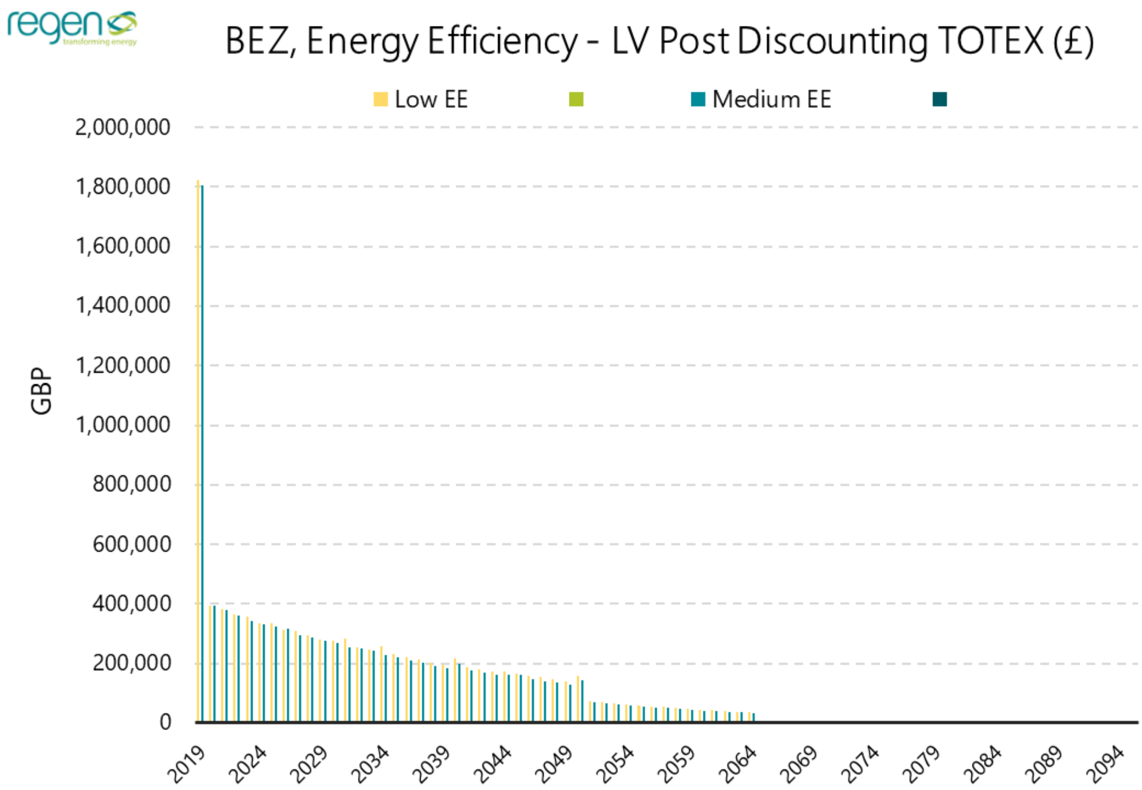

Figure 25: Annual LV TOTEX by year to 2050 on the Dorchester St primary

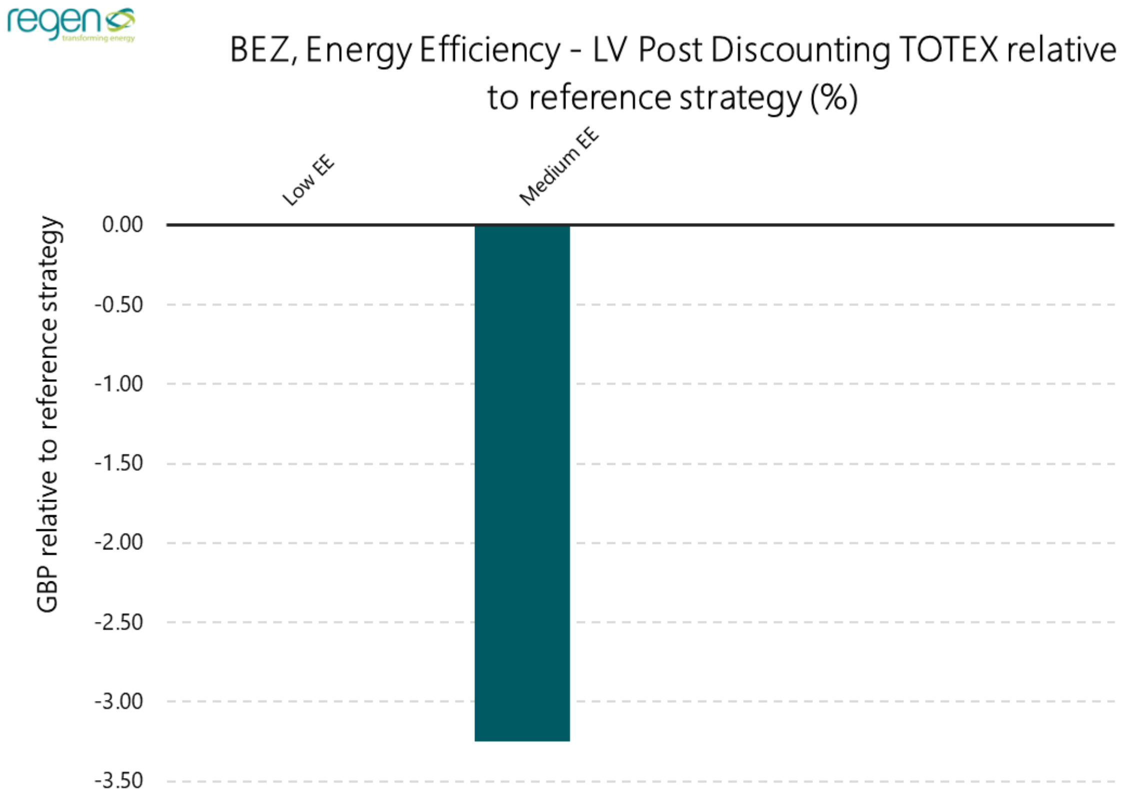

Figure 26: Total LV TOTEX on the Dorchester St primary relative to the Low EE strategy

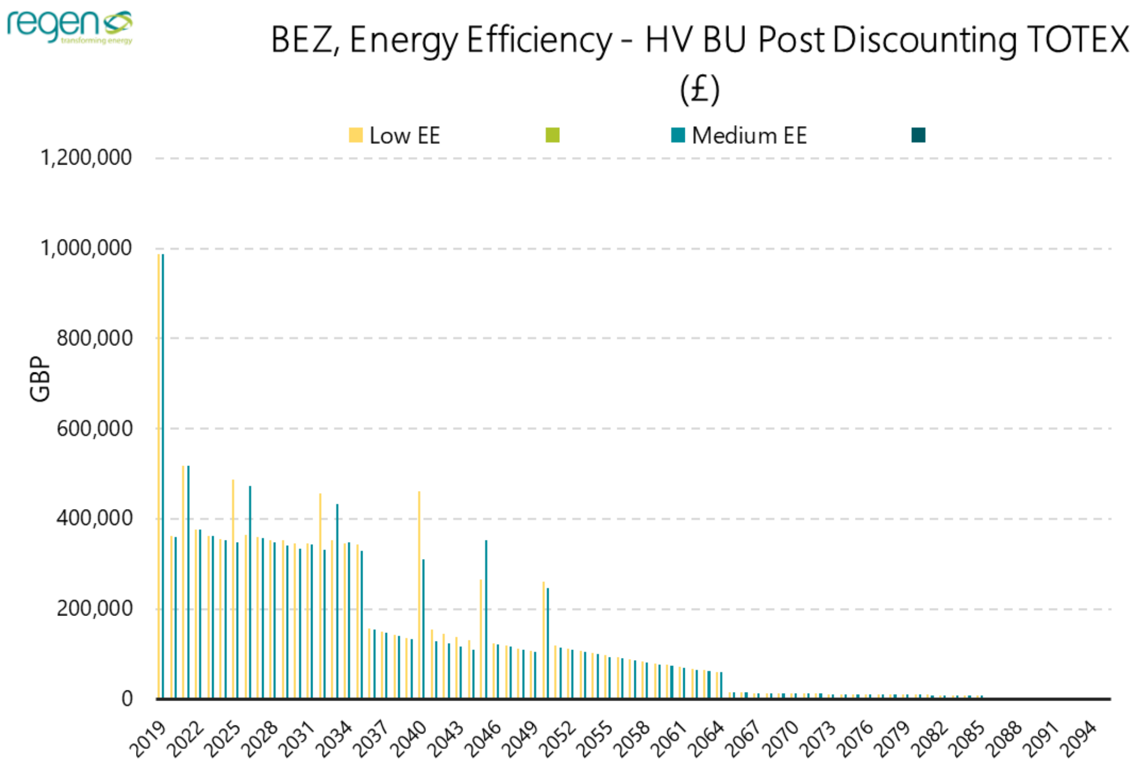

Figure 27: Annual HV TOTEX by year to 2050 on the Dorchester St primary, from bottom up analysis

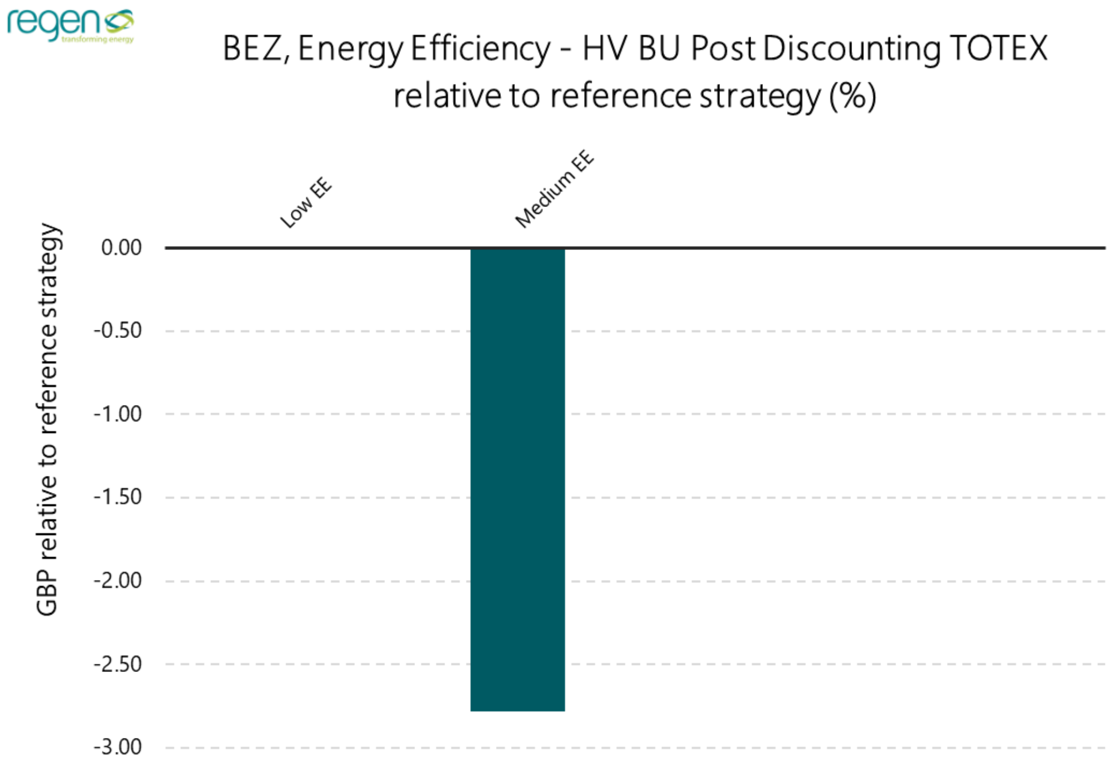

Figure 28: Total HV TOTEX on the Dorchester St primary relative to the Low EE strategy, from bottom up analysis

7. APPENDIX 2 – Cribbs Causeway significant results

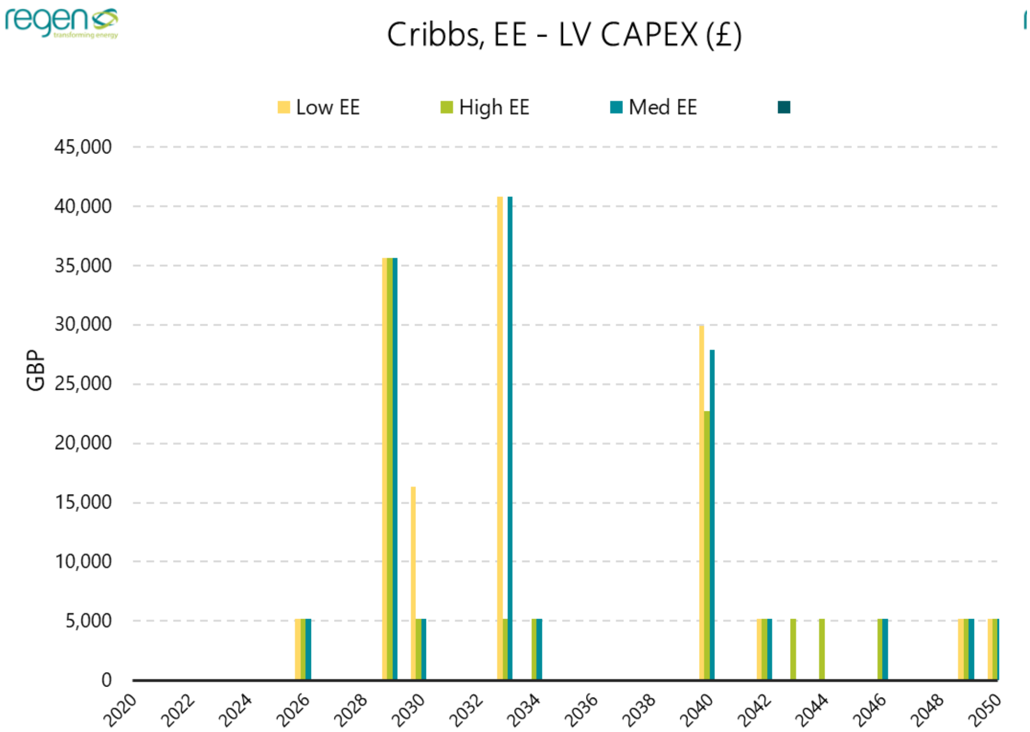

Figure 29: Annual LV CAPEX by year to 2050 on the Cribbs Causeway primary

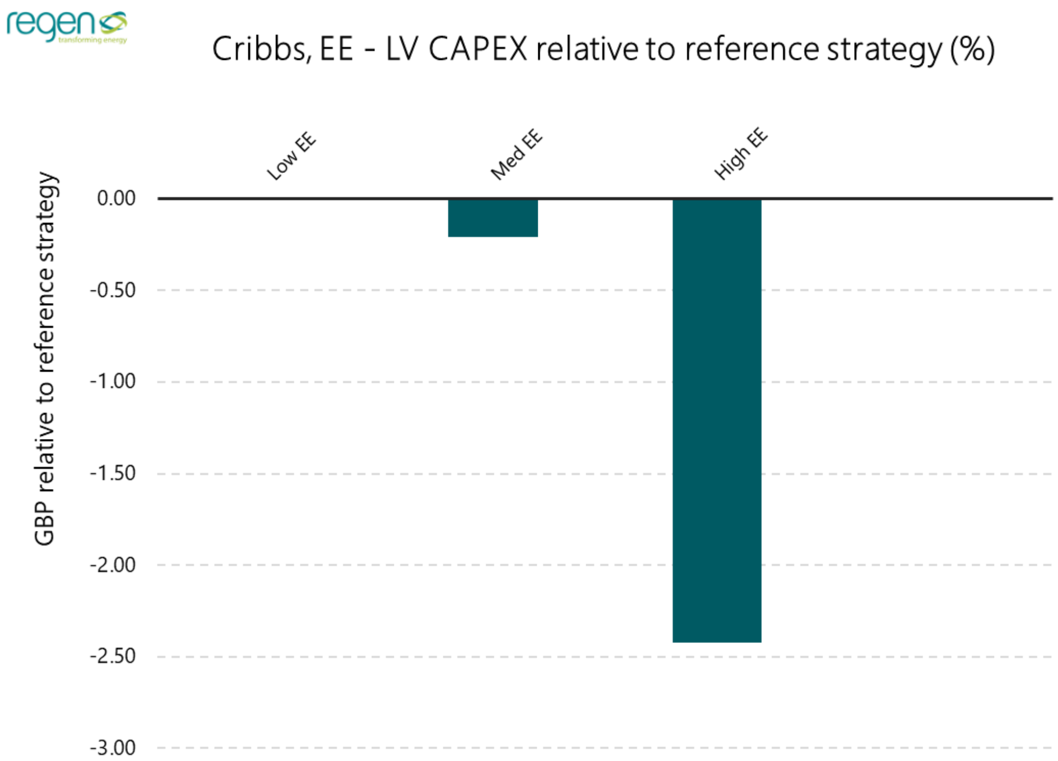

Figure 30: Total LV CAPEX on the Cribbs Causeway primary, relative to the Low EE strategy

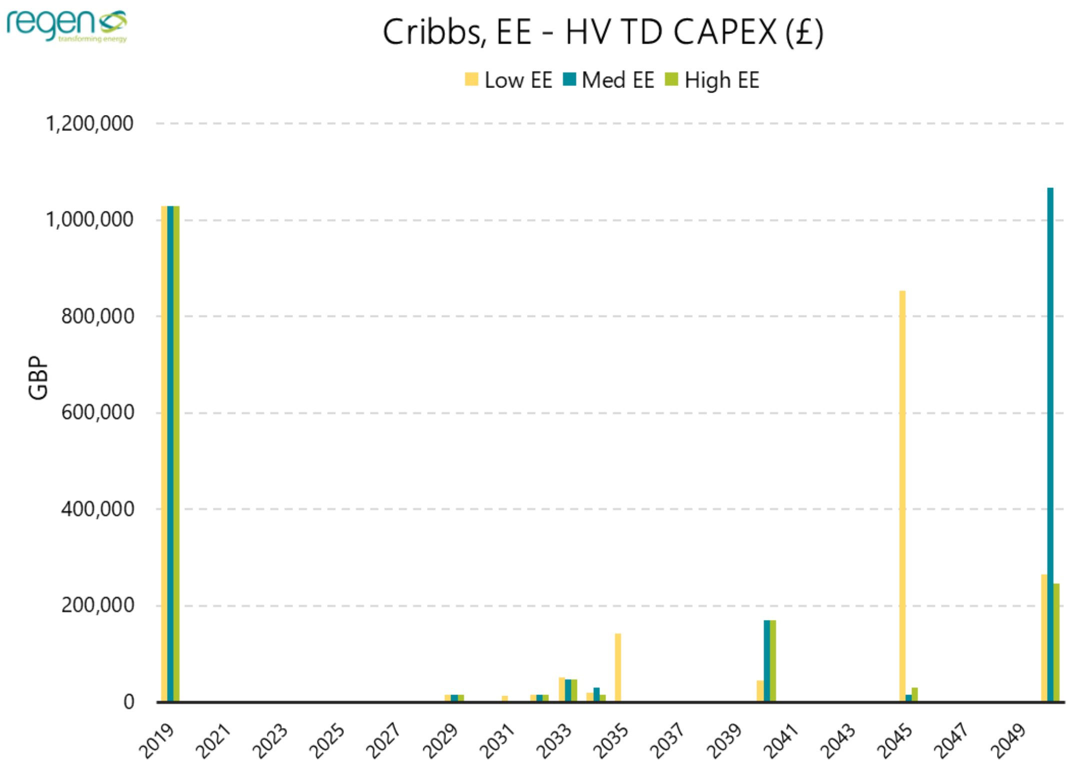

Figure 31: Annual HV CAPEX by year to 2050 on the Cribbs Causeway primary, from top down analysis

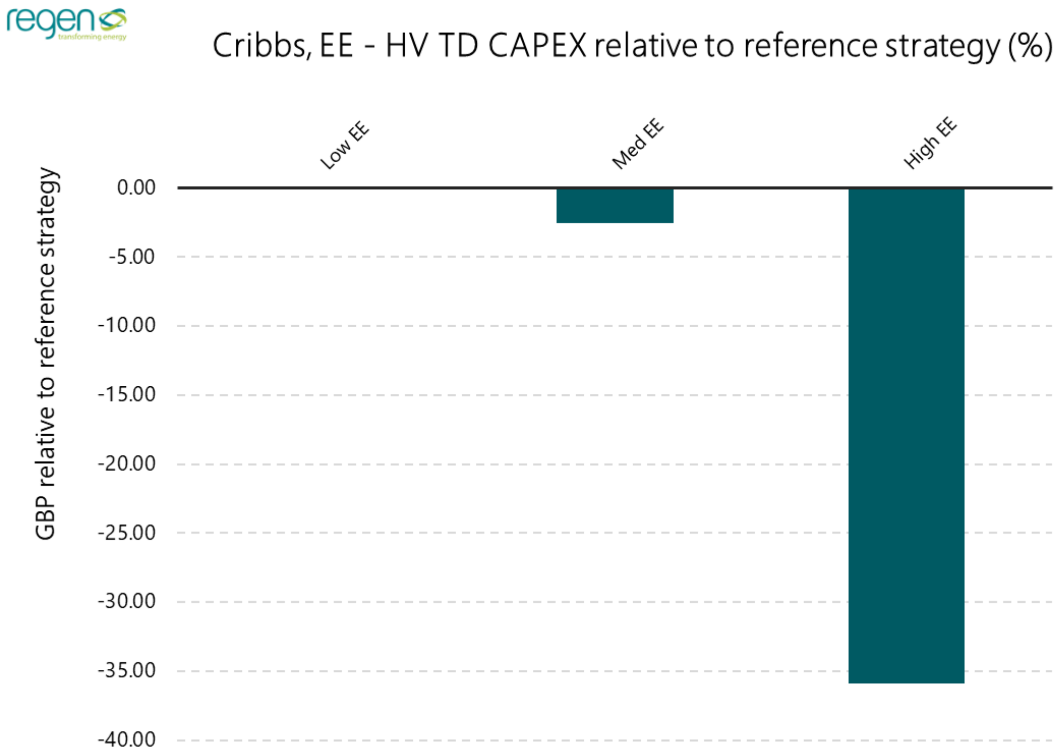

Figure 32: Total HV CAPEX on the Cribbs Causeway primary relative to the Low EE strategy

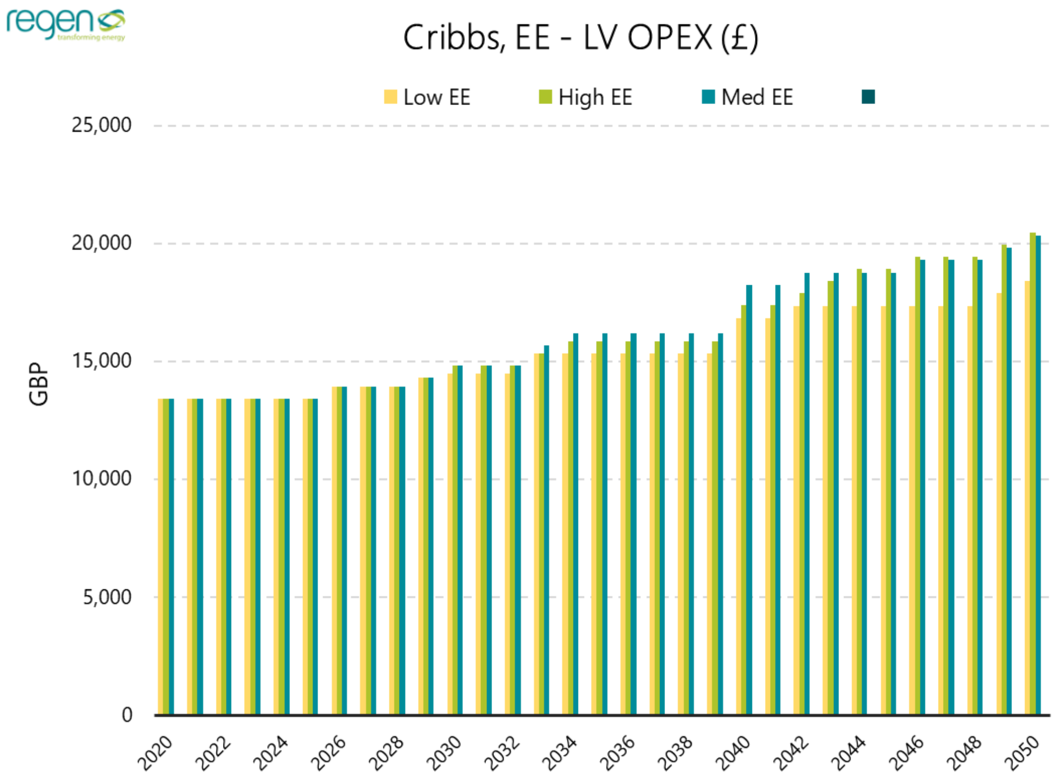

Figure 33: Annual LV OPEX by year to 2050 on the Cribbs Causeway primary, from bottom up analysis

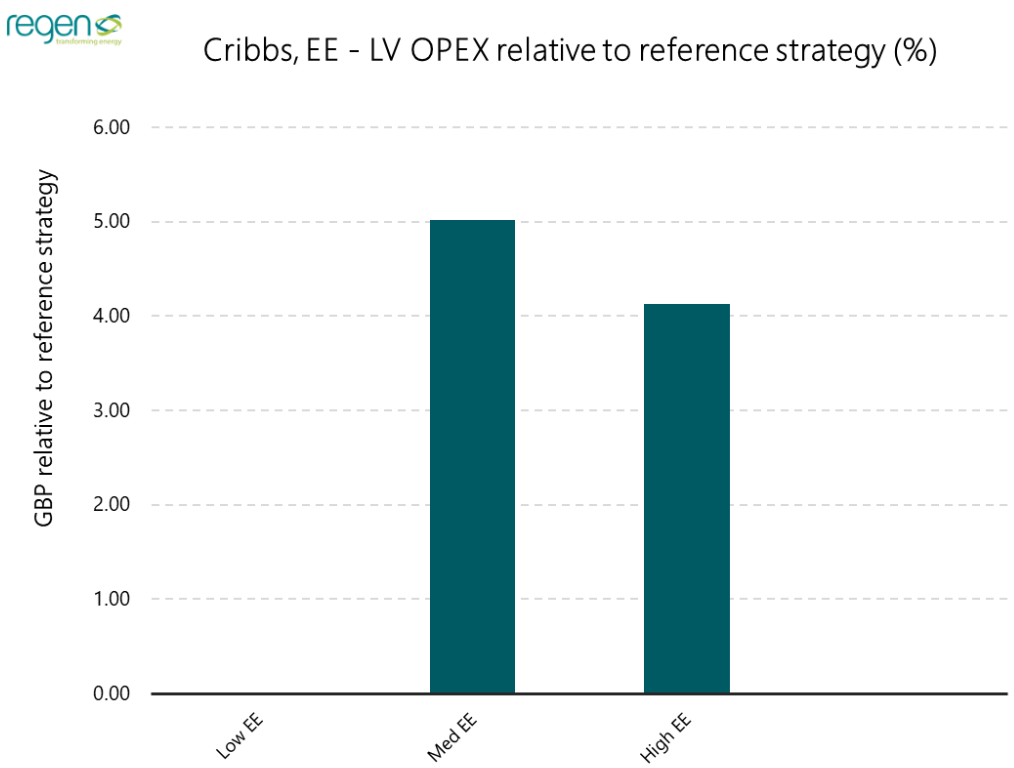

Figure 34: Total LV OPEX on the Cribbs Causeway primary relative to the Low EE strategy

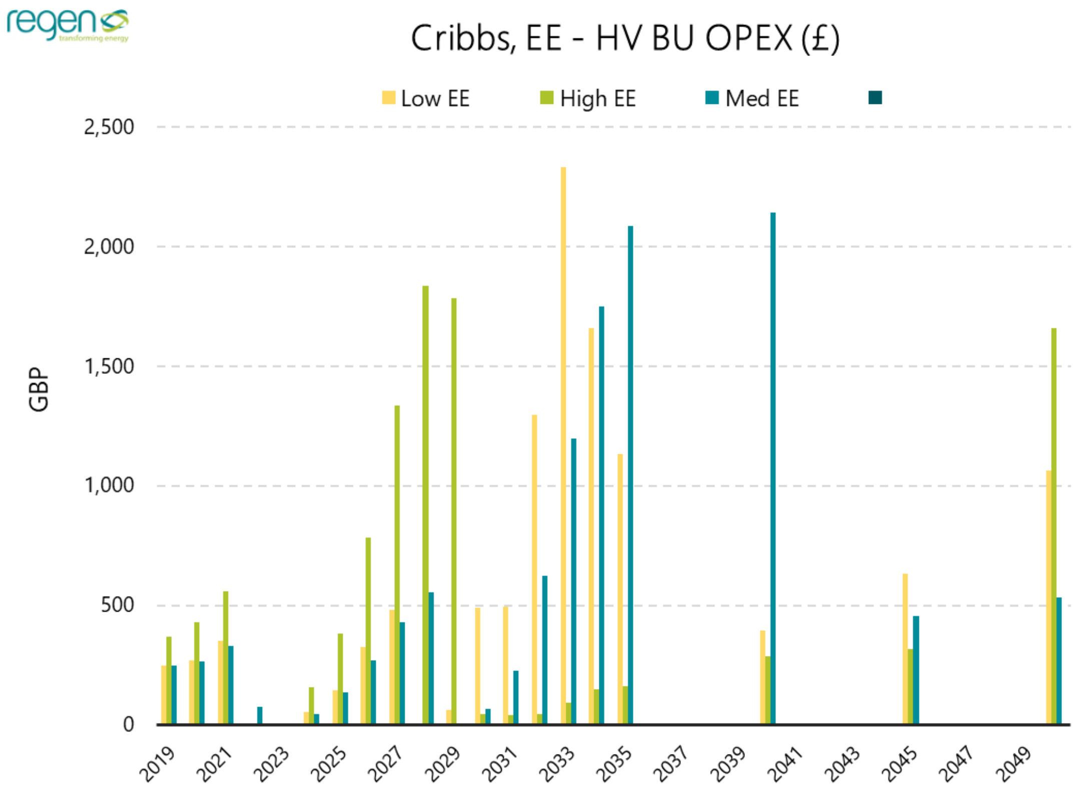

Figure 35: Annual HV OPEX by year to 2050 on the Cribbs Causeway primary, from bottom up analysis

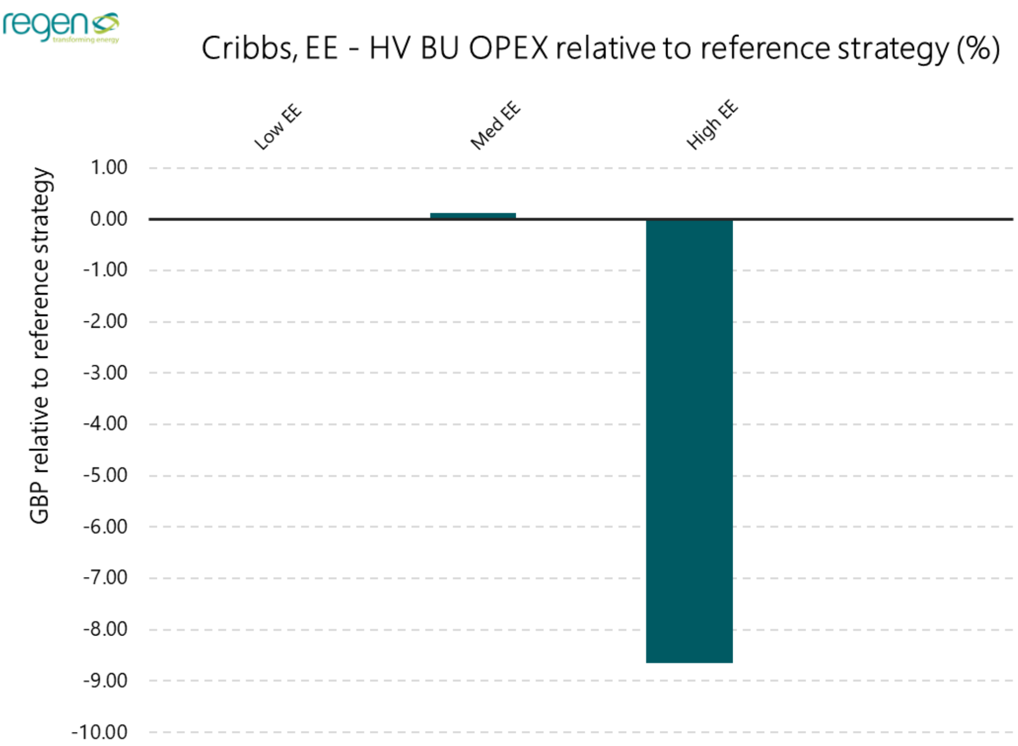

Figure 36: Total HV OPEX on the Cribbs Causeway primary relative to the Low EE strategy

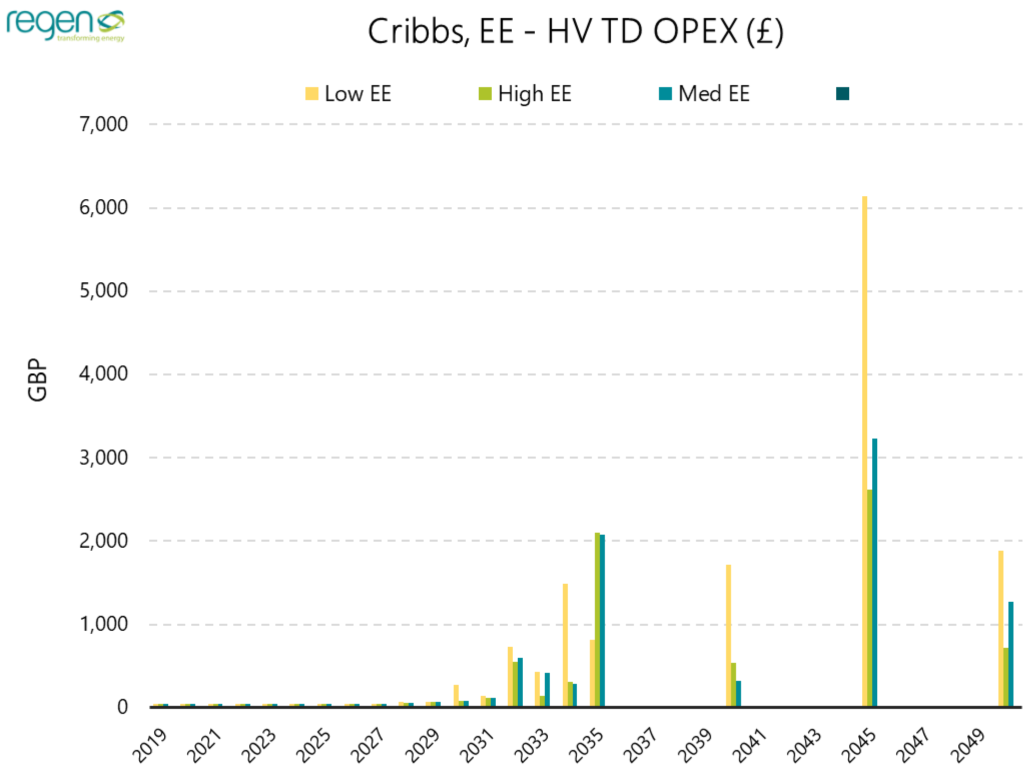

Figure 37: Annual HV CAPEX by year to 2050 on the Cribbs Causeway primary, from top down analysis

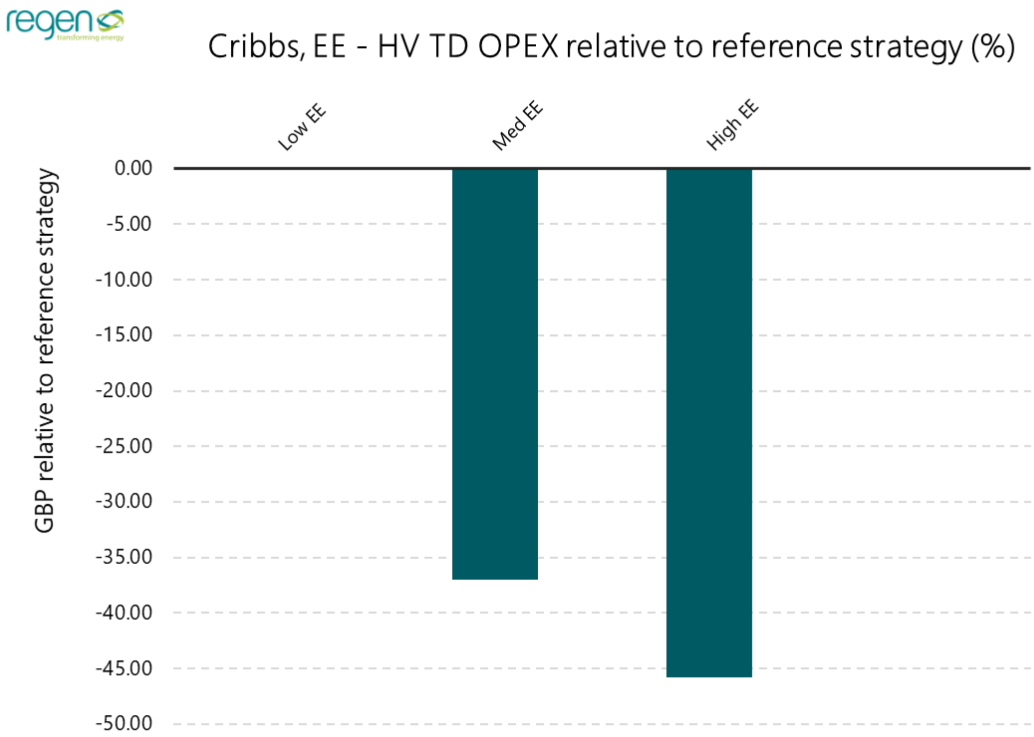

Figure 38: Total HV CAPEX on the Cribbs Causeway primary relative to the Low EE strategy

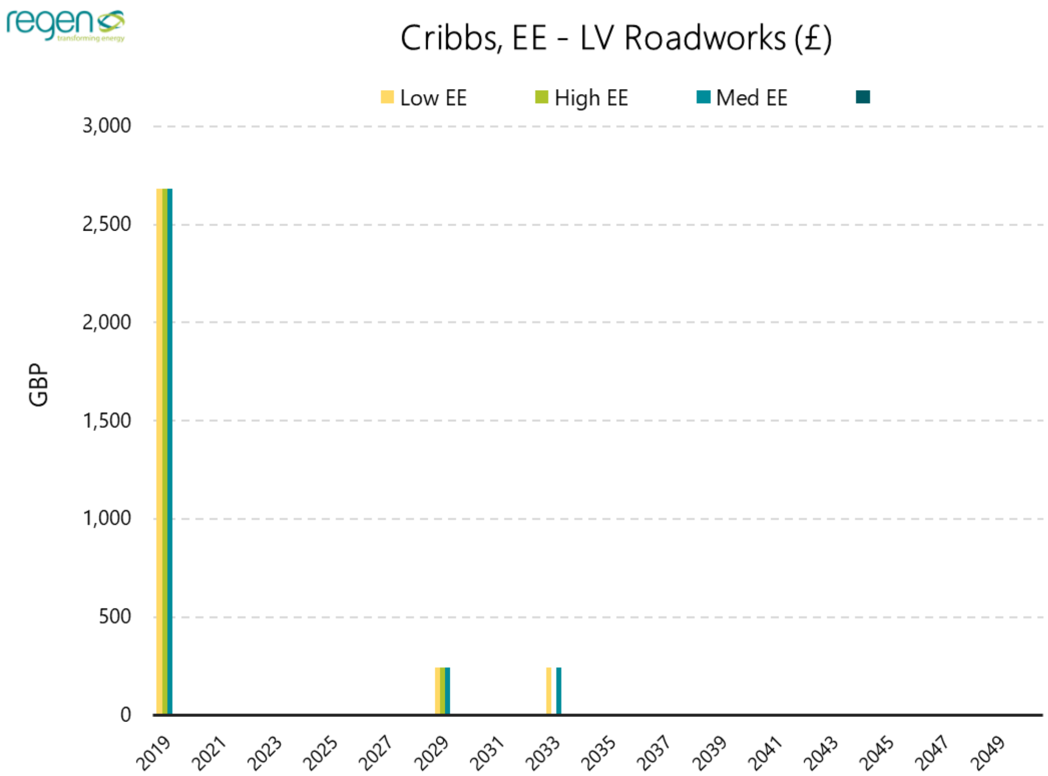

Figure 39: Annual LV roadworks by year to 2050 on the Cribbs Causeway primary, from bottom up analysis.

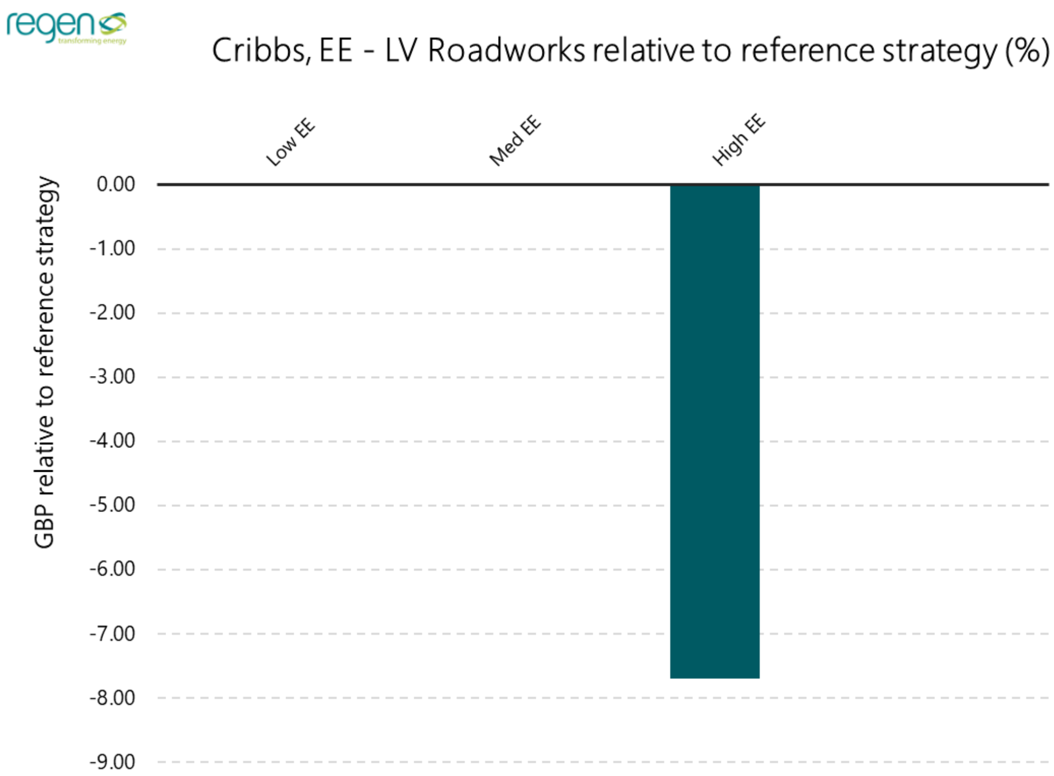

Figure 40: Total LV roadworks on the Cribbs Causeway primary relative to the Low EE strategy

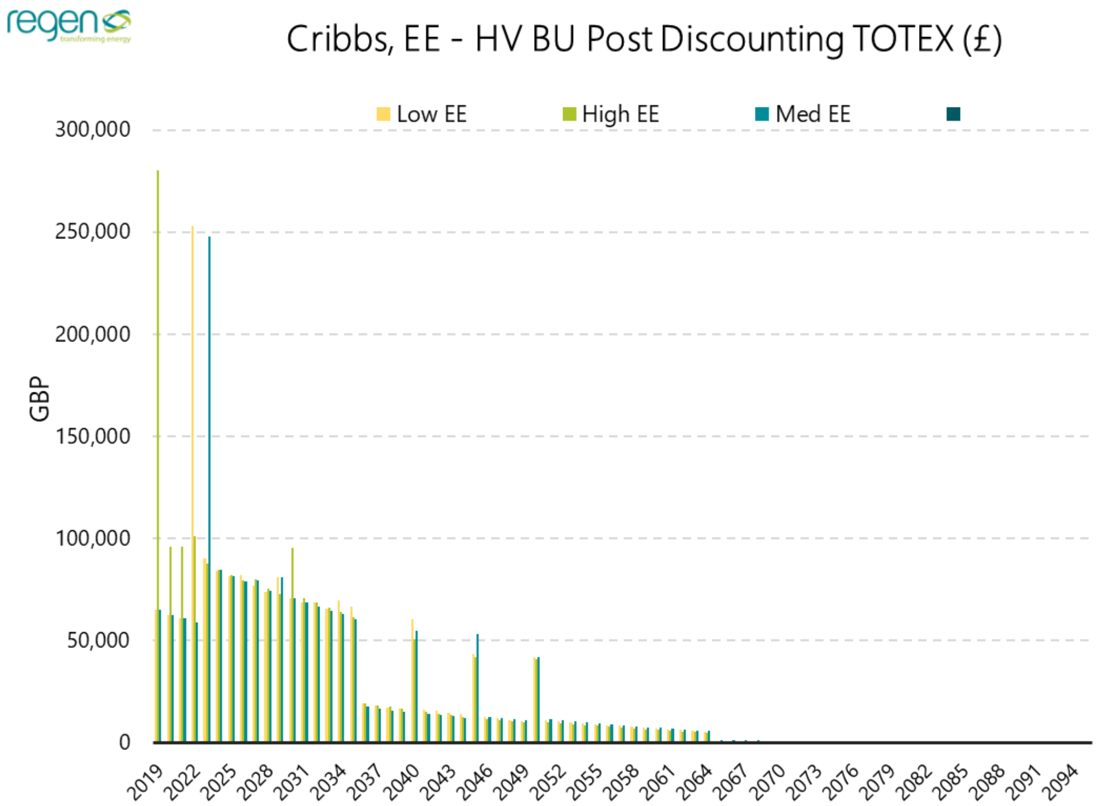

Figure 41: Annual HV TOTEX by year to 2050 on the Cribbs Causeway primary, from bottom up analysis

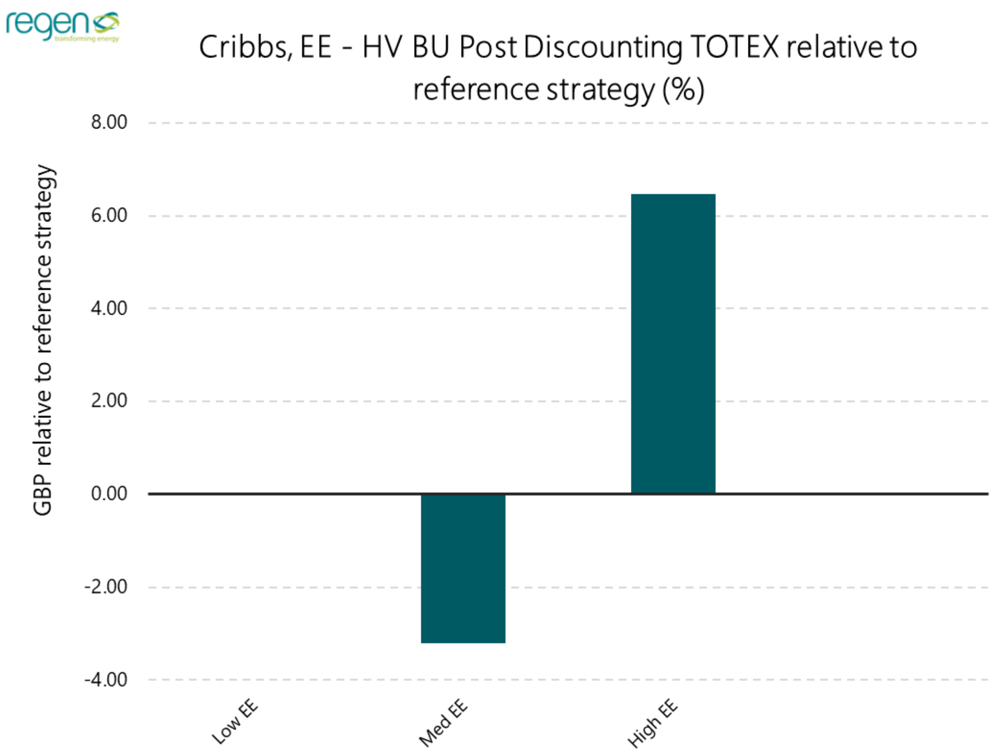

Figure 42: Total HV TOTEX on the Cribbs Causeway primary relative to the Low EE strategy

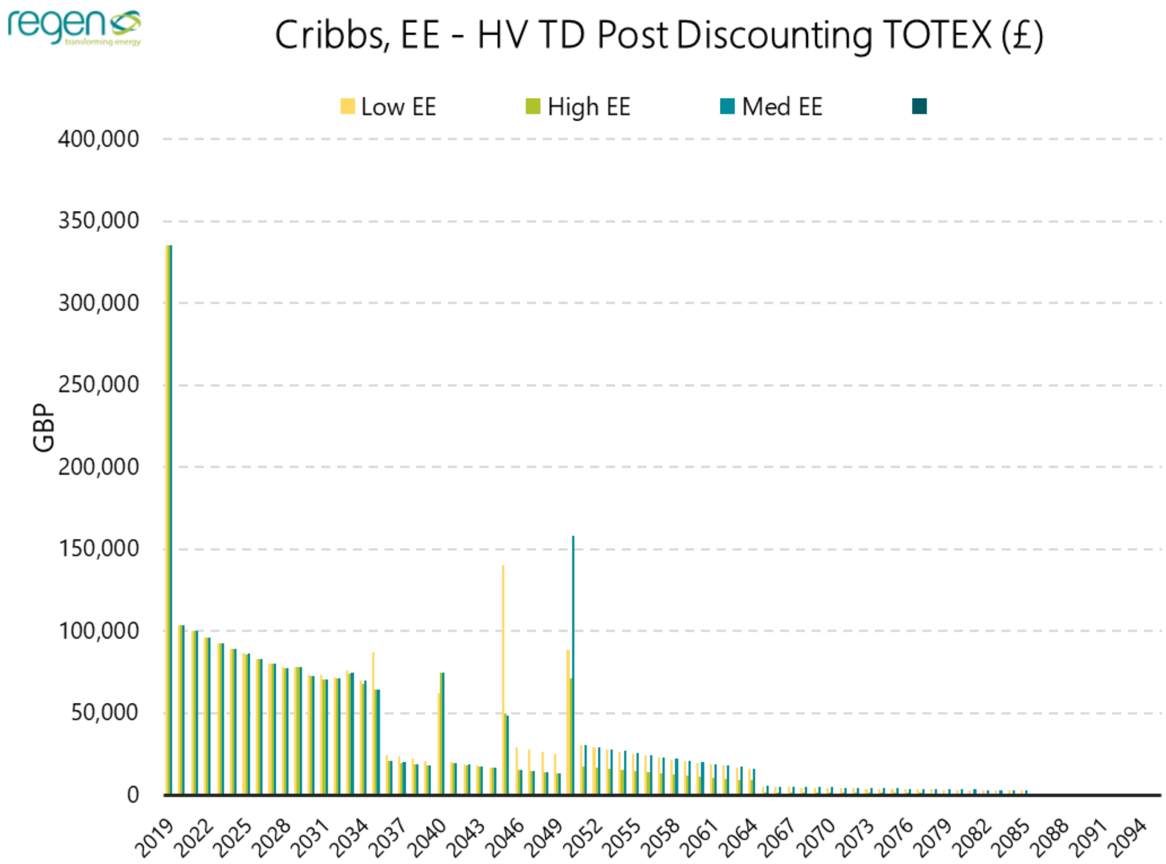

Figure 43: Annual HV TOTEX by year to 2050 on the Cribbs Causeway primary, from bottom up analysis

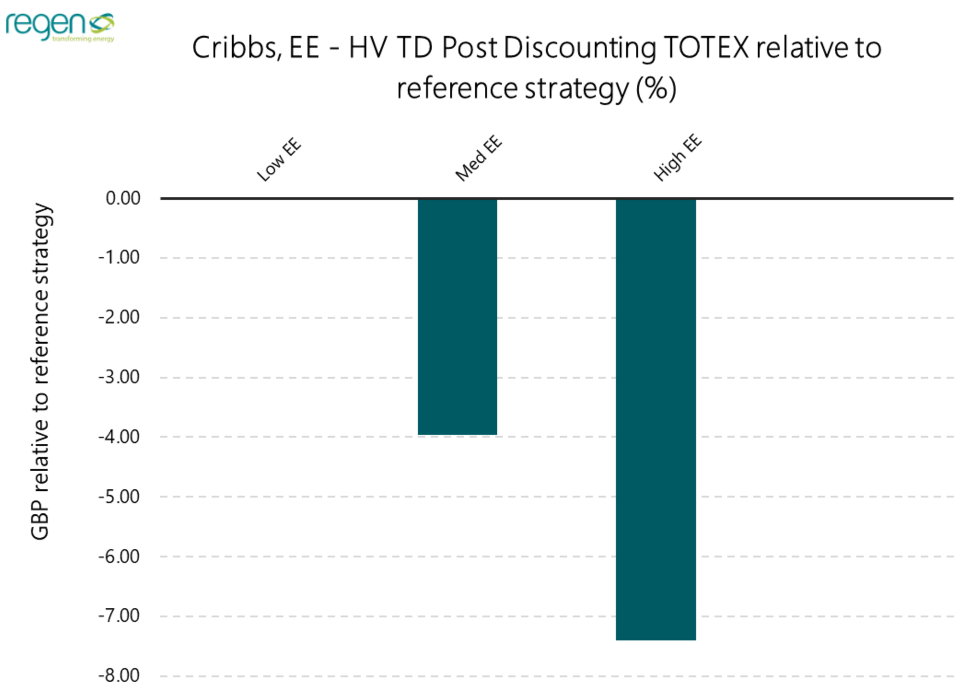

Figure 44: Total HV TOTEX on the Cribbs Causeway primary relative to the Low EE strategy

8. APPENDIX 3: Nailsea Significant impacts

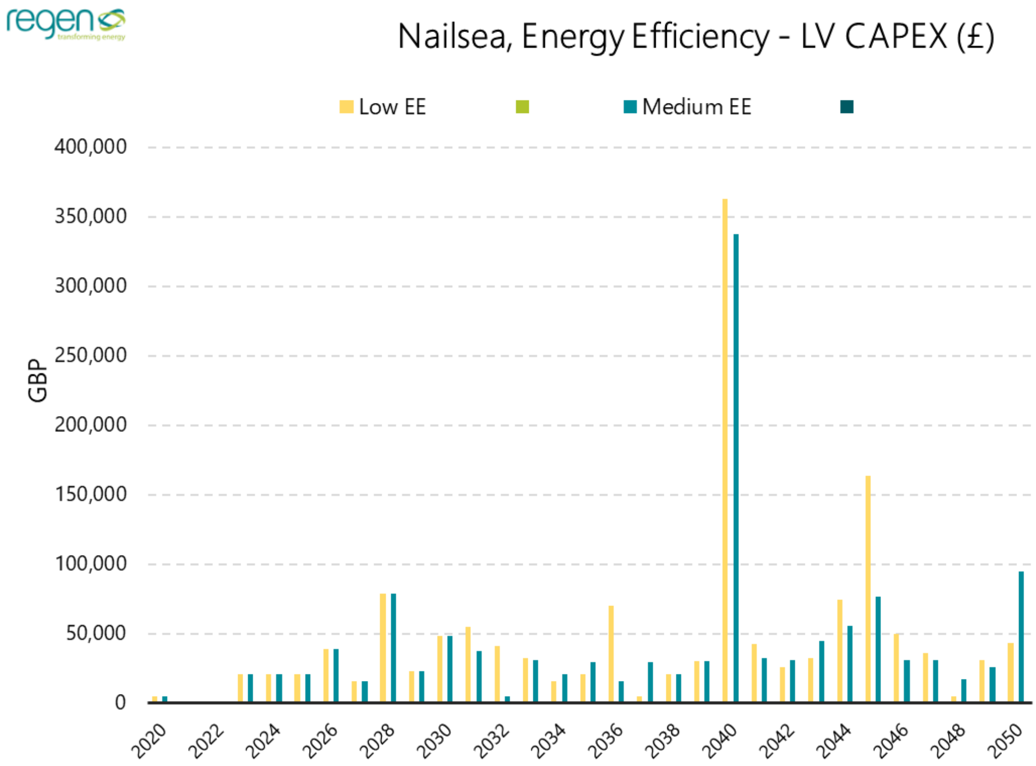

Figure 45: Annual LV CAPEX by year to 2050 on the Nailsea primary, from bottom up analysis:

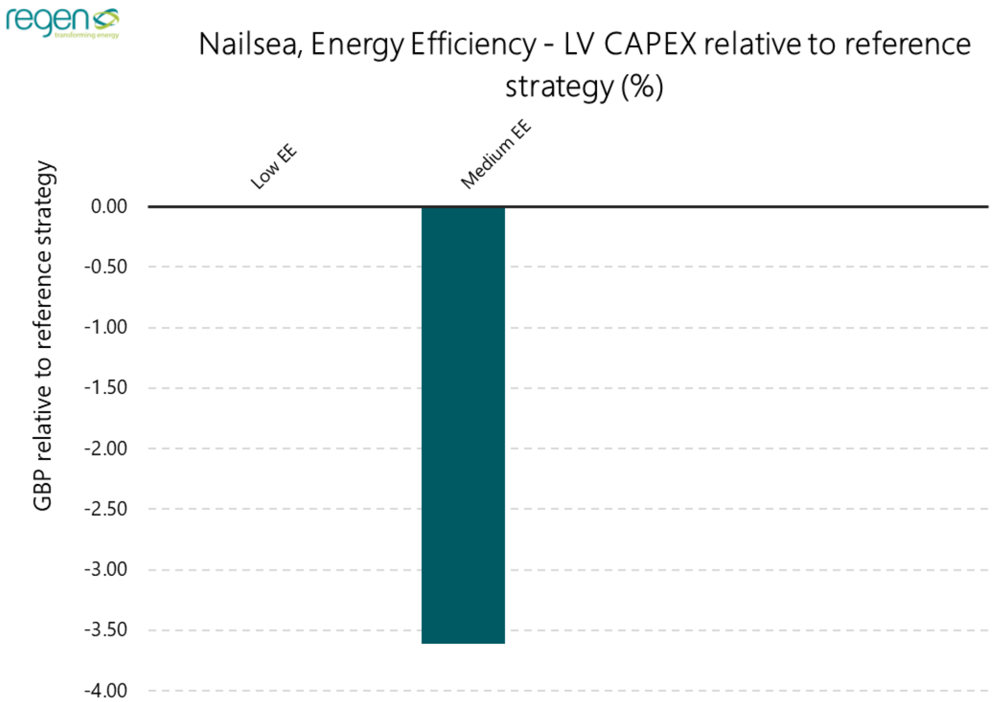

Figure 46: Total LV CAPEX on the Nailsea primary relative to the Low EE strategy

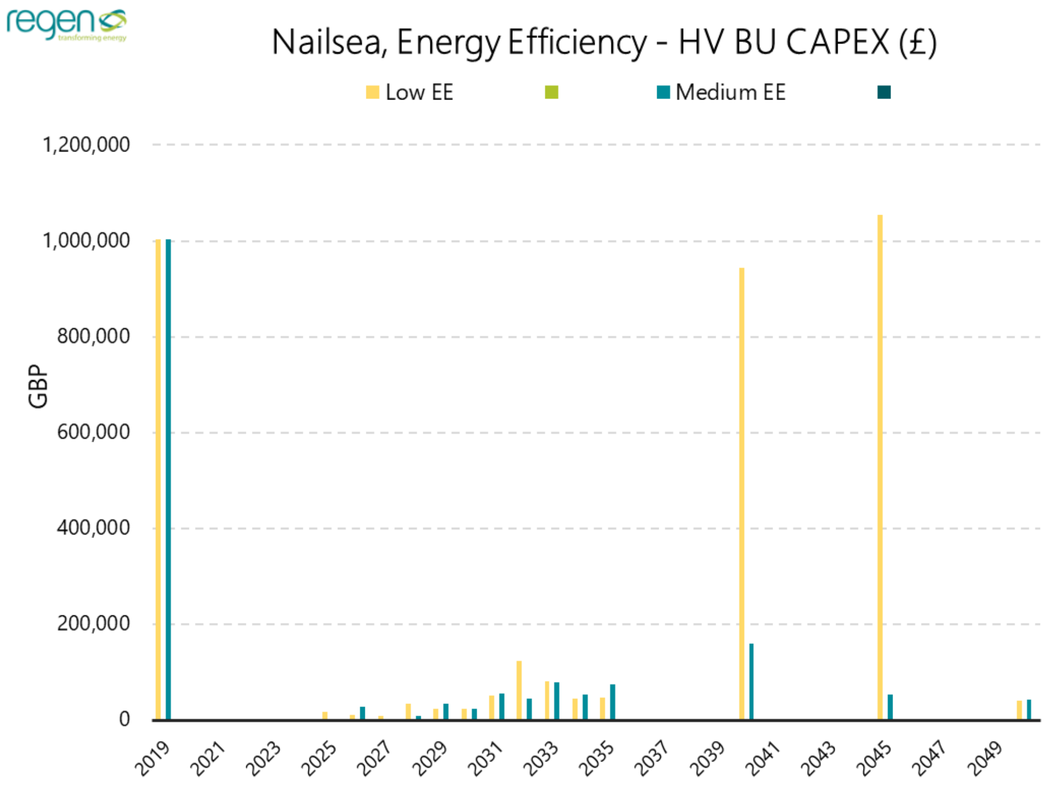

Figure 47: Annual HV CAPEX by year to 2050 on the Nailsea primary, from bottom up analysis

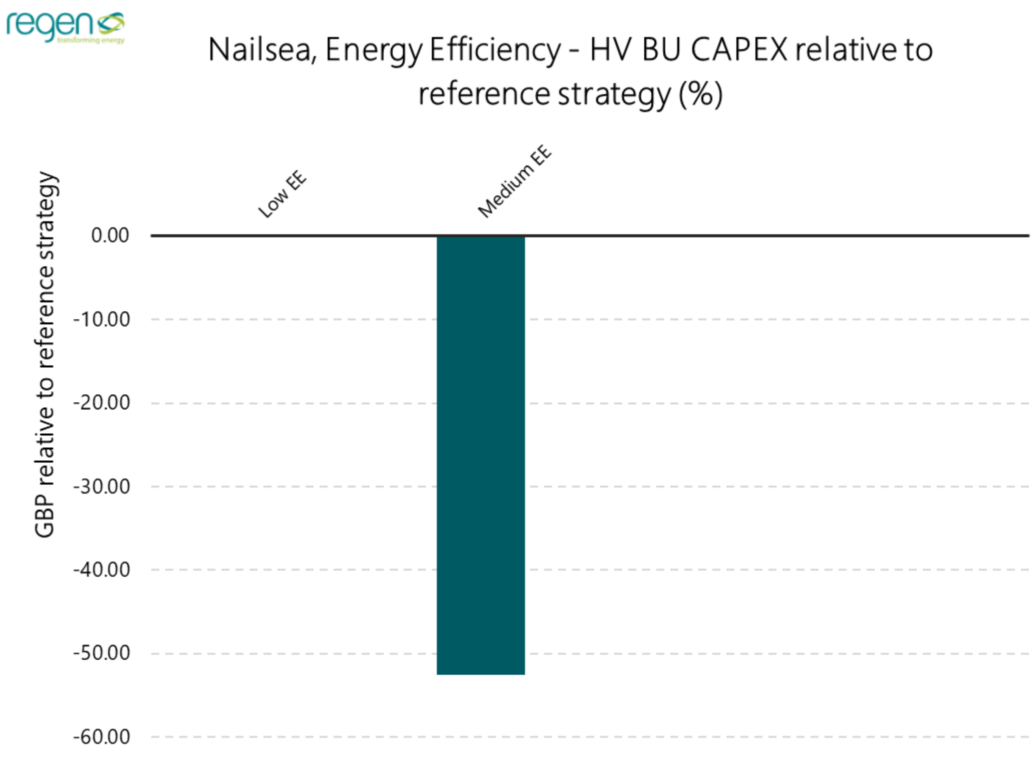

Figure 48: Total HV CAPEX on the Nailsea primary relative to the Low EE strategy

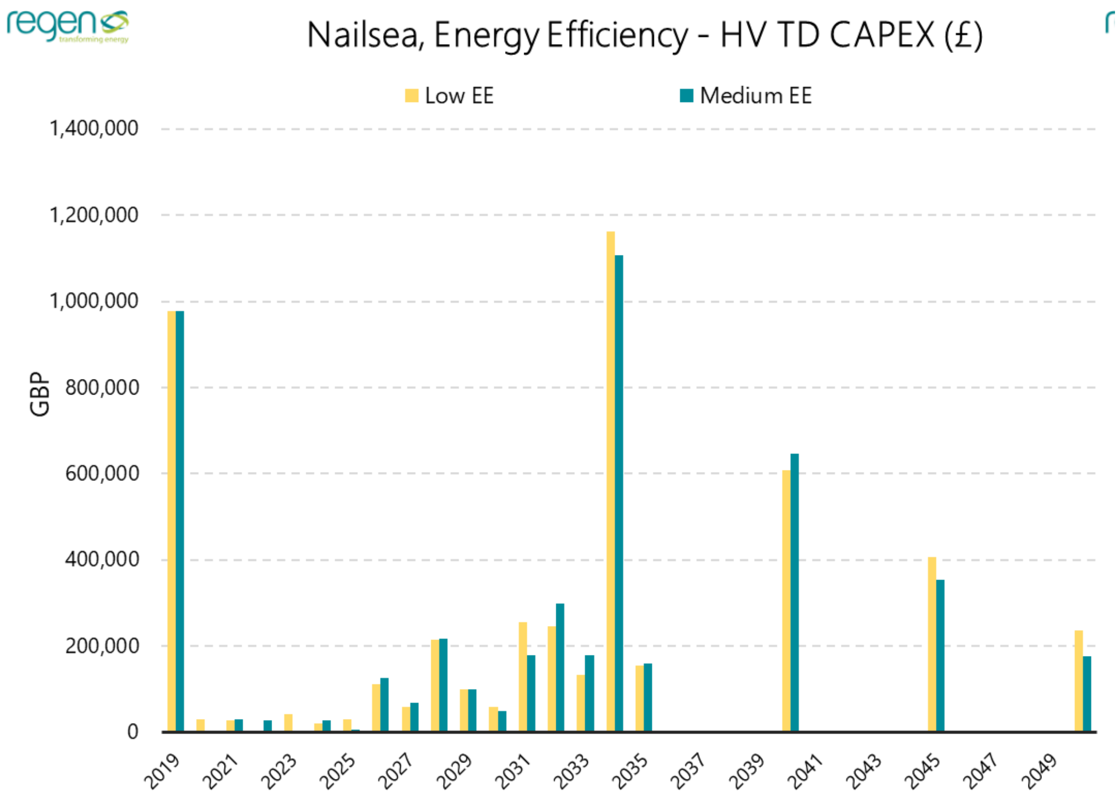

Figure 49: Annual HV CAPEX by year to 2050 on the Nailsea primary, from top down analysis

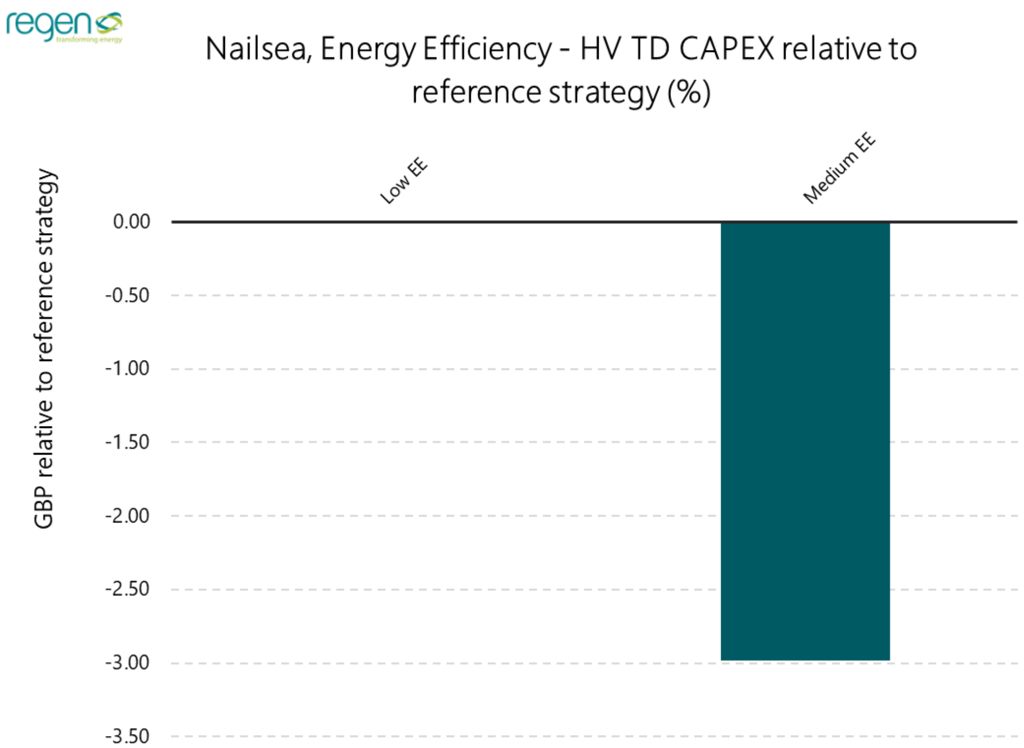

Figure 50: Total HV CAPEX on the Nailsea primary relative to the Low EE strategy

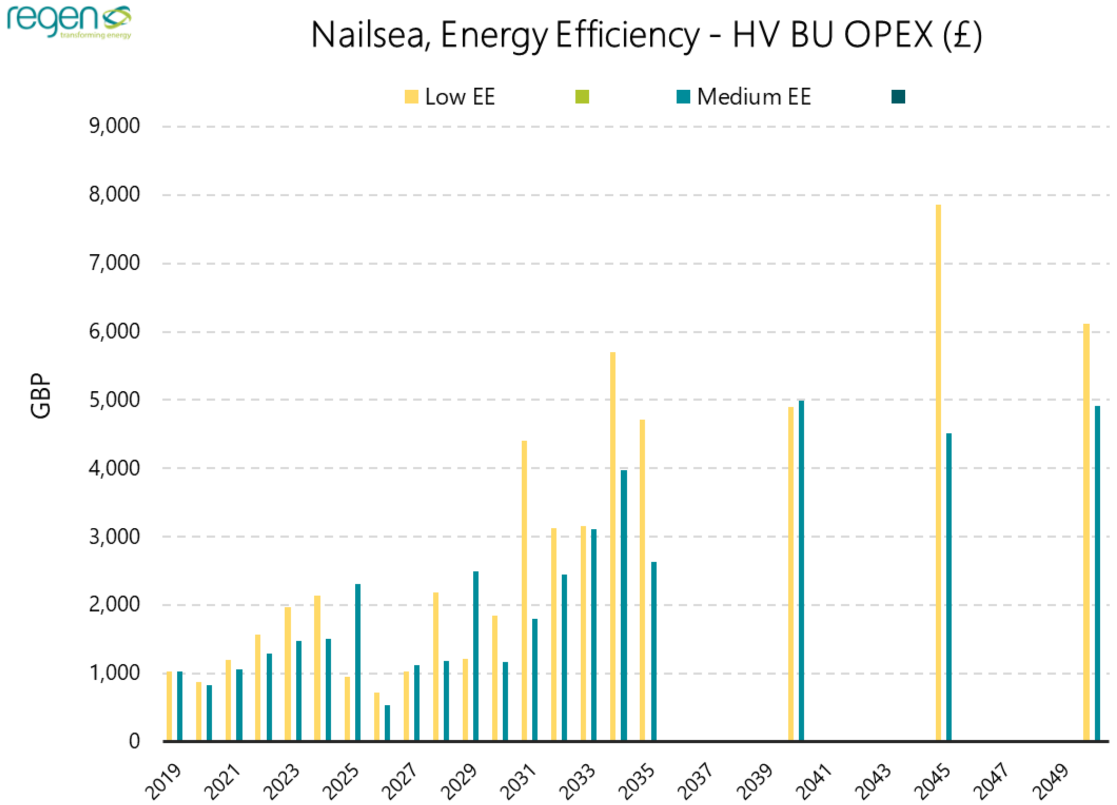

Figure 51: Annual HV OPEX by year to 2050 on the Nailsea primary, from bottom up analysis.

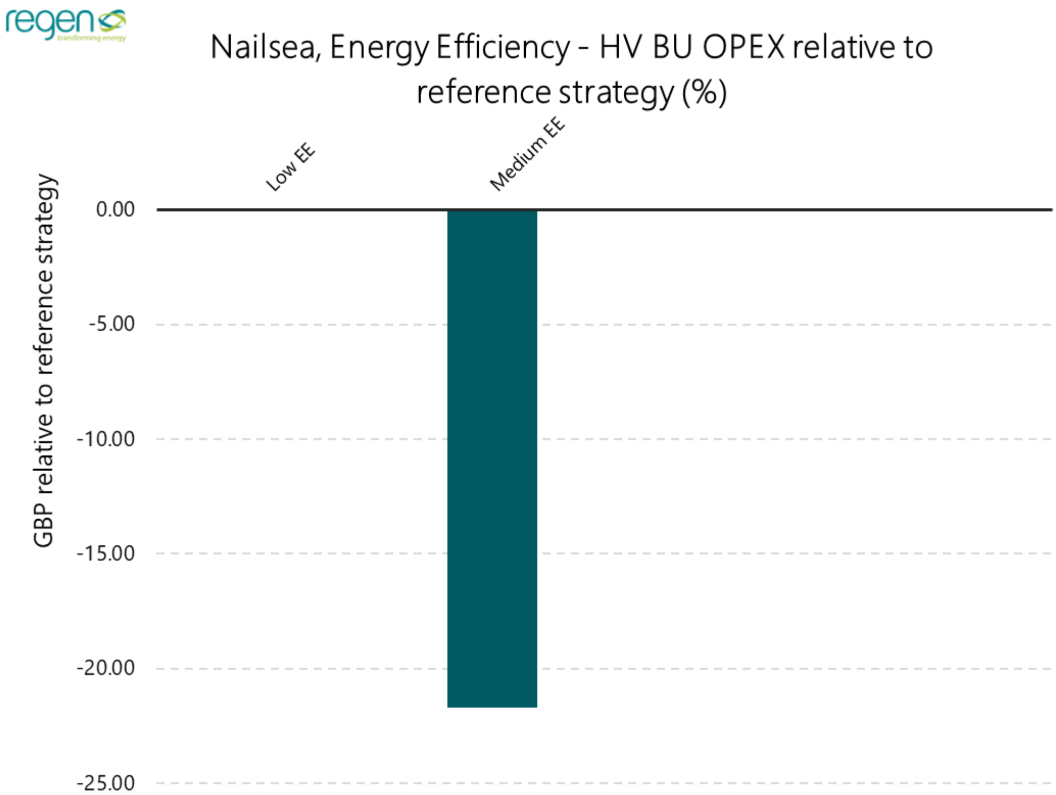

Figure 52: Total HV OPEX on the Nailsea primary relative to the Low EE strategy

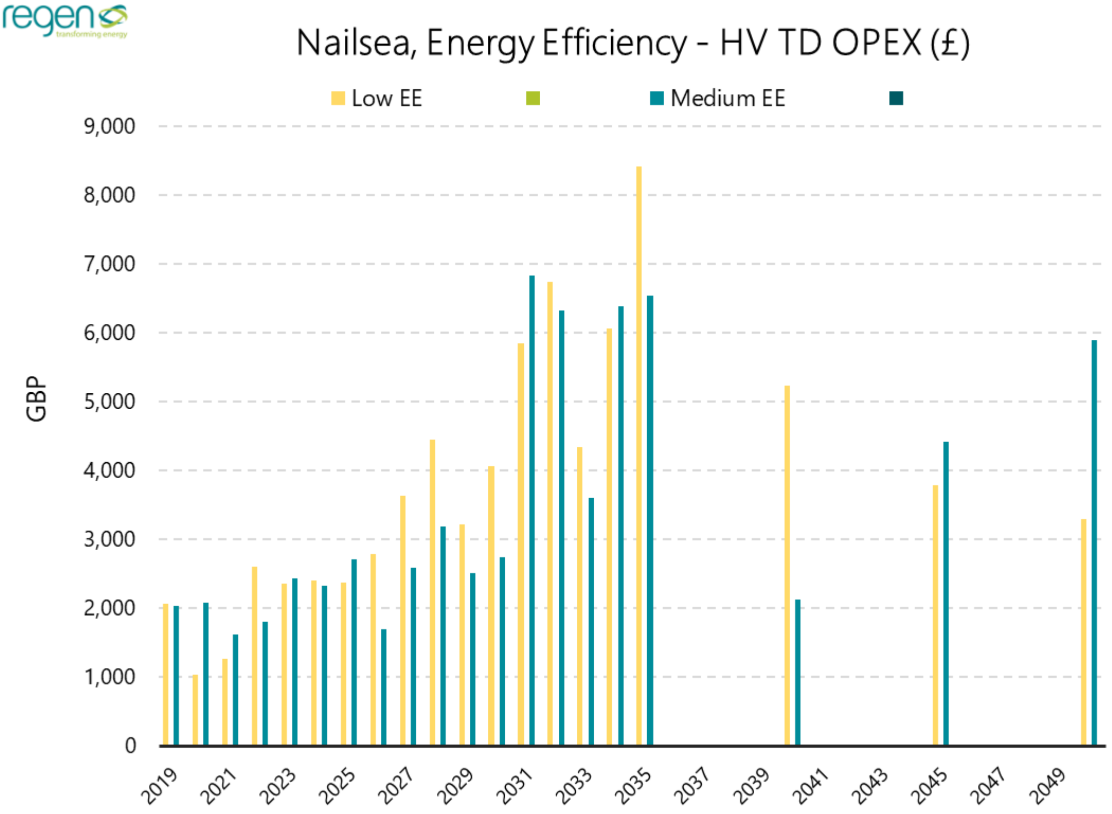

Figure 53: Annual HV OPEX by year to 2050 on the Nailsea primary, from top down analysis.

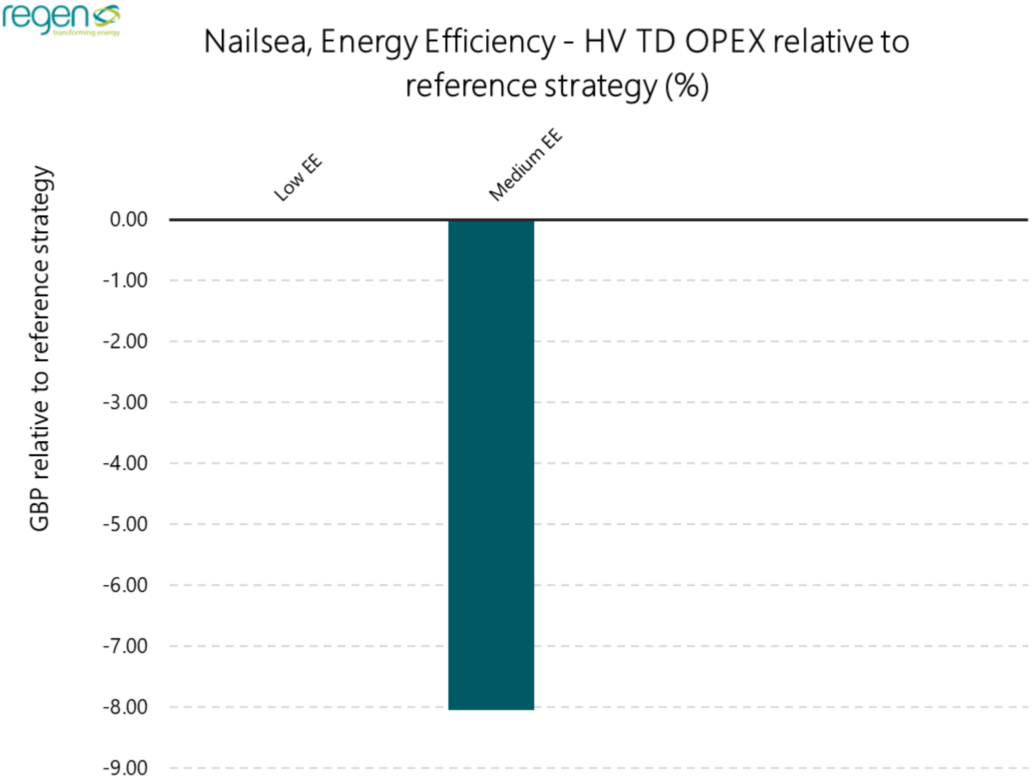

Figure 54: Total HV OPEX on the Nailsea primary relative to the Low EE strategy

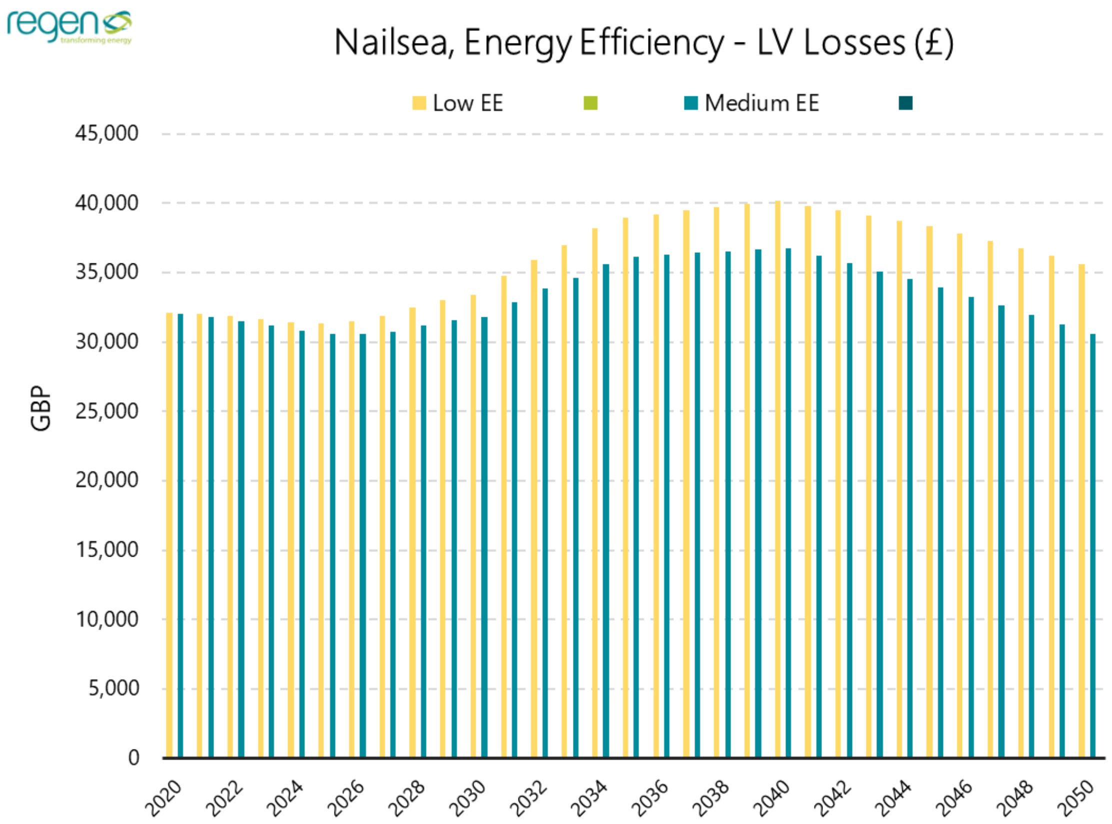

Figure 55: Annual LV Losses by year to 2050 on the Nailsea primary,

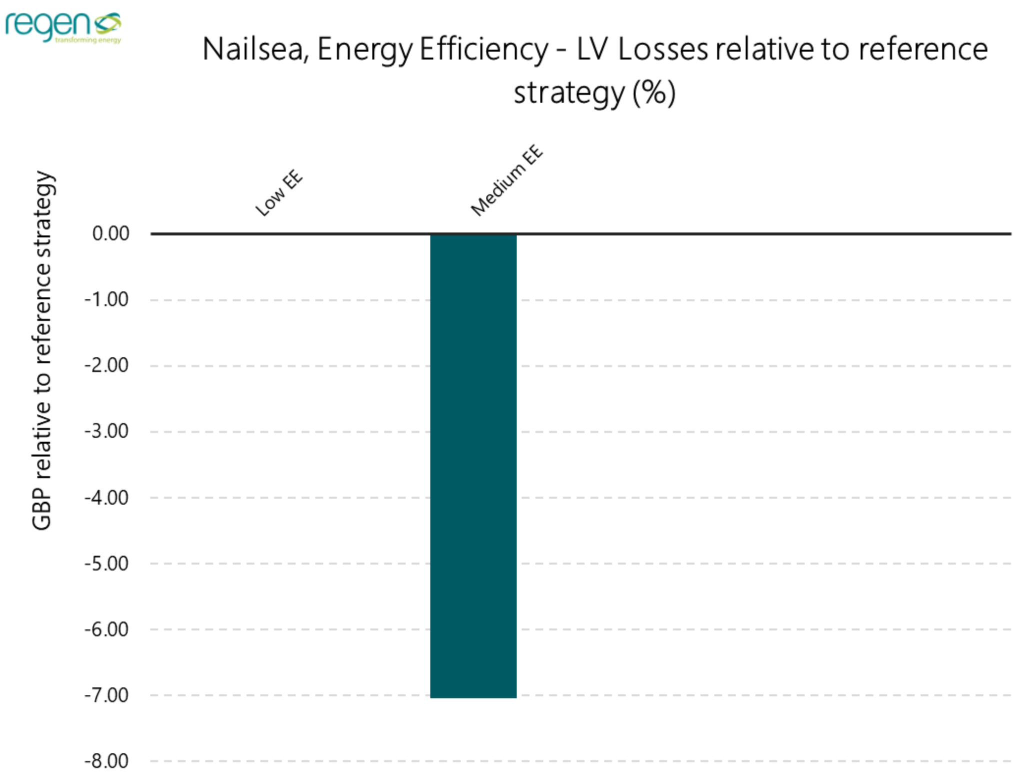

Figure 56: Total LV Losses on the Nailsea primary relative to the Low EE strategy

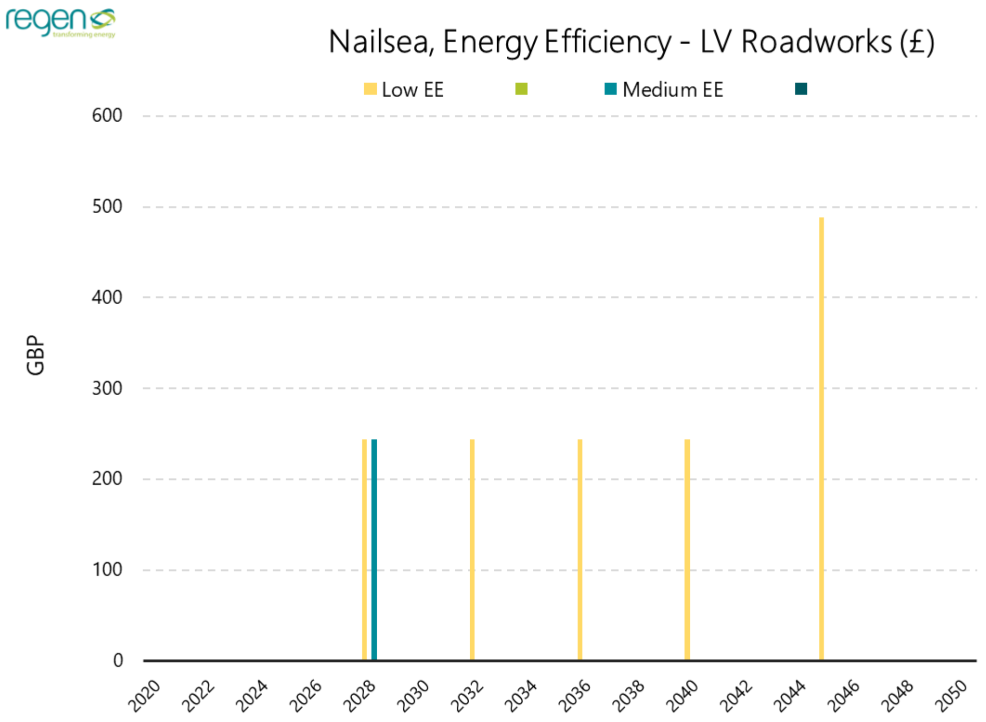

Figure 57: Annual LV Roadworks by year to 2050 on the Nailsea primary,

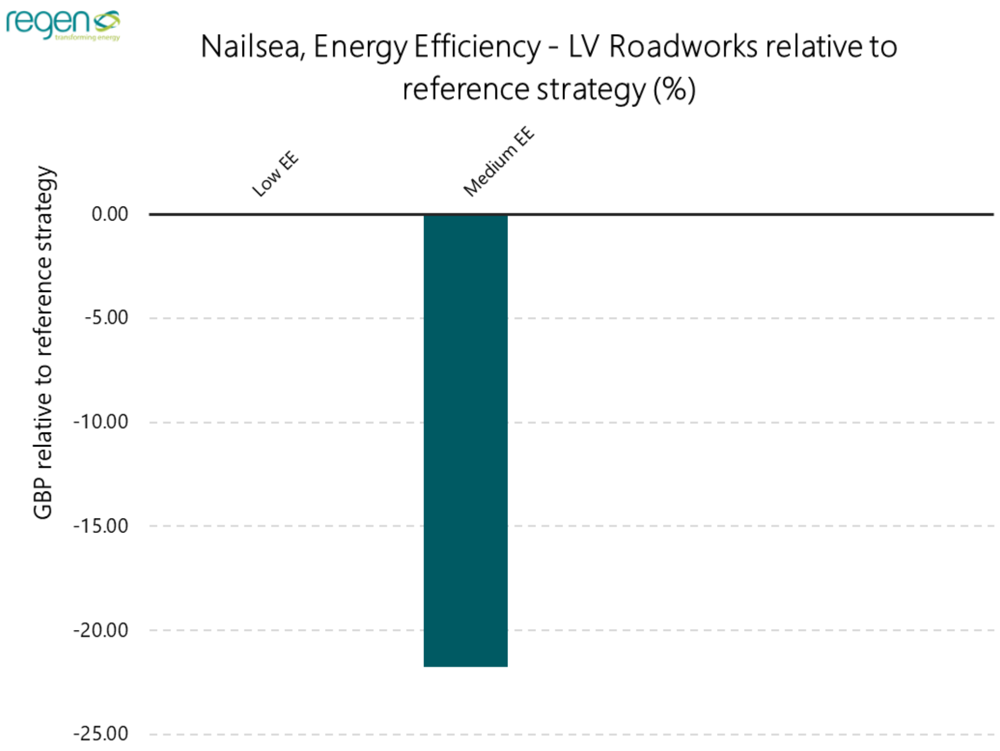

Figure 58: Total LV Roadworks on the Nailsea primary relative to the Low EE strategy

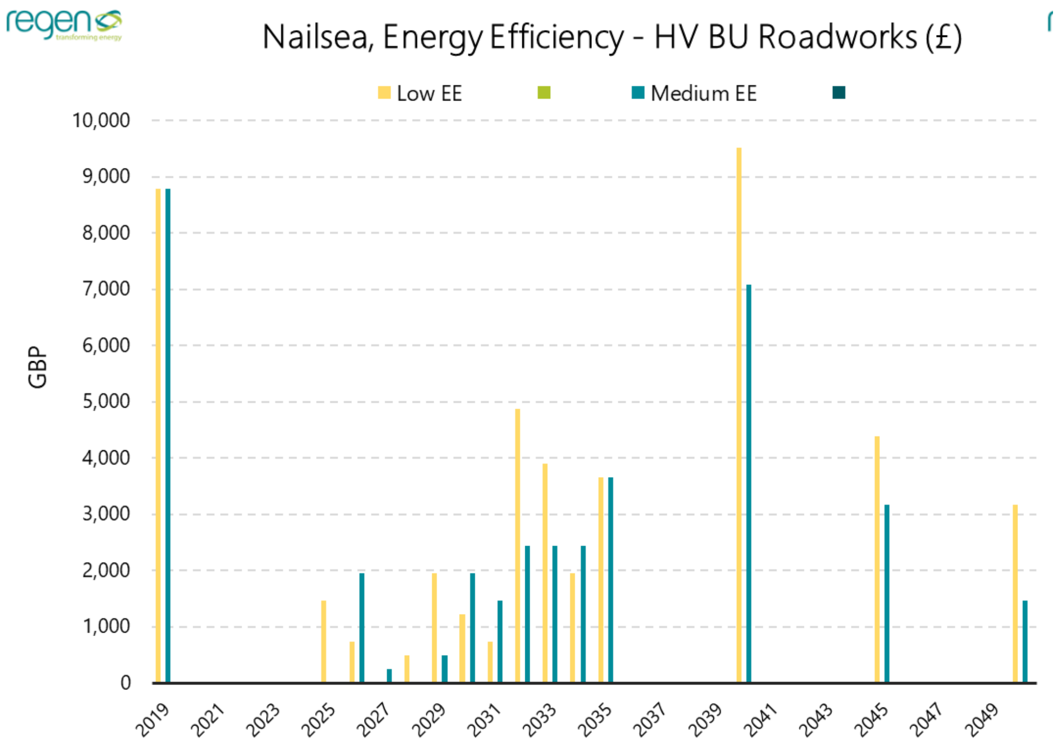

Figure 59: Annual HV Roadworks by year to 2050 on the Nailsea primary, from bottom up analysis

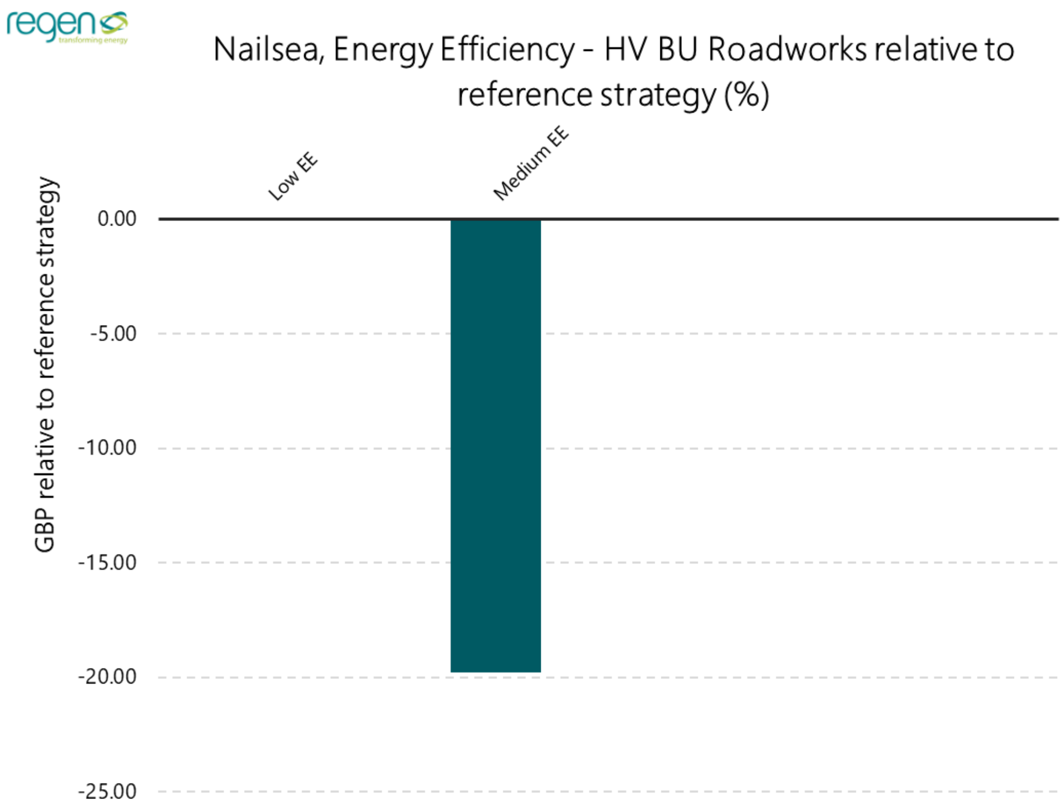

Figure 60 Total HV Roadworks on the Nailsea primary relative to the Low EE strategy

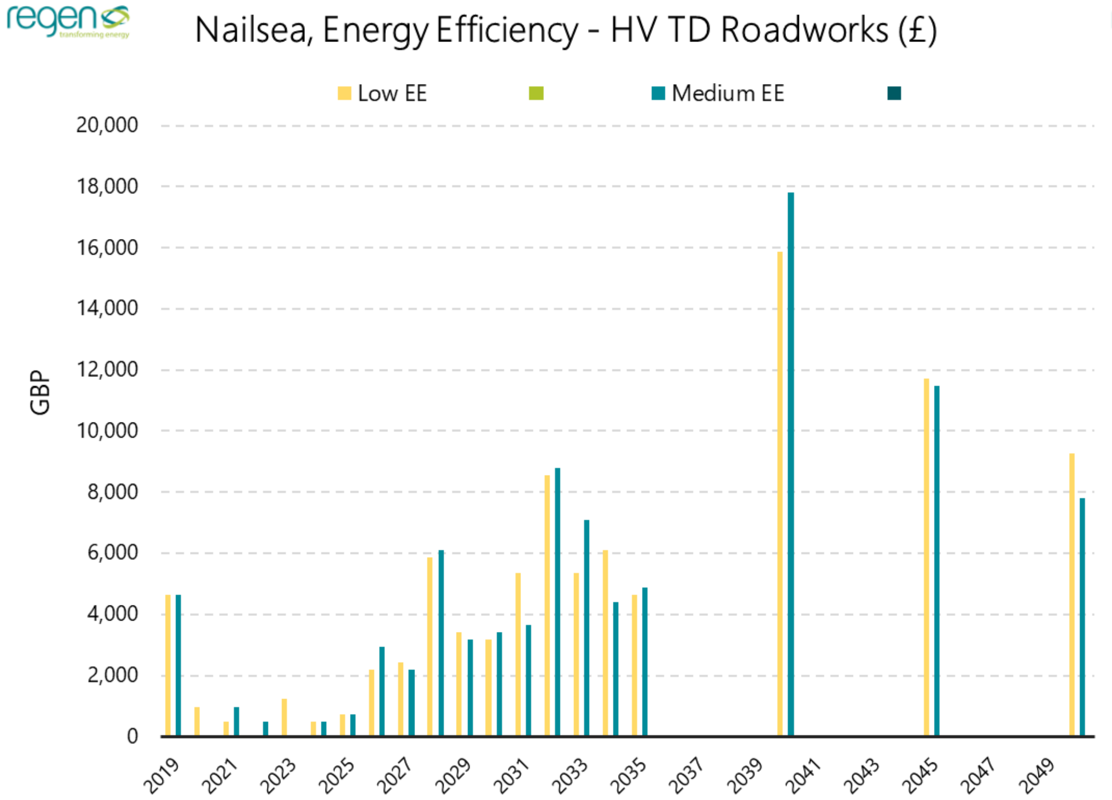

Figure 61: Annual HV Roadworks by year to 2050 on the Nailsea primary, from top down analysis

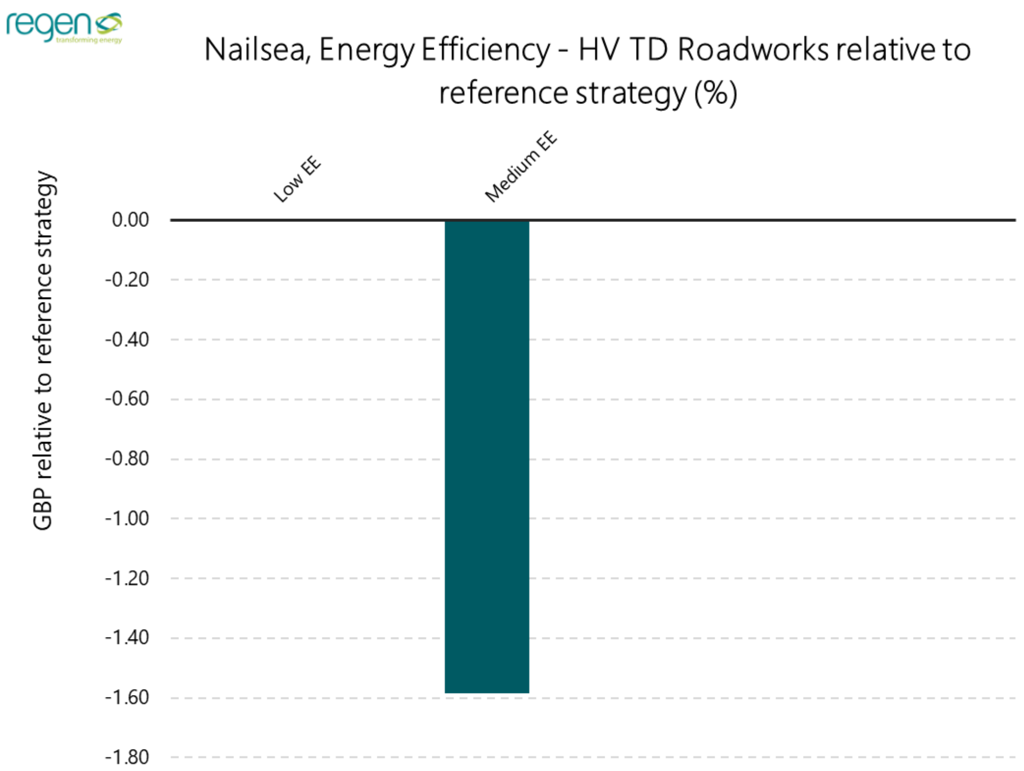

Figure 62: Total HV Roadworks on the Nailsea primary relative to the Low EE strategy

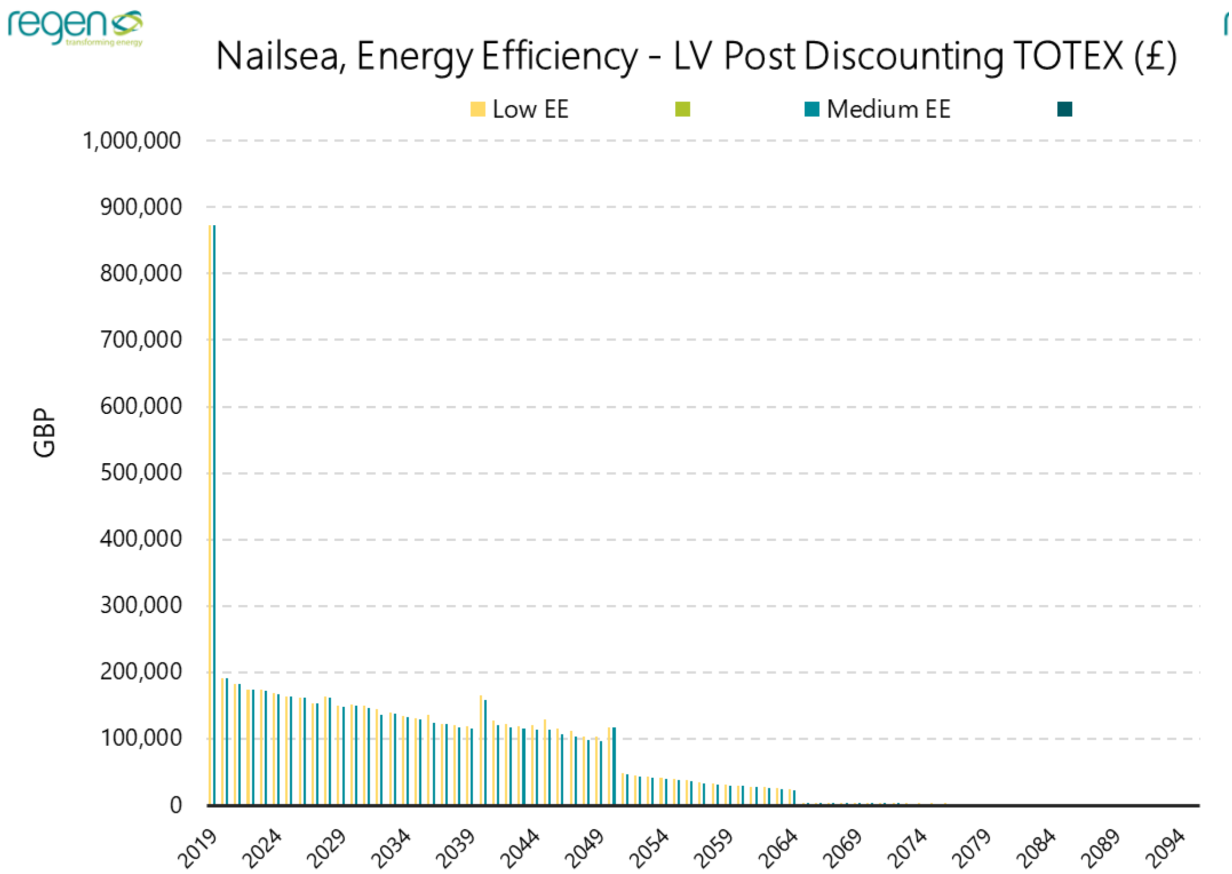

Figure 63: Annual LV TOTEX by year to 2095 on the Nailsea primary

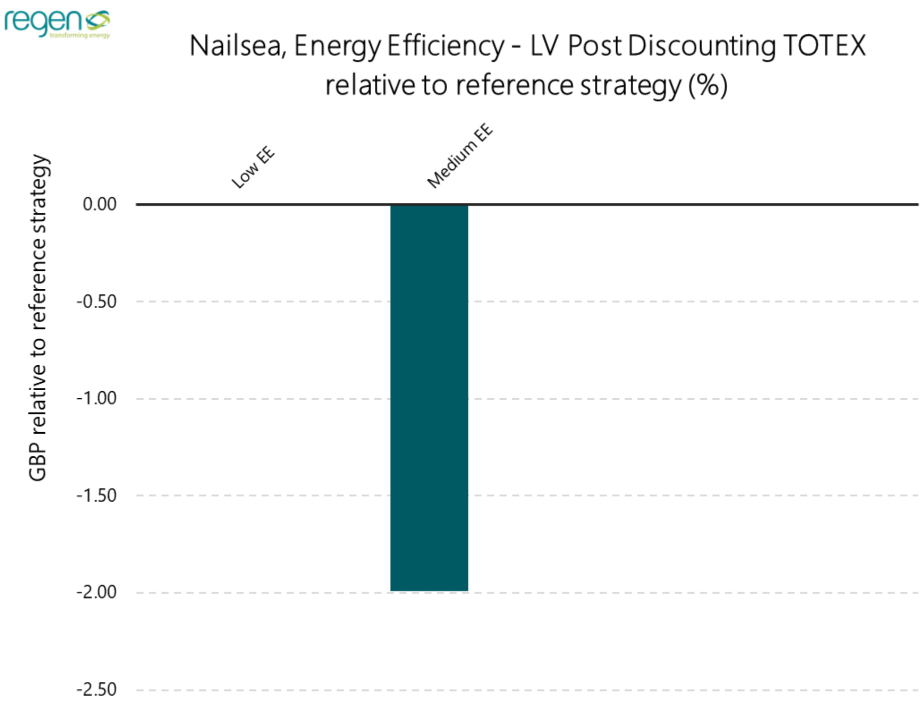

Figure 64: Total LV TOTEX on the Nailsea primary relative to the Low EE strategy

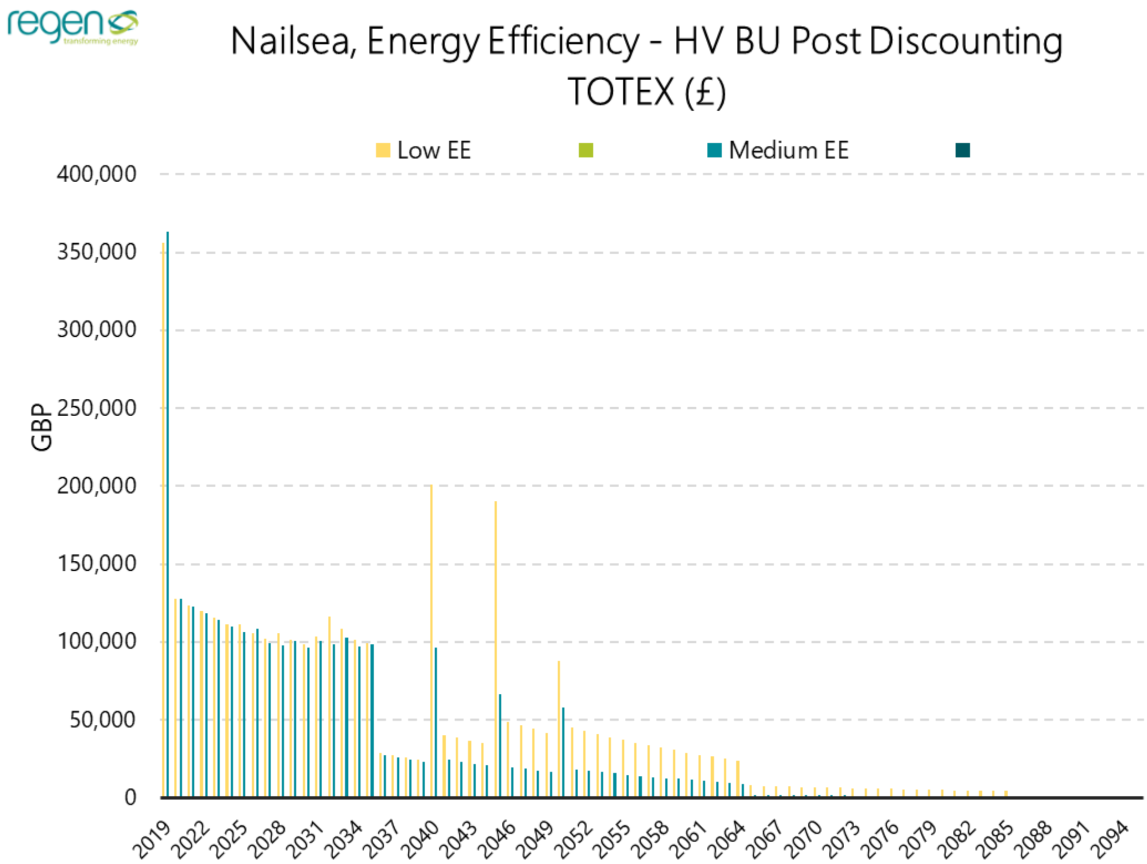

Figure 65: Annual HV TOTEX by year to 2095 on the Nailsea primary

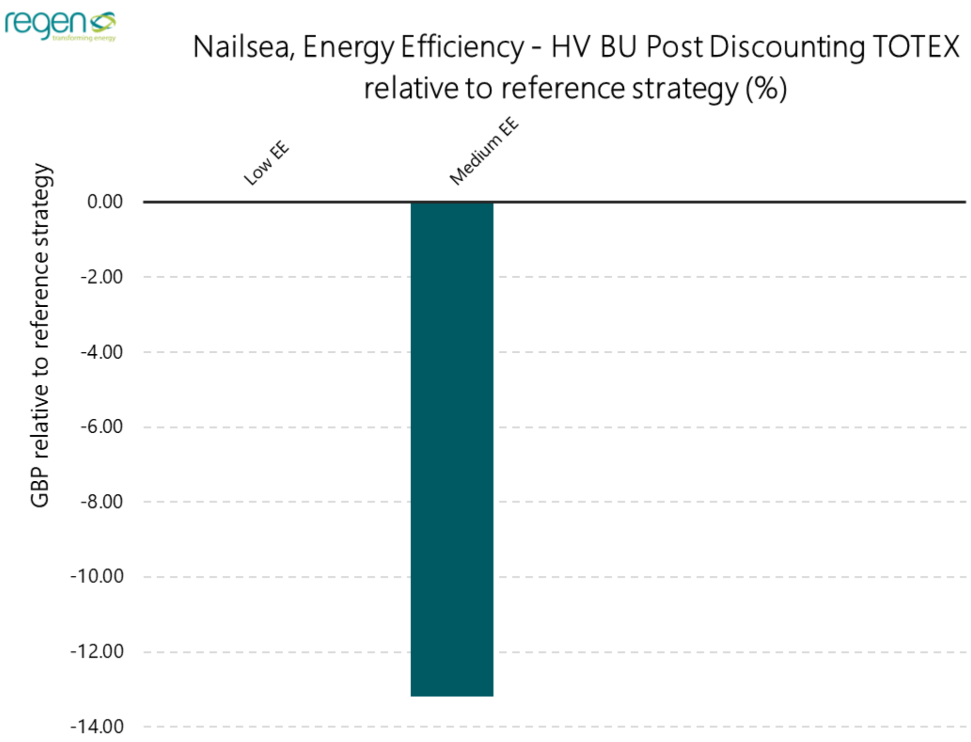

Figure 66: Total HV TOTEX on the Nailsea primary relative to the Low EE strategy

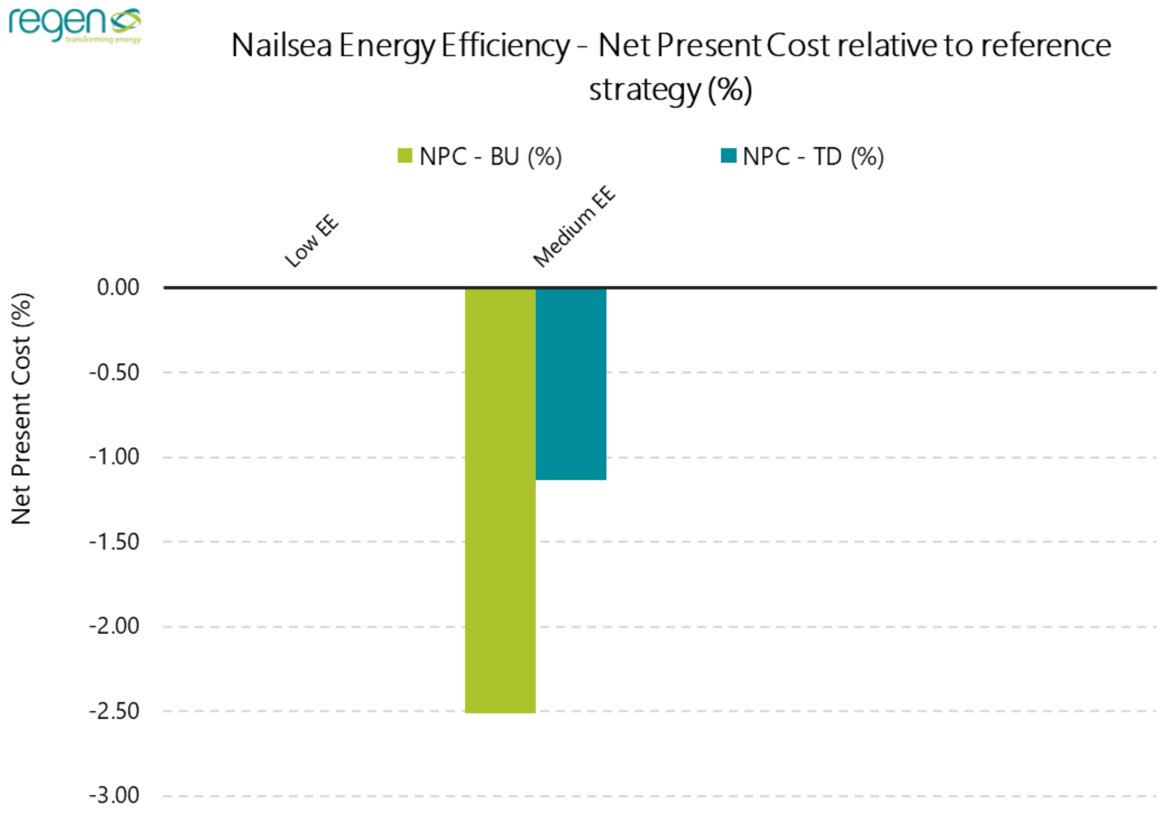

Figure 67: Whole system net present cost of the Medium EE strategy on the Nailsea primary relative to the Low EE strategy, on the Nailsea primary, from both bottom up and top down analysis