Project EPIC

Work Package 6:

Network investment results for Use Case 4: 'Just in Time' vs. 'Fit for the Future' investment strategies

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
ENA	Energy Networks Association
ESA	Electricity Supply Area

Abbreviation	Term
EPIC	Energy Planning Integrated with Councils
EV	Electric Vehicle
FFF	Fit for the Future
HV	High Voltage
HV NAT	High Voltage Network Analysis Tool
INM	Integrated Network Model
JIT	Just in Time
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
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 4**, assessing the impact on the network and society of a 'Just in Time' or 'Fit for the Future' approach to network intervention.

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 the 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 West 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).

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

This use case, comparing two investment strategies, 'Just in Time' (JIT) and 'Fit for the Future' (FFF), produced significant results in most of the cost categories being assessed. Across all primaries, FFF resulted in significant savings in network CAPEX and OPEX. The HV network was especially impacted with a 20% average CAPEX reduction and 40% average OPEX reduction by 2050. There are some unexpected trends in these results, which this report details. However, due to an alternate method of HV analysis which was employed in this use case, analysis of the timings of HV CAPEX interventions was not possible. The CAPEX savings are echoed within the HV analysis report that shows the same assets are upgraded more than one time for Run 1. While the value differs according to whether the top-down or bottom-up approach has been taken, any duplicated upgrades provide an opportunity for savings under the Fit for the Future approach, and where this involves primary transformers the costs are considerable.

The significant impacts in individual network cost categories carry though to significant network TOTEX savings for FFF on all three primaries. Of the three LV networks, Cribbs Causeway's sees the largest impact, with a 12% LV TOTEX saving. Whilst Dorchester St's HV network is the most impacted, with an 18% HV TOTEX saving for FFF.

Societal impact is assessed though the societal value of emissions, roadworks, and availability of spare network capacity. A carbon emissions impact is not captured in these results, with equal electricity demand assumed across the two strategies. While these results suggest that the Just in Time strategy results in an increase in spare capacity, to the benefit of society. This additional spare capacity is not easily traced back to specific CAPEX interventions, this prevents a deeper understanding of what is causing this.

The cost of roadworks saw significant variation between the strategies. While on the LV network, there was zero change in roadworks requirement on the Dorchester St and Nailsea primary, and increased roadworks for FFF on the Cribbs Causeway primary, on the HV network, there were large savings in roadworks across all primaries for FFF. These contributed to significant savings for society from reduced roadworks. Dorchester St was especially impacted, if its 70% saving in roadworks is considered at a customer level, it equates to £1000 per customer by 2050. Reduction in roadworks costs are expected as FFF should reduce the instances where the same asset is upgraded more than once within the evaluation timeframe and should be the minimum cost of achieving a network without thermal or voltage issues in 2050. Reduction in roadworks costs are expected as FFF should reduce the instances where the same asset is upgraded more than once within the evaluation timeframe and should be the minimum cost of achieving a network without thermal or voltage issues in 2050.

When these network and societal TOTEX values are combined into a whole systems cost, Fit for the Future does result in significant savings. Dorchester St primary sees a maximum whole system saving of 11%, the most significant whole system impact seen in the EPIC trial run; Nailsea sees a 7% whole system saving. While these impacts may seem small in percentage terms, the CBA methodology employed in this trial has made significant whole systems impacts very uncommon, so these are notable results. Figure 1 below, visualises this.

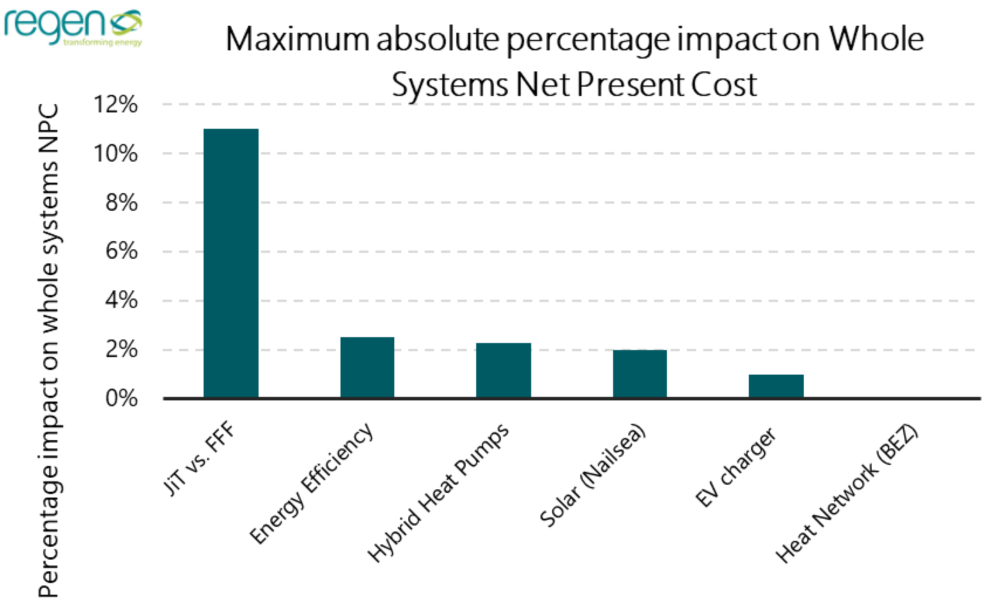

Figure 1: The maximum absolute percentage impact on whole systems net present cost seen in each of the EPIC Trial use cases.

The presence of consistent and significant savings for the Fit for the Future strategy does suggest that it is an approach that should be investigated further by the networks, the demonstrated impact on whole systems cost and specifically, the societal savings from reduced roadworks disruption should be considered by Local Authorities as they consider implementing LAEPs or similar long term investment strategies. It suggests that new developments should have networks with generous spare capacity to anticipate future load growth. This is a significant shift away from the investment strategies that have been encouraged by the regulatory environment previously where the focus has been on the avoidance of stranded assets by only investing in the minimum cost scheme to achieve a sufficient network. Investing ahead of need to avoid greater overall costs in the next thirty years requires a great deal of confidence in both the long term forecasts but also that the savings provided by that approach (or a fair proportion of them) would be returned to the investors that had provided the higher levels of early funding. While some steps like phasing out smaller sized cables and moving to supply new customers with three phase service cables have already been implemented there may be benefits from further changes to planning approaches to favour a longer term view that may in turn require new regulatory approaches.

3.1. Limitations of the modelling

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 FFF 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 small percentage decreases.

This use case is the only one within the EPIC Trial to see network TOTEX impacts over 10%, and these result in the whole system savings for FFF described above.

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.

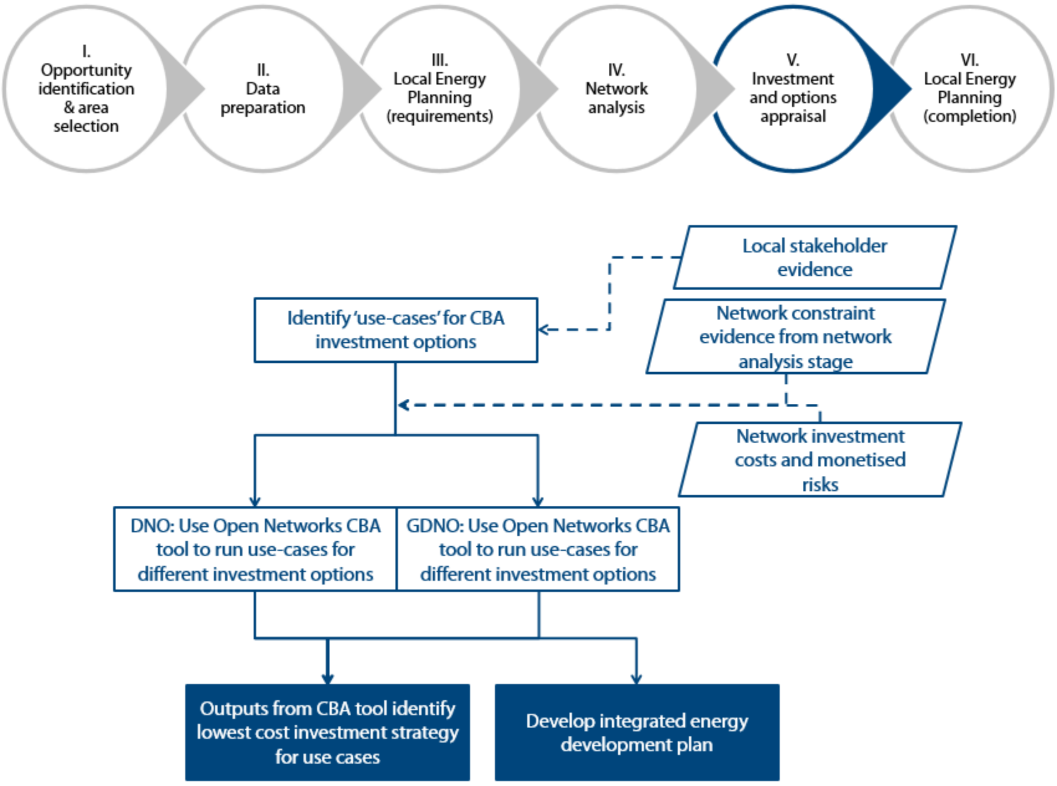

Figure 2: The EPIC Trial Planning Process.

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 the HV 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. 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:

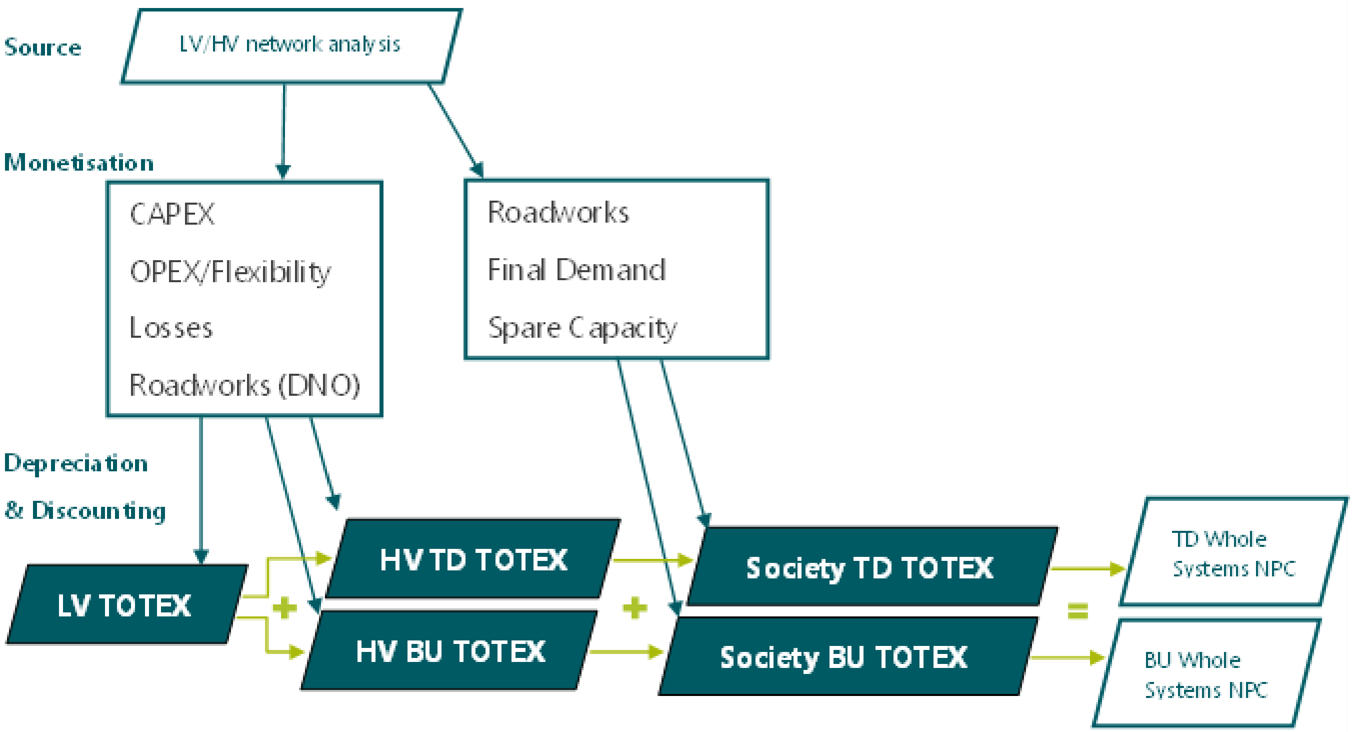

Figure 4: The processes involved in generating results from the WS CBA tool.

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.

[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.

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 3: Just in Time vs. Fit for the Future

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.

This use case compares the impact on the network and society of two differing approaches to asset intervention on the electricity network. A 'Just in Time' approach, , whereby assets are replaced or upgraded based on near term demand growth with the minimal investment to achieve compliance with network requirements, or a 'Fit for the Future' approach, where a longer term view of demand growth is considered and "oversized" upgrades are used. This longer term view could lead to greater initial investment as more expensive solutions may be required to provide sufficient capacity. However, it may ultimately result in lower expenditure and less disruption if multiple interventions are avoided.

In the LV NIFT and HV NAT analysis tools, solutions were selected to resolve constraints for an entire 'look ahead' period. This look ahead period was the only variable which was altered to produce 'Just in Time' and 'Fit for the Future' results:

- The 'Just in Time' approach deployed solutions to meet capacity requirements for three years.
- 'Fit for the Future' approach deployed solutions to meet capacity requirements for twenty years.

With only one variable being altered, this has resulted in a relatively simple comparison between the two investment approaches. While absolute costs have been calculated for each strategy, the focus of the report is on the relative costs/benefits of the 'Fit for the Future' strategy and these will be expressed as percentages of the reference strategy.

In this case, **the reference strategy is the "Just in Time" variation**, and **percentage increases or savings** for the **"Fit for the Future"** strategy will be reported.

Table 2: The investment strategies being tested in Use Case 4 and impacts discussed in this report.

Strategy 1: **Just in Time** (reference strategy)	Strategy 2: **Fit for the Future**
N/A - Reference strategy	% change in costs/benefits

Table 3, below, illustrates the relative impact of the Fit for the Future strategy 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 significant downward impacts on the electricity network costs, in only a single instance (LV roadworks on Cribbs Causeway) does the Fit for the Future strategy result in increased costs. The large impacts on the Dorchester St primary are also of note, resulting in a significant whole system saving for Fit for the Future. This is the only whole systems impact above 10% in seen in the EPIC trial run.

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		-30%	-25%		-50%	-70%					-70%	-58%						
Cribbs Causeway	-12%	-11%				-20%				15%		-13%				20%		
Nailsea		-10%	-25%		-35%	-40%					-18%	-40%						

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		-18%	-14%			-11%	-7%
Cribbs Causeway	-12%	-12%					
Nailsea			-12%				-7%

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

To complete 'Fit for the Future' runs on HV NAT, the approach to assessing CAPEX and roadworks was different than for the other runs. The tool looked backwards from each year being investigated and assessed all upgrade requirements to resolve all constraints up to that year. This means that in the results, the annual CAPEX costs were cumulative, and it could not be assumed that solutions deployed when one year was investigated, were also deployed in a subsequent year's results. This means that it is not valid to take the differentials of two consecutive years and create a non-cumulative timeline of CAPEX. As a result, a comparison of the timings of HV CAPEX interventions is not possible. This approach reduced the complexity of the development of the HV NAT, which was an overall benefit, but there is a risk that not all required reinforcement is captured by this approach, for example if the network is assessed with 2050 load requirements there are likely to be lots of investments compared to 2022, however it is still possible that loads under some scenarios could be higher before 2050 and then reduce e.g. as a result of energy efficiency or with the assumption that greater use of public transport reduces the overall EV charging load requirements. In these cases there may be a need for some reinforcement work to manage the long term peak loads which then subsequently reduce. If such a planning tool were to be incorporated into BAU then it should be possible to check for those situations using the forecasted load profiles that are created during the analysis process and force the network assessment to insert an interim analysis year at the network peak before assessing the final year.

5.1.1. Dorchester St

On the Dorchester St primary the Fit for the Future strategy results in a LV CAPEX saving of 3% by 2050. This is driven by a large saving in 2019 on 2034. The expectation for initially higher CAPEX followed by longer term savings is not present in the results, there is no clear trend in when the savings arise.

Savings of 25-30 % are seen on the HV network.

5.1.2. Cribbs Causeway

The LV network sees 12% savings in CAPEX from the FFF strategy on this primary. This is the largest saving on the LV side from all three primaries, it is primarily due to a large saving in 2019. Again, this is not necessarily an expected trend, with FFF expected to deliver its savings in the long term.

Savings of 8-11 % are seen on the HV network.

5.1.3. Nailsea

On the Nailsea primary, the LV network sees 4.5% savings with the FFF strategy. In this case the LV CAPEX savings do follow a more expected trend, with most savings coming post 2040.

On the HV network, 10-25% savings place this result between the larger savings seen on Dorchester St, and the smaller savings on Cribbs causeway.

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

OPEX on the LV network is decreased with the FFF strategy, a total saving of 70% out to 2050. Annual savings on OPEX have a trend of increasing year on year. The OPEX values are dependent on the number of smart solutions being deployed by LV NIFT, with smart solutions having greater OPEX than a traditional CAPEX intervention. The increasing year on year savings on Dorchester St OPEX suggests that each year, less smart solutions are being deployed by the Fit for the Future strategy, than are deployed in the just in time strategy. This is consistent with expectations as the Fit for the Future strategy is likely to result in sufficient network capacity being provided that smart solutions are not required.

5.2.2. Cribbs Causeway

OPEX on the LV network is decreased with the FFF strategy, a total saving of 9% out to 2050. While this is a similar result to Dorchester St, the trend of increasing annual savings is not seen, instead, savings are highest in the 2020s, and lower in the 2030s and 2040s. This suggests that relatively fewer smart solutions are deployed in the 2020s, compared to the 2030s and 2040s.

On the HV side, there is an interesting result, with bottom up analysis resulting in marginal difference between JIT and FF, whilst the top down analysis suggests 20% savings for FFF. This saving is highly driven by a single year’s savings in 2045.

5.2.3. Nailsea

While the LV OPEX result is marginal on this primary, the trend is once again different to the other primaries, Fit for the Future is initially more expensive in the 2020s, before delivering increasing savings in the 2030s and 2040s. This results suggests that with FFF, more smart solutions are deployed in the 2020s, relative to the just in time strategy, and this then reverses in the 2030s and 2040s.

The HV network sees 35%-40% savings, with the bottom up and top down approaches this time being aligned.

Very large savings are seen on the HV network, 50% and 70% resulting from bottom up and top down analysis respectively. In both cases these savings rise in the 2020s and remain high in the 2030s and 2040s.

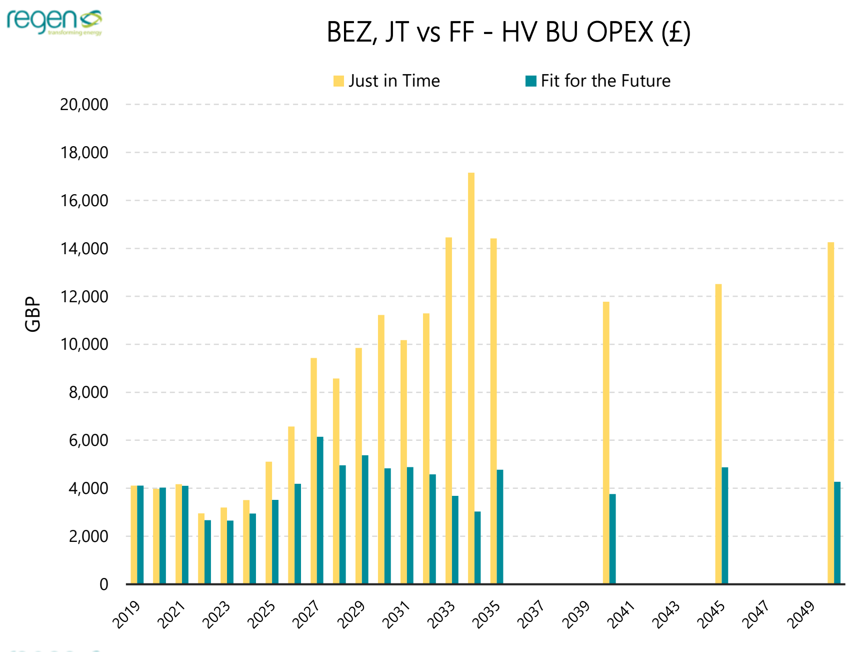

Figure 5: Annual HV OPEX on the Dorchester St primary, from bottom up analysis

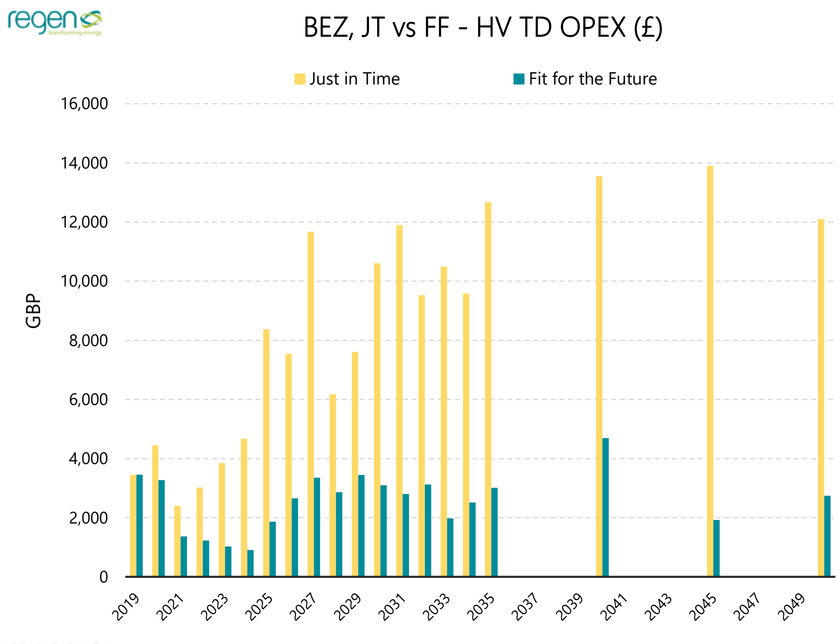

Figure 6: Annual HV OPEX on the Dorchester St primary, from top down analysis

5.3. Losses – no significant impacts

5.4. Roadworks

5.4.1. Dorchester St

There is no difference in total LV roadworks out to 2050, but the timings are impacted by the FFF strategy. This a result shared by the Nailsea primary.

Very large savings of 70% result from bottom up analysis of the HV network. The CAPEX impact was a relatively large 30%, but to have this translate into such a significant roadworks impact is not necessarily expected. The Top down analysis does produce a similarly large 55% saving.

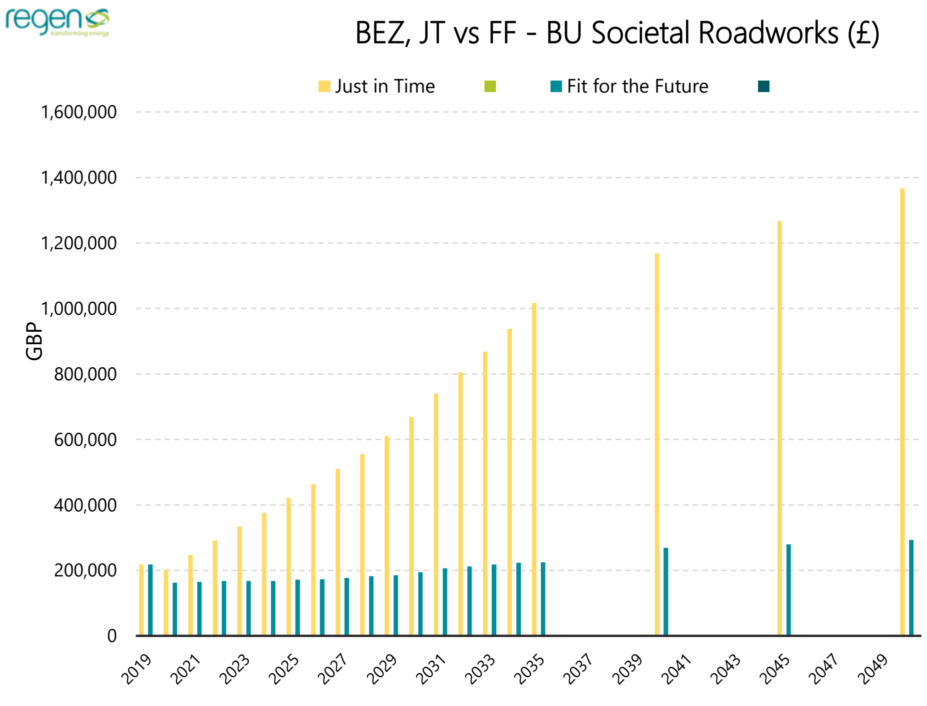

Figure 7: Cumulative annual roadworks on the Dorchester St primary, from bottom up analysis

5.4.2. Cribbs Causeway

An interesting result on this primary, with FFF actually resulting in 16% increased LV roadworks.

The HV network does see savings of 7-14% for FFF.

5.4.3. Nailsea

On the LV side, as with Dorchester St, There is no difference in total roadworks requirements out to 2050, the only variation between the strategies comes with the timing of the roadworks.

However, on the HV network, there is an 18% and 40% saving from bottom up and top down analysis.

5.5. Emissions (Final Demand)

Emissions impacts are estimated using final demand values from HV analysis and an assumed reducing grid carbon factor. The results across all three primaries indicate zero impact on emissions for the FFF strategy. This is the expected result as the only variable changed in the network modelling was the look ahead period, all demand variables were kept equal. In reality, oversizing cables under a FFF strategy would result in lower impedances and therefore slightly lower losses and carbon impact, however the scale of the benefit is likely to be small.

It is worth noting that despite these zero impacts, the monetisation method applied to emissions (based on the social cost of carbon) leads to high absolute costs when viewed against the other cost categories. This cost category dominates the 'Societal TOTEX' calculation described below, and means that societal impacts from roadworks and spare capacity to not make a significant impact on societal TOTEX.

5.6. Spare Capacity

In contrast to the other use cases, there were some significant difference in the amount of spare capacity being unlocked by the two investment strategies. However the results went against expectations with Just in Time strategies having a higher benefit from the spare capacity metric than Fit for the Future, where oversized assets would logically result in additional space capacity.

5.6.1. Dorchester St

The LV network results as per figure 20 show the Just in Time strategy releases 4% more spare capacity by 2050 than the FFF strategy. A large part of this is delivered in 2020 owing to the larger 2019 CAOPEX investment for JIT.

On the HV side, figures 22 and 24 show that, Just in Time released 10% more spare capacity. As on the LV side, this is primarily due to differing 2019 investments between the strategies.

5.6.2. Cribbs Causeway

On the LV network a 20% reduction in spare capacity is provided by the FFF strategy. Again, primarily due to a significantly smaller 2019 CAPEX investment compared to JIT. This is shown in figure 51

There is marginal difference in HV network spare capacity on this primary. This aligns with the CAPEX result, being the least impacted of all the primaries.

5.6.3. Nailsea

In a very similar result to Dorchester St, the JIT strategy releases 4% additional spare capacity by 2050, driven by a large 2019 CAPEX differential.

The HV network also sees 4-5% additional spare capacity for the JIT strategy, with a relatively even annual distribution.

5.7. TOTEX

Summing the above cost categories produces TOTEX values for the LV and HV network. Societal TOTEX is comprised of roadworks, emissions and spare capacity.

As described above the scale of the emissions valuation means that the societal TOTEX sum is dominated by emissions and so mostly presents negligible or small societal impact. In this use case, the larger impacts on roadworks do pass through to create non-marginal Societal TOTEX differences on Dorchester and Cribbs Causeway:

5.7.1. Dorchester St

While on the LV network the FFF strategy has a small (2%) downward impact on TOTEX, its impact on HV TOTEX is far greater, at 14-18%. This is the result of significant savings in CAPEX, OPEX and Roadworks.

In bottom analysis, Societal TOTEX is reduced by 3.5% by the FFF strategy, due to reduced roadworks.

5.7.2. Cribbs Causeway

Here, there is a larger 12% downward impact on LV network TOTEX, this is primarily driven by the significant difference in 2019 CAPEX investments. The HV network also sees a 12% reduced TOTEX, again being driven by CAPEX.

An interesting result, FFF delivers a 4.5% increased Societal TOTEX. This due to the results highlighted on the LV network (increased roadworks and less spare capacity for FFF).

5.7.3. Nailsea

On the Nailsea primary, there are smaller TOTEX impacts than on the other primaries. A negligible LV impact and a 12% HV TOTEX reduction for the FFF strategy. This HV result comes from a relatively balanced contribution of CAPEX, OPEX and roadworks.

5.8. Whole Systems

Combining networks TOTEX with societal costs results in a whole systems cost. In this Use Case there are more significant whole systems results than are present in the other use cases. In the case of Dorchester St, this is due to large impacts in all cost categories, and focussed on the HV network, combining into an 11% saving for FFF from bottom up analysis, this is the largest whole systems impact captured in the EPIC trial; top down analysis yields a 7% saving.

Nailsea is similarly impacted, with top down analysis resulting in a 7% whole system saving for the FFF strategy.

Cribbs Causeway has negligible whole systems impact for FFF, despite significant impacts on the LV and HV networks.

6. APPENDIX 1: Dorchester St significant results

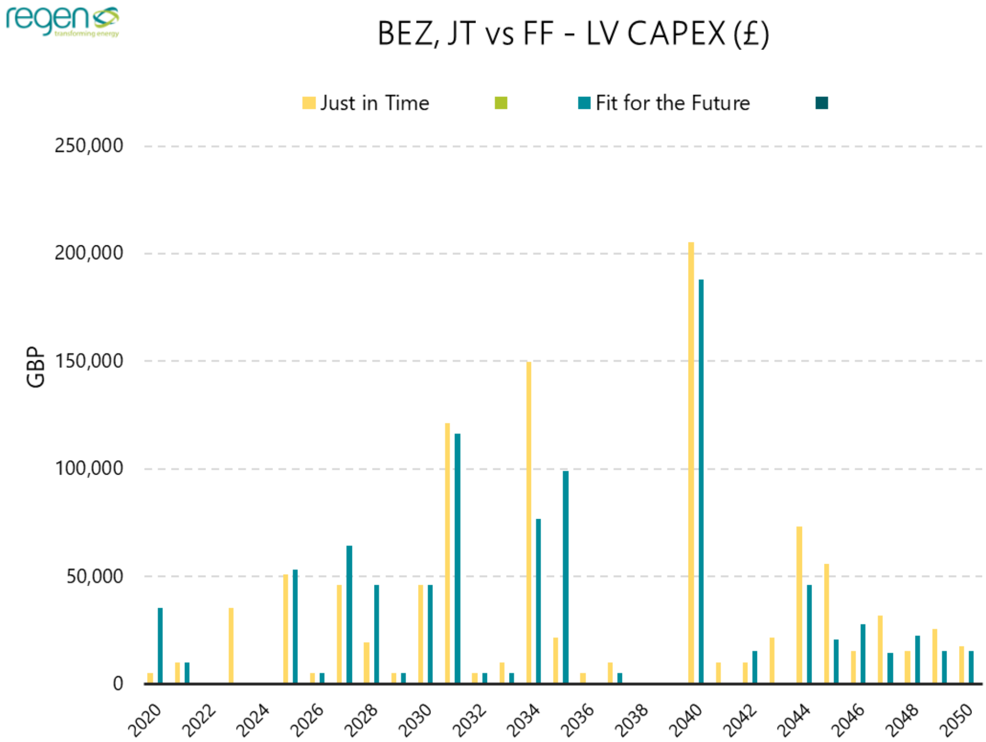

Figure 8: LV CAPEX by year on the Dorchester St primary

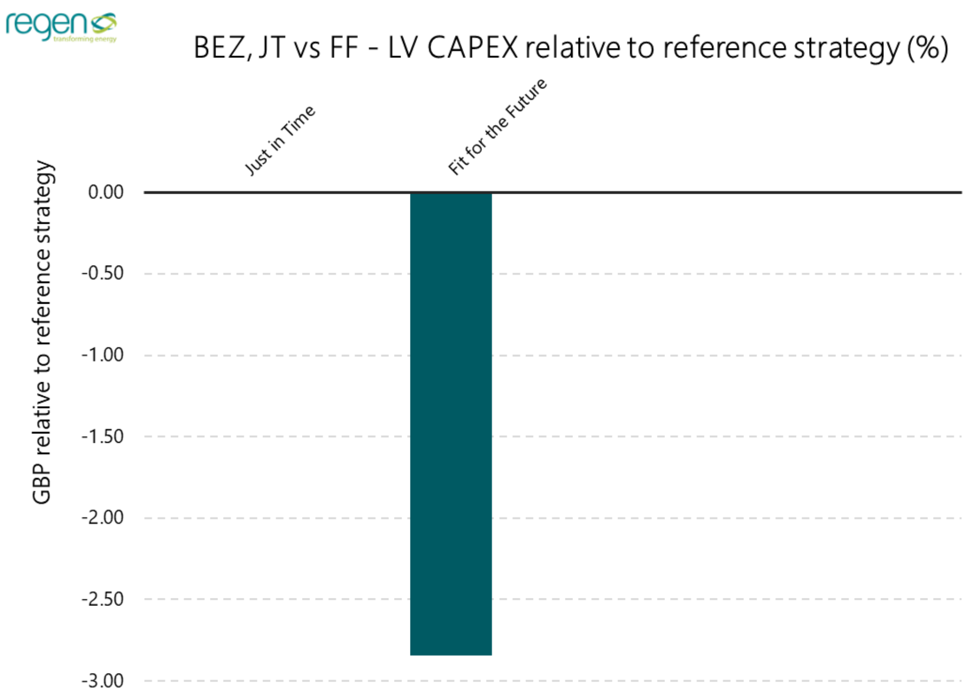

Figure 9: Total LV CAPEX by 2050 on the Dorchester St primary

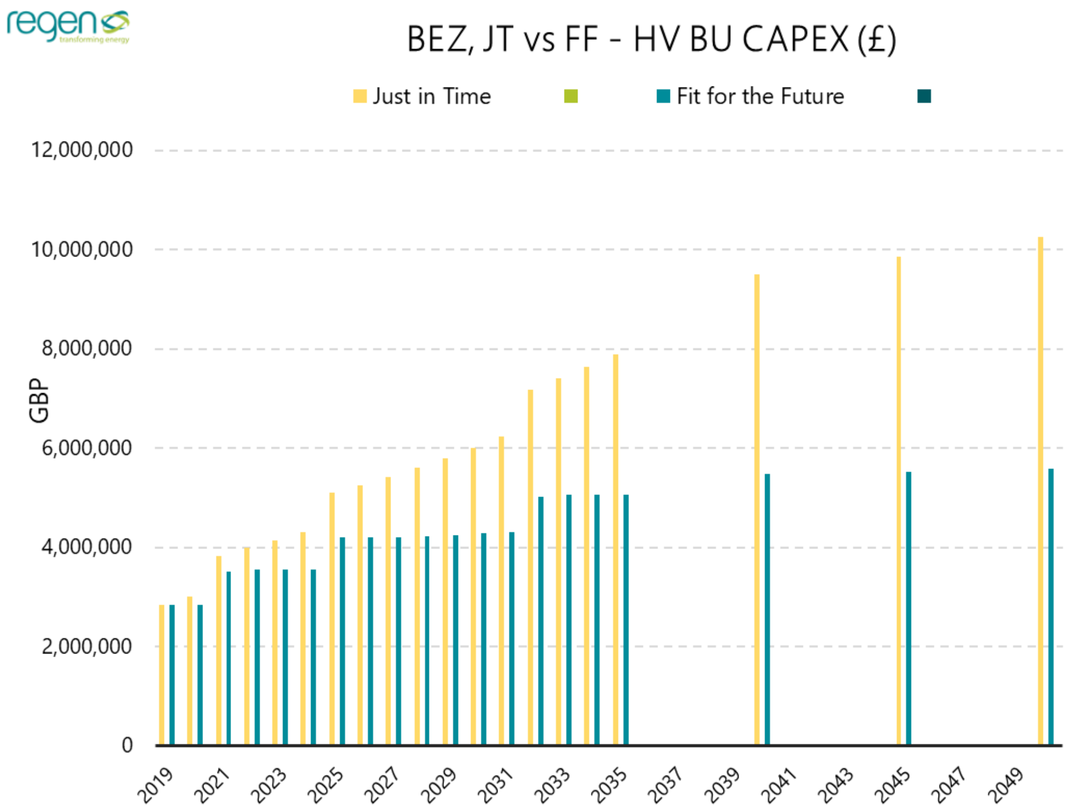

Figure 10: HV CAPEX by year on the Dorchester St primary

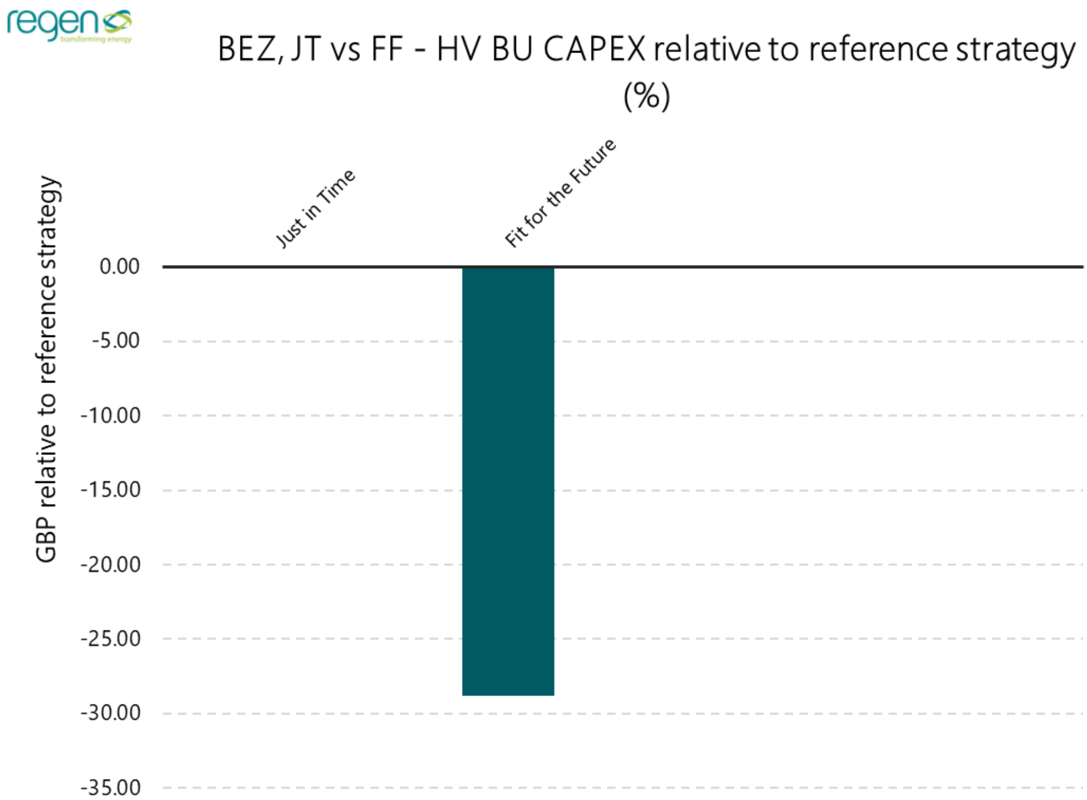

Figure 11: Total HV CAPEX by 2050 on the Dorchester St primary

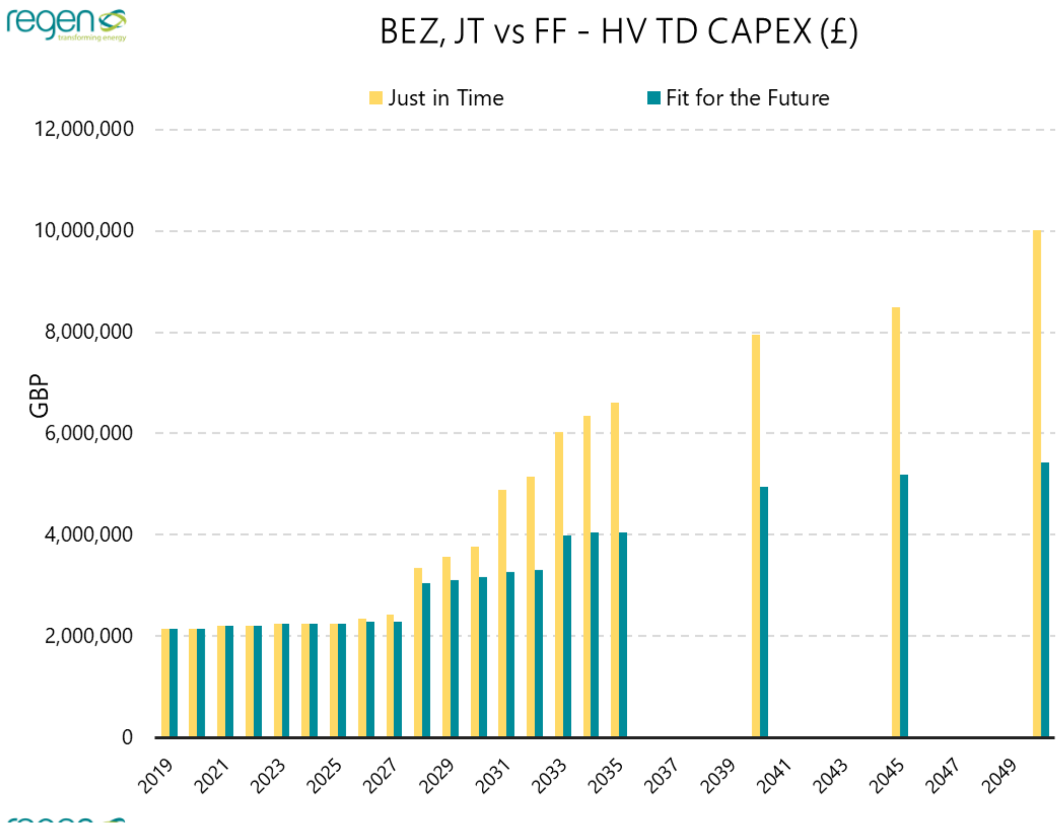

Figure 12: HV CAPEX by year on the Dorchester St primary, from top down analysis

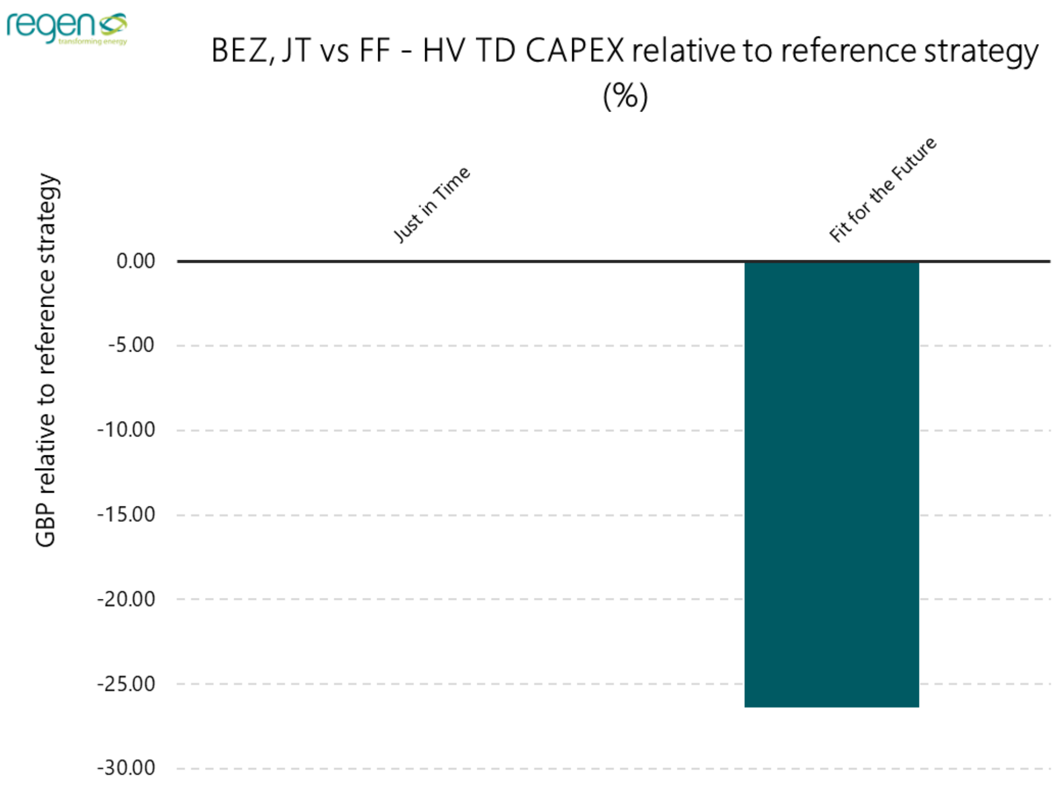

Figure 13: Total HV CAPEX by 2050 on the Dorchester St primary, from top down analysis

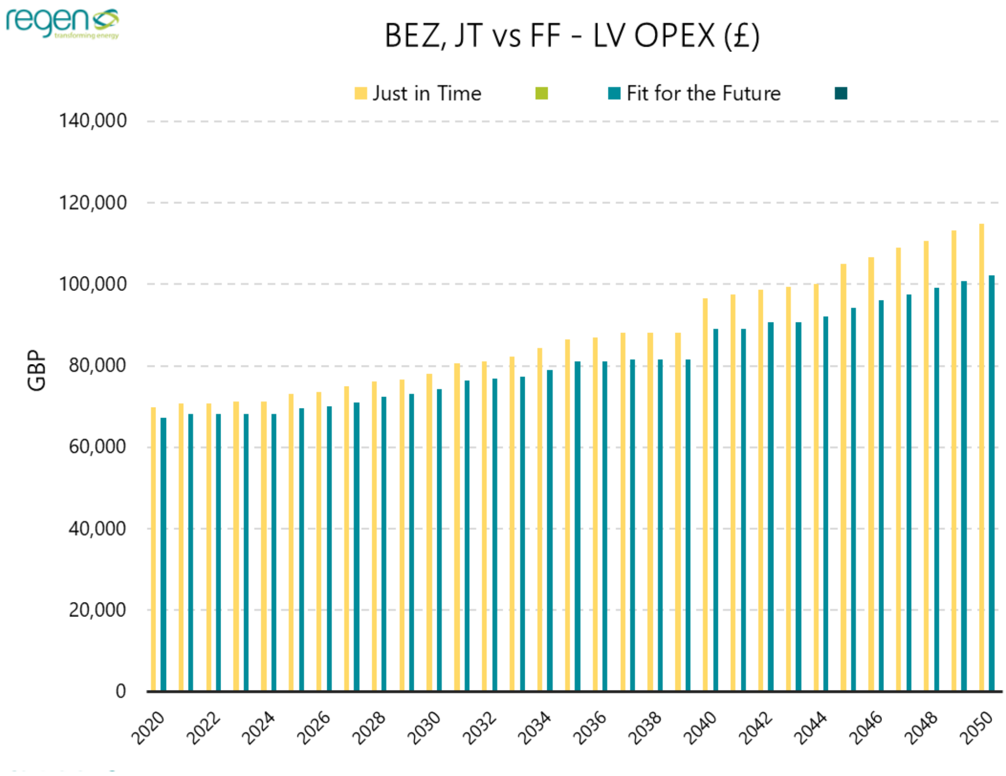

Figure 14: LV OPEX by year on the Dorchester St primary

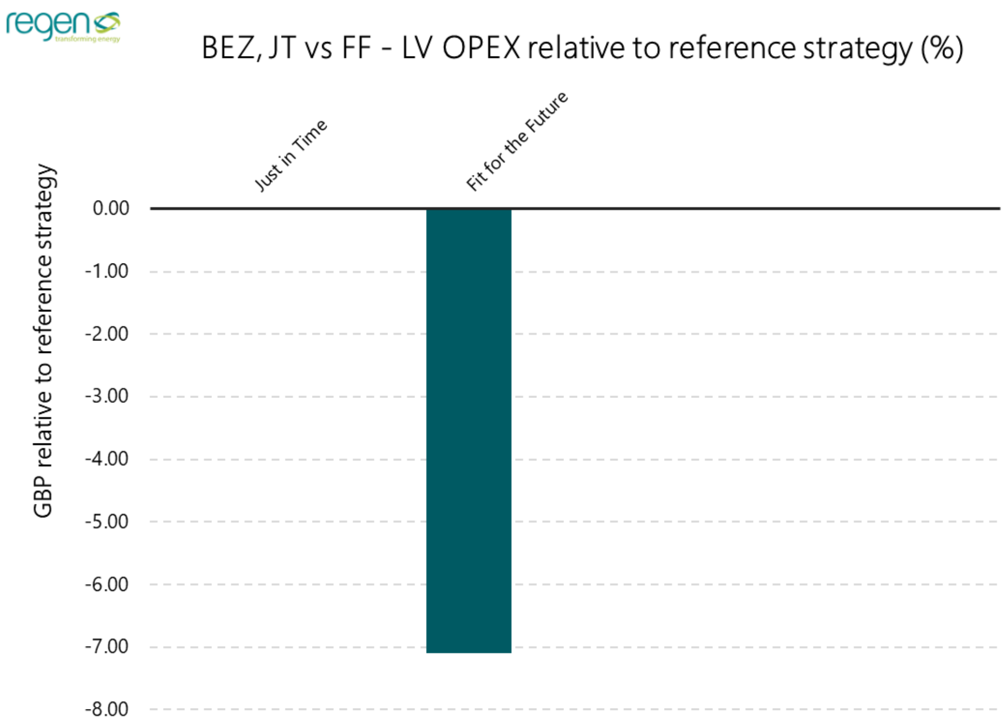

Figure 15: Total LV OPEX by 2050 on the Dorchester St primary

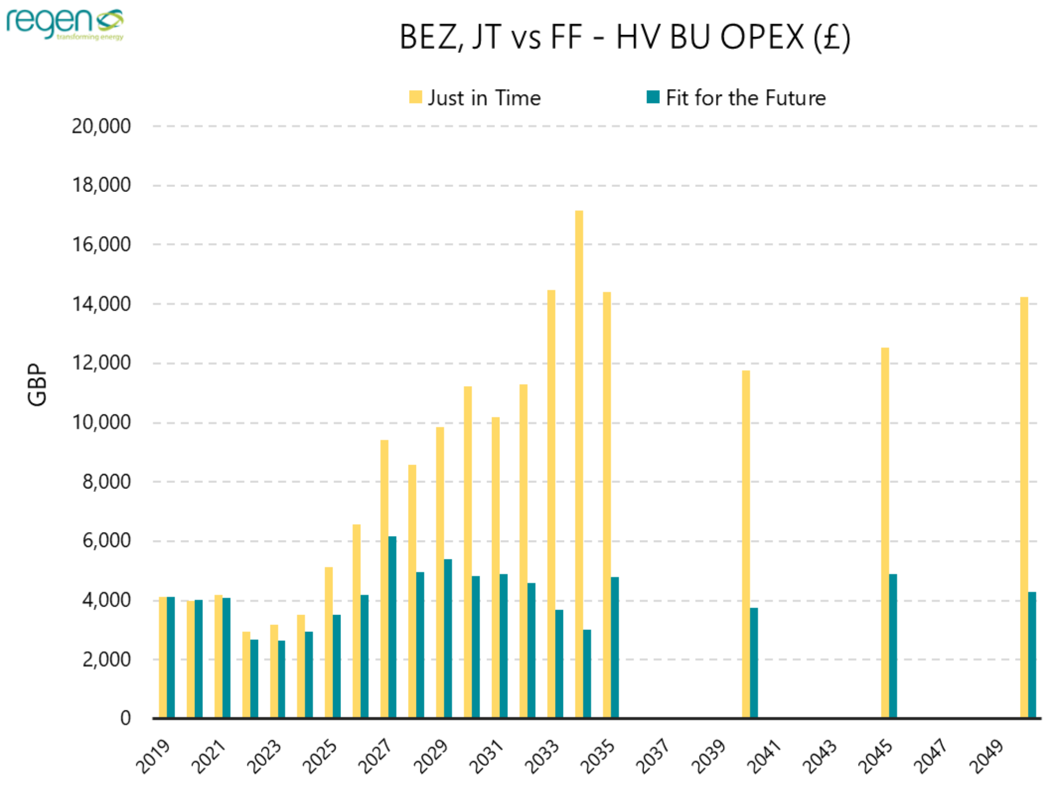

Figure 16: HV OPEX by year on the Dorchester St primary

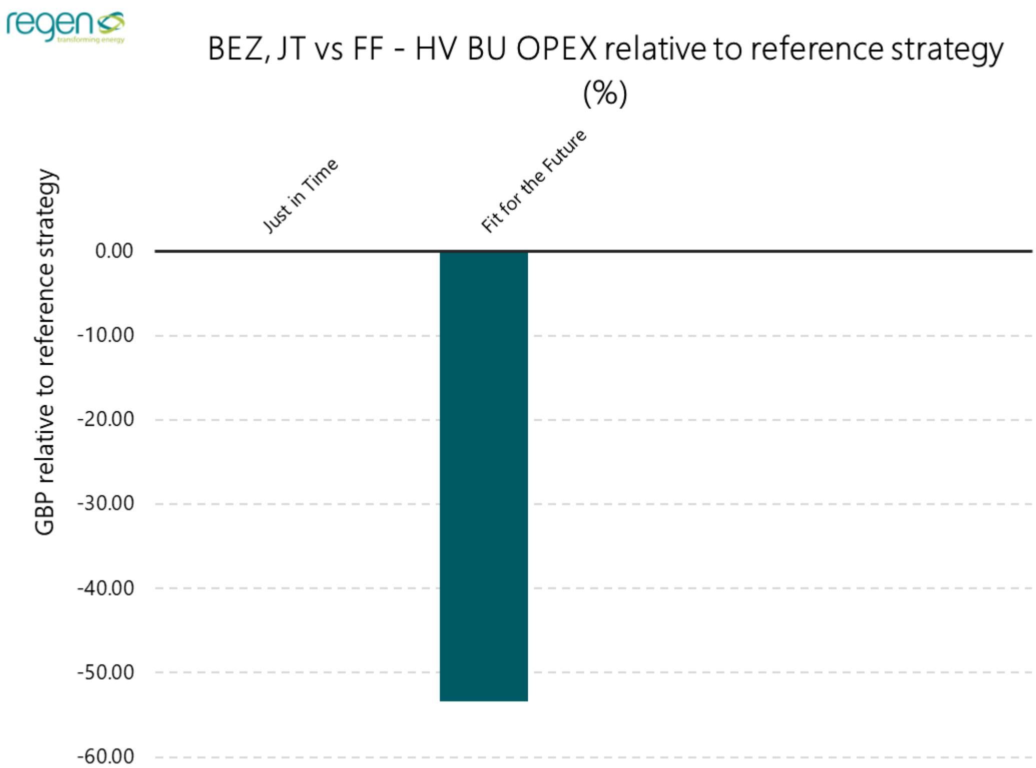

Figure 17: Total HV OPEX by 2050 on the Dorchester St primary

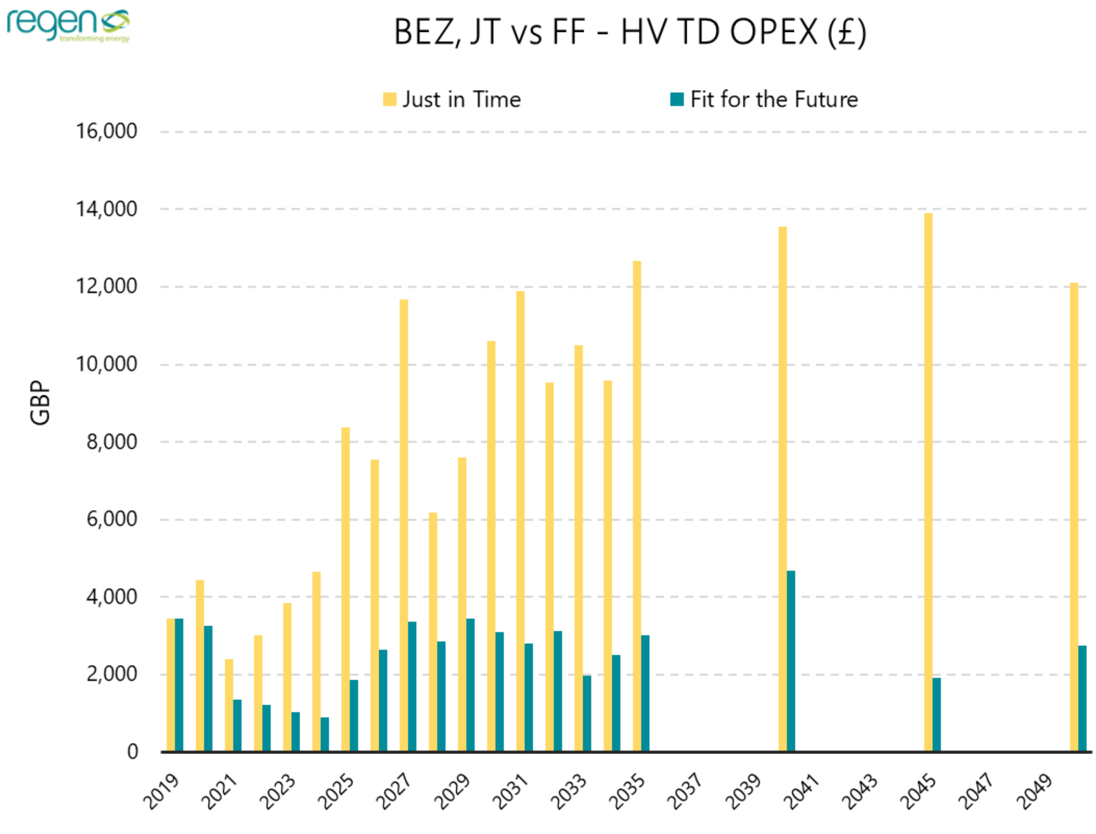

Figure 18: HV OPEX by year on the Dorchester St primary, from top down analysis

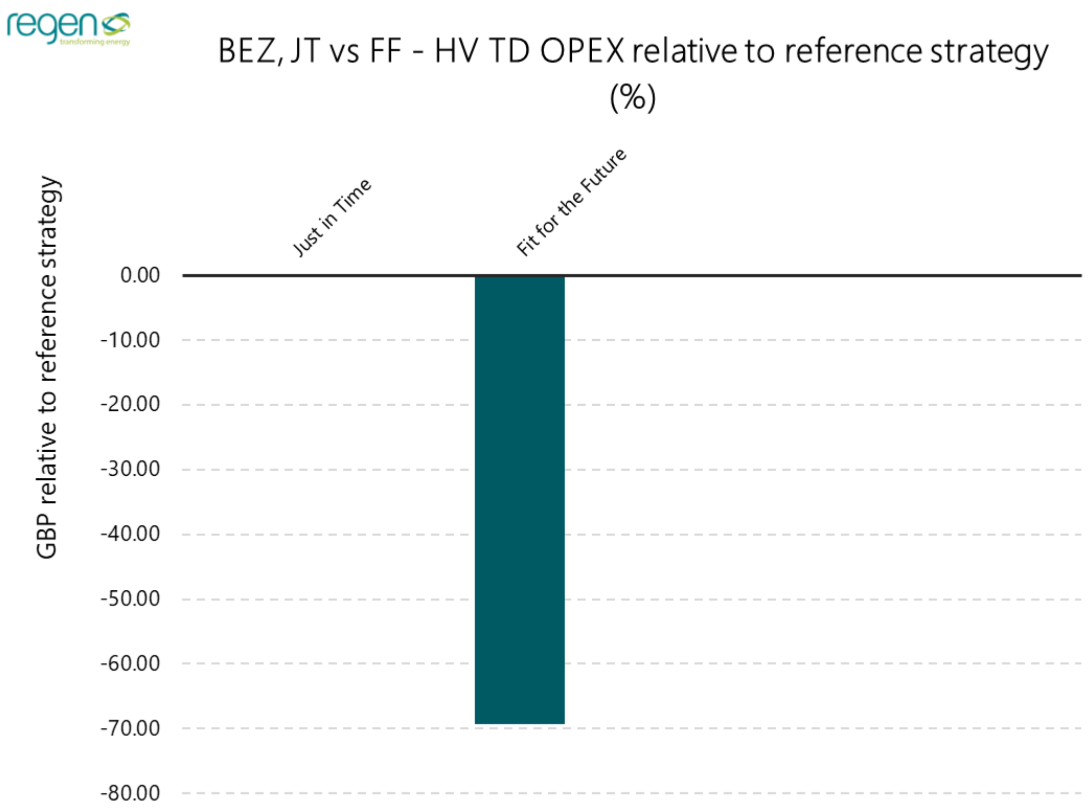

Figure 19: Total HV OPEX by 2050 on the Dorchester St primary, from top down analysis

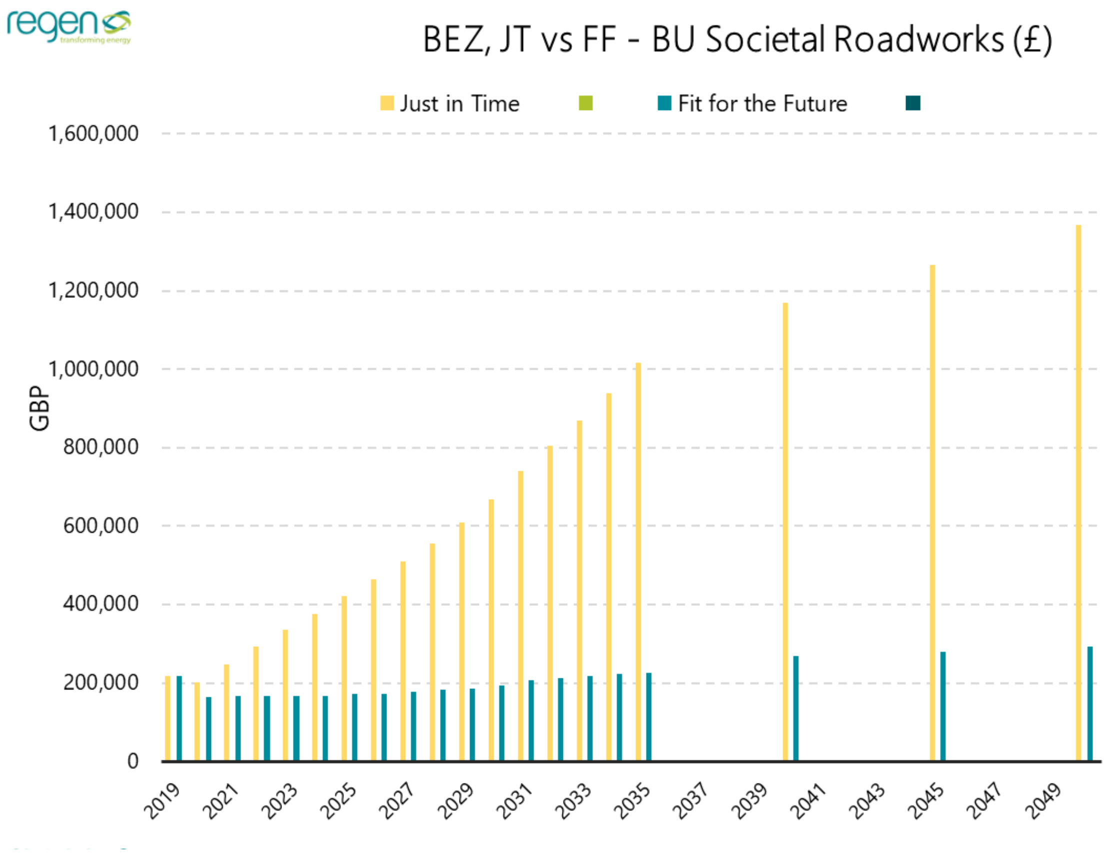

Figure 20: Societal cost of roadworks by year on the Dorchester St primary

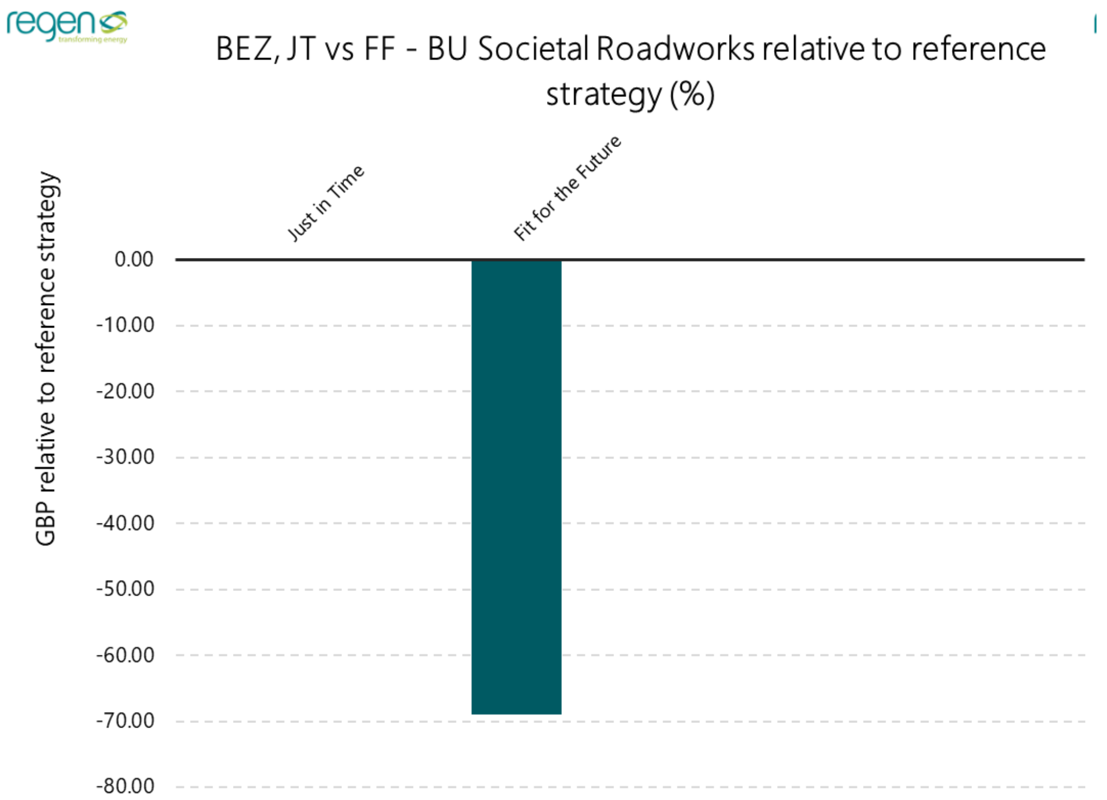

Figure 21: Total roadworks cost by 2050 on the Dorchester St primary

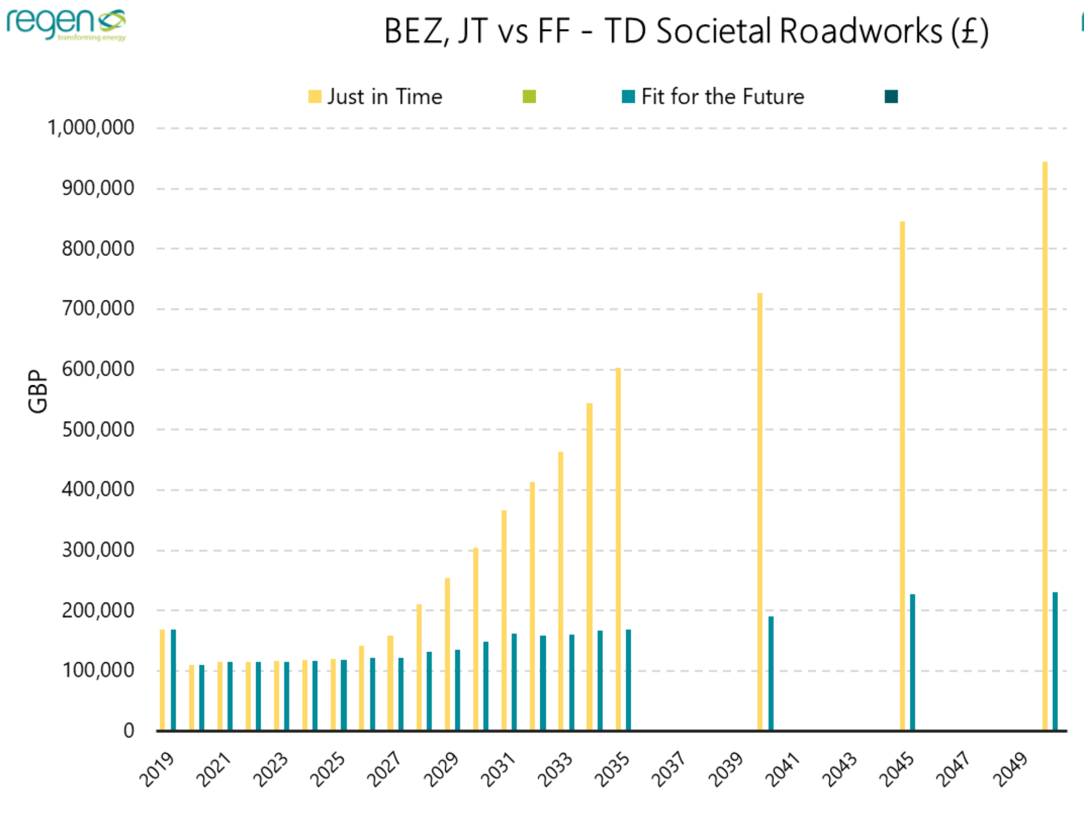

Figure 22: Societal cost of roadworks by year on the Dorchester St primary, from top down analysis

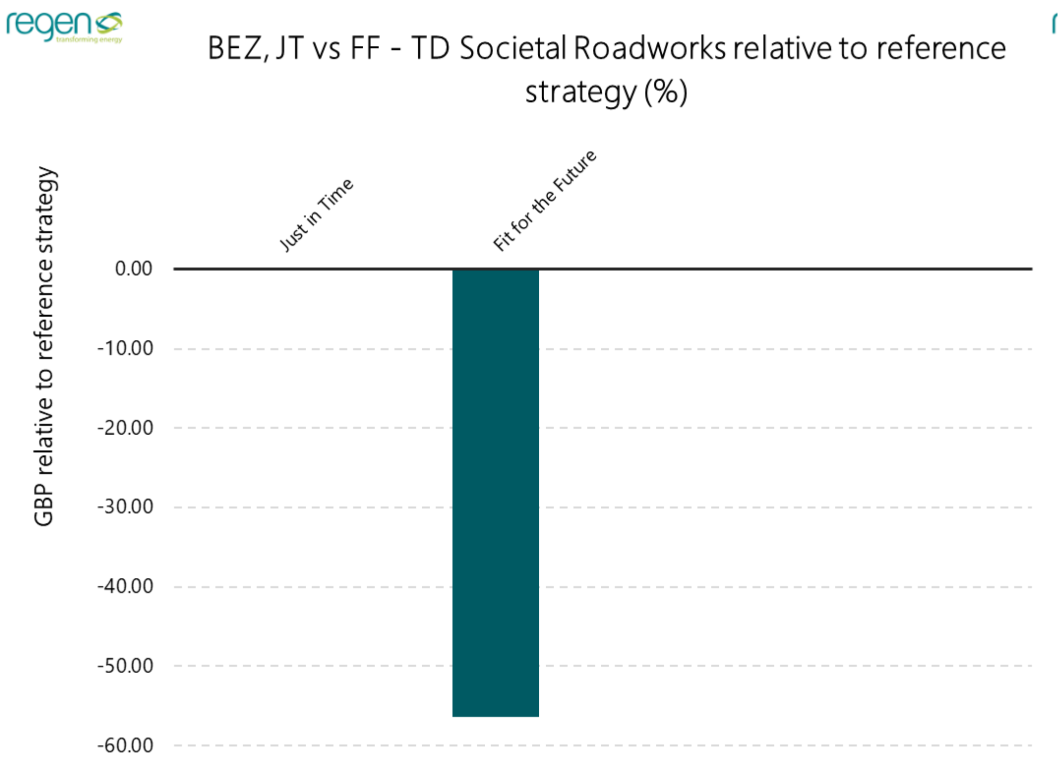

Figure 23: Total roadworks cost by 2050 on the Dorchester St primary, from top down analysis

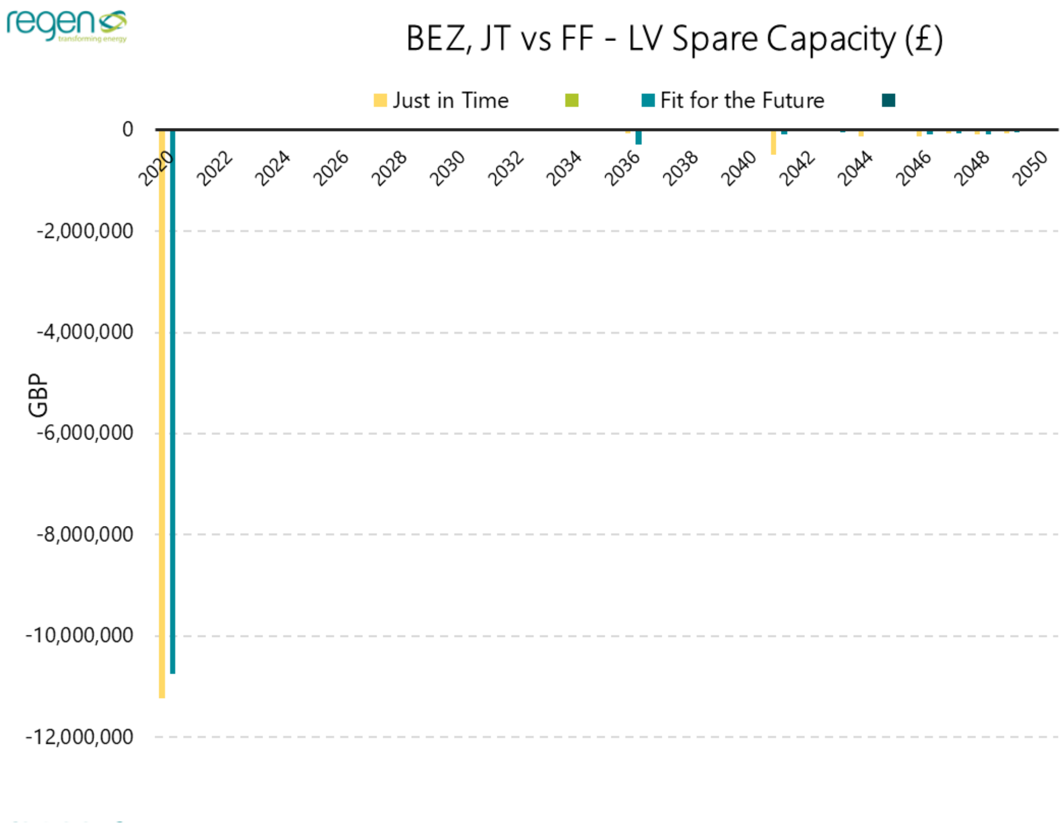

Figure 24: Monetised LV Spare Capacity by year on the Dorchester St primary

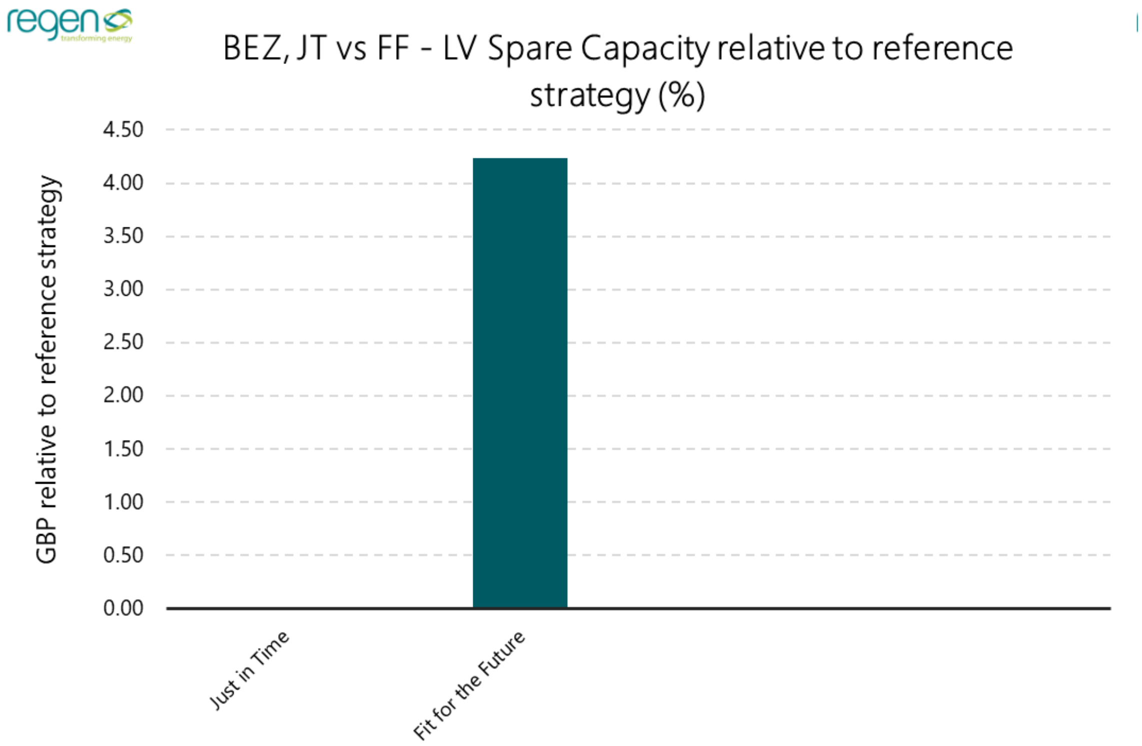

Figure 21: Total monetised LV spare capacity by 2050 on the Dorchester St primary

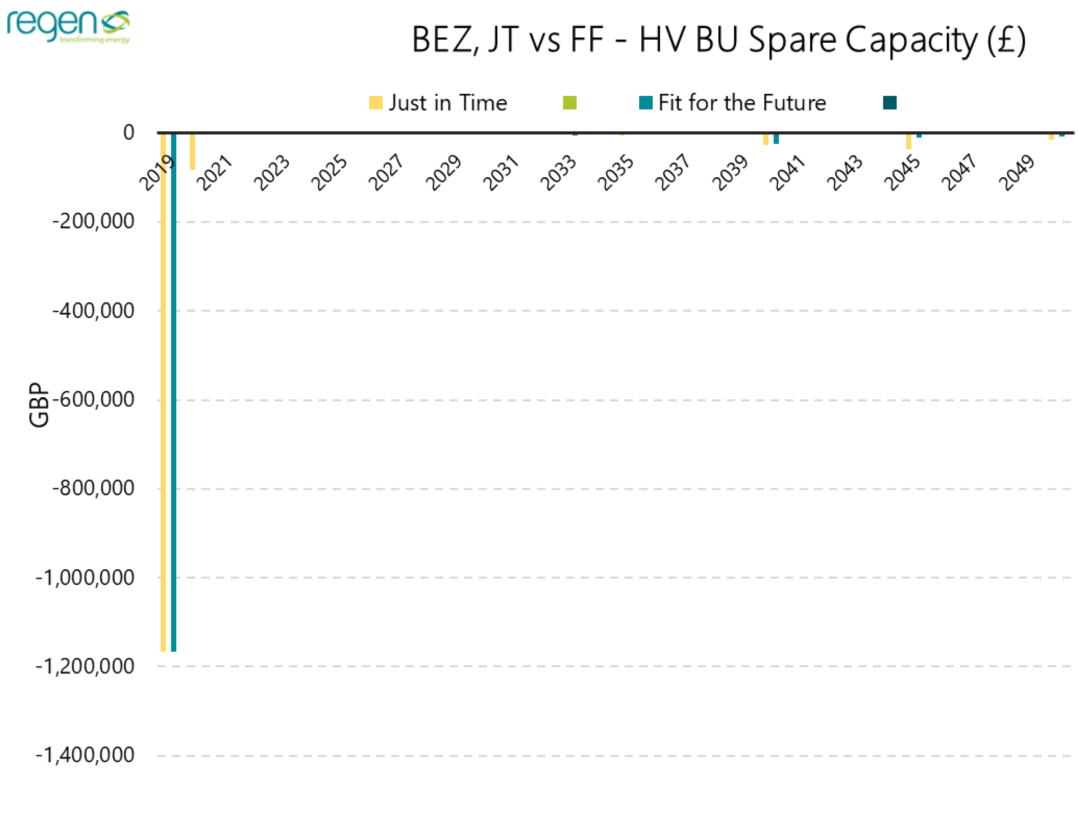

Figure 25: Monetised HV spare capacity by year on the Dorchester St primary

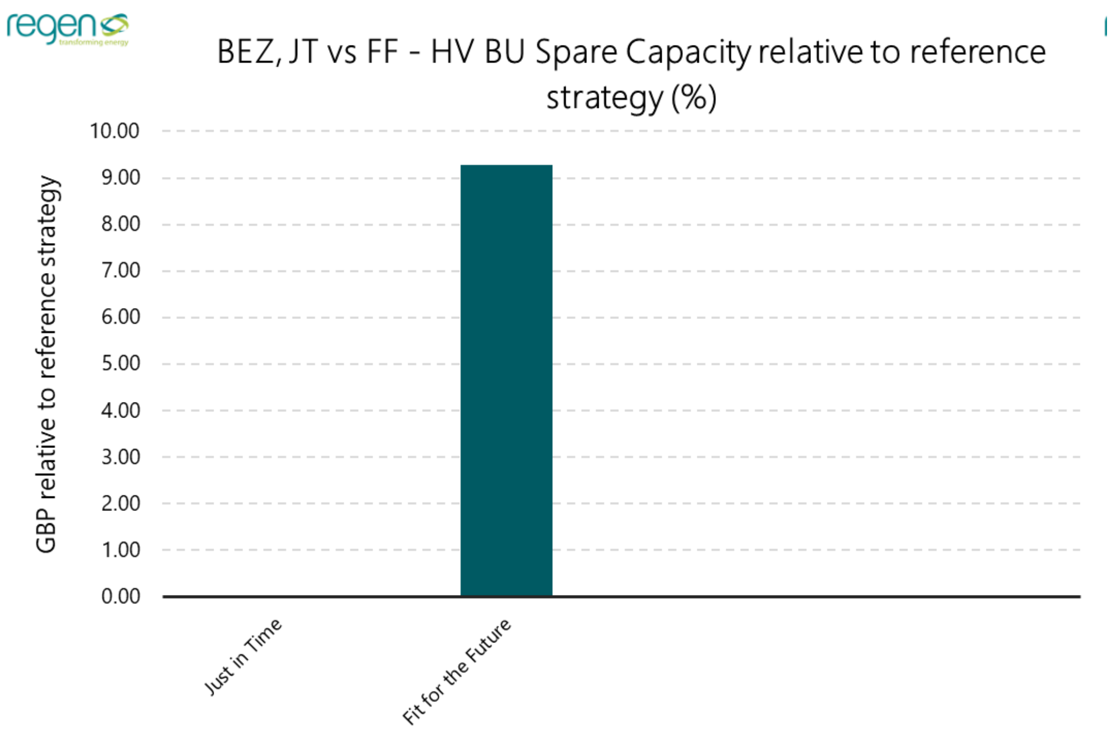

Figure 26: Total monetised HV spare capacity by 2050 on the Dorchester St primary

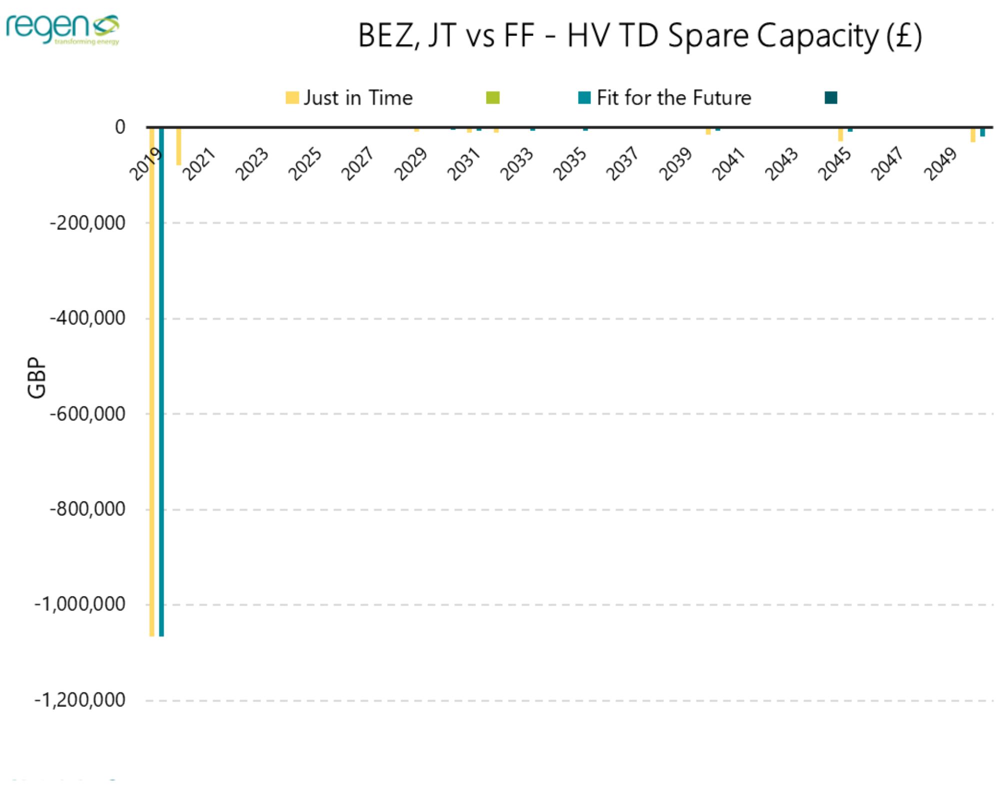

Figure 27: Monetised HV spare capacity by year on the Dorchester St primary, from top down analysis

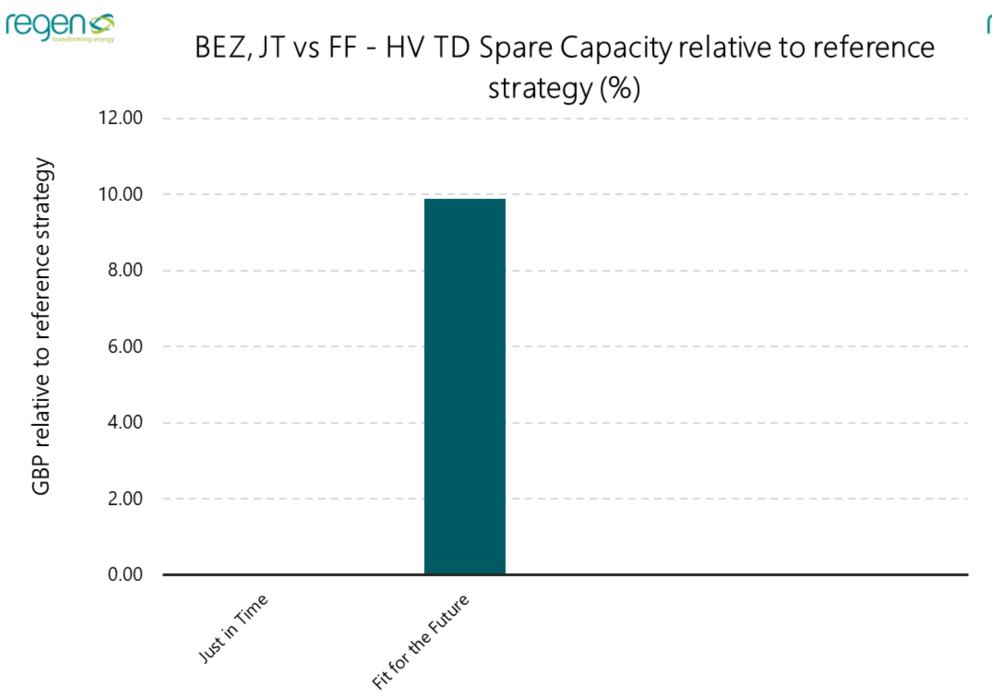

Figure 28: Total monetised HV spare capacity by 2050 on the Dorchester St primary, from top down analysis

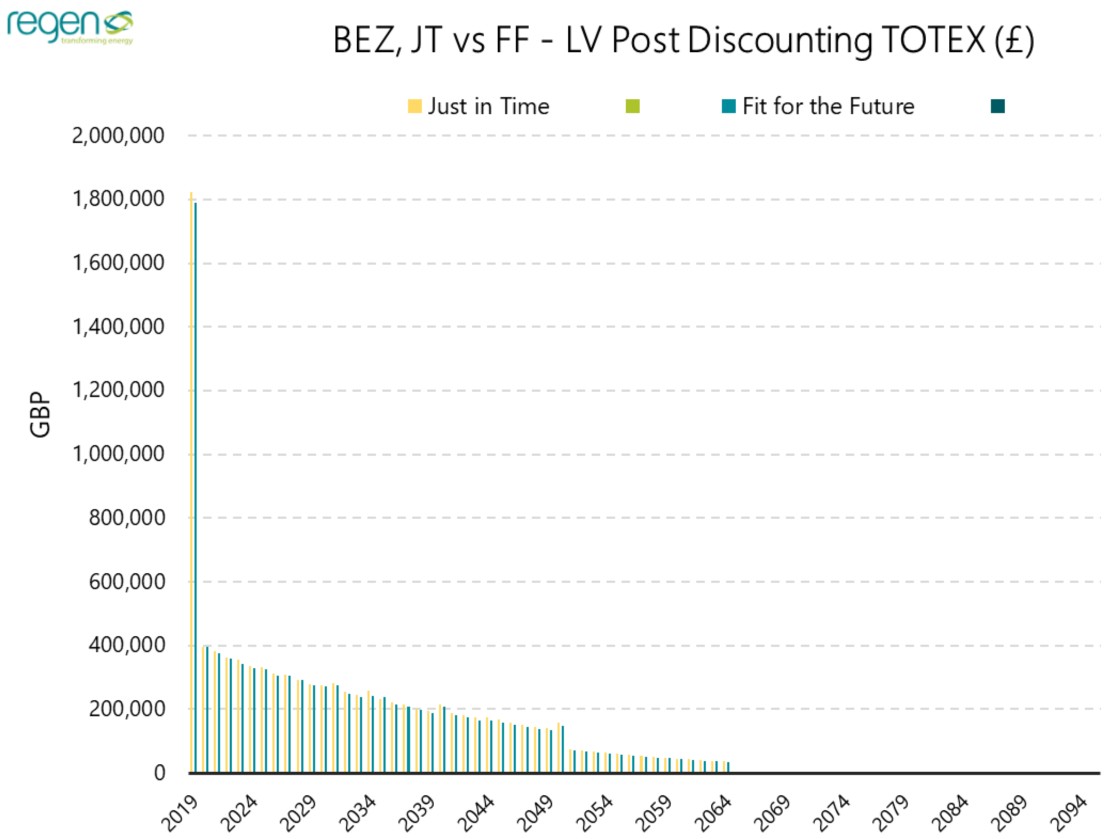

Figure 29: Post Discounting LV TOTEX by year on the Dorchester St primary

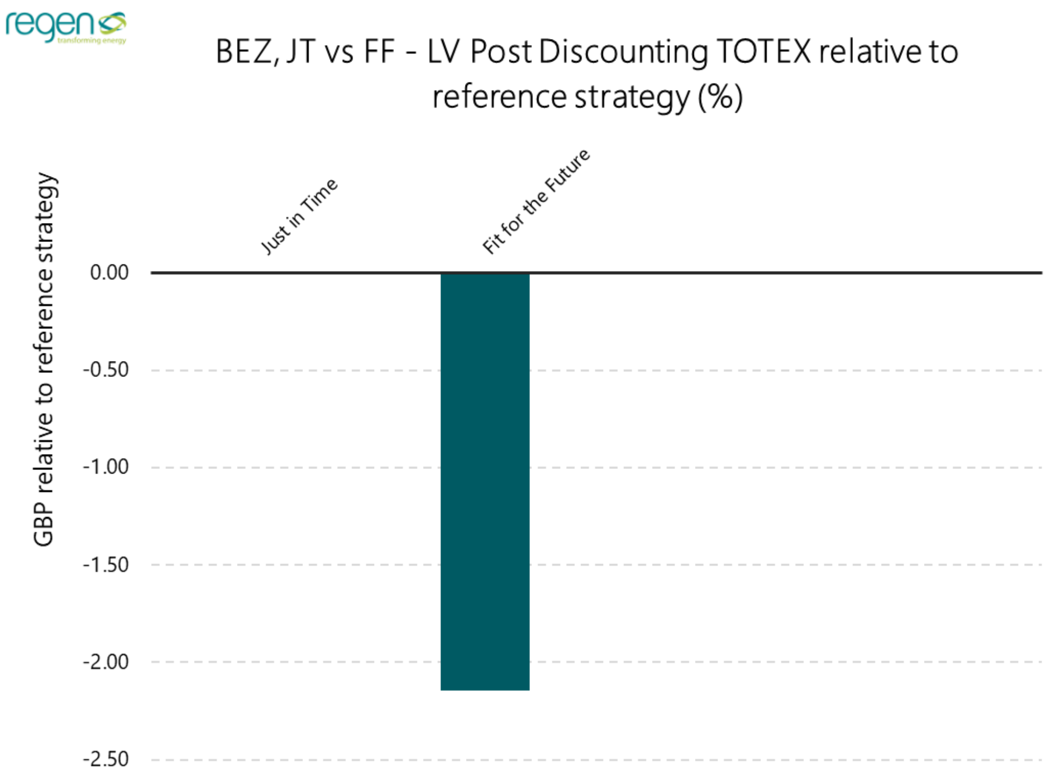

Figure 30: Total post discounting LV TOTEX by 2050 on the Dorchester St primary

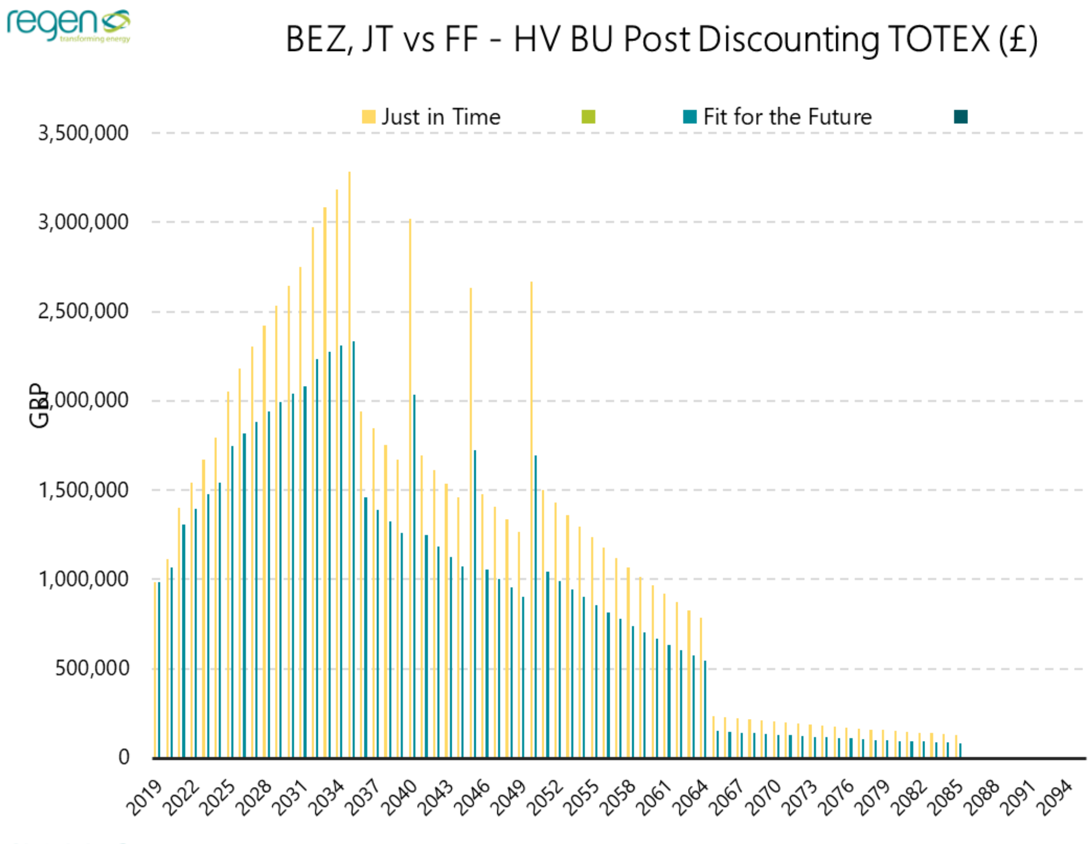

Figure 31: Post Discounting HV TOTEX by year on the Dorchester St primary

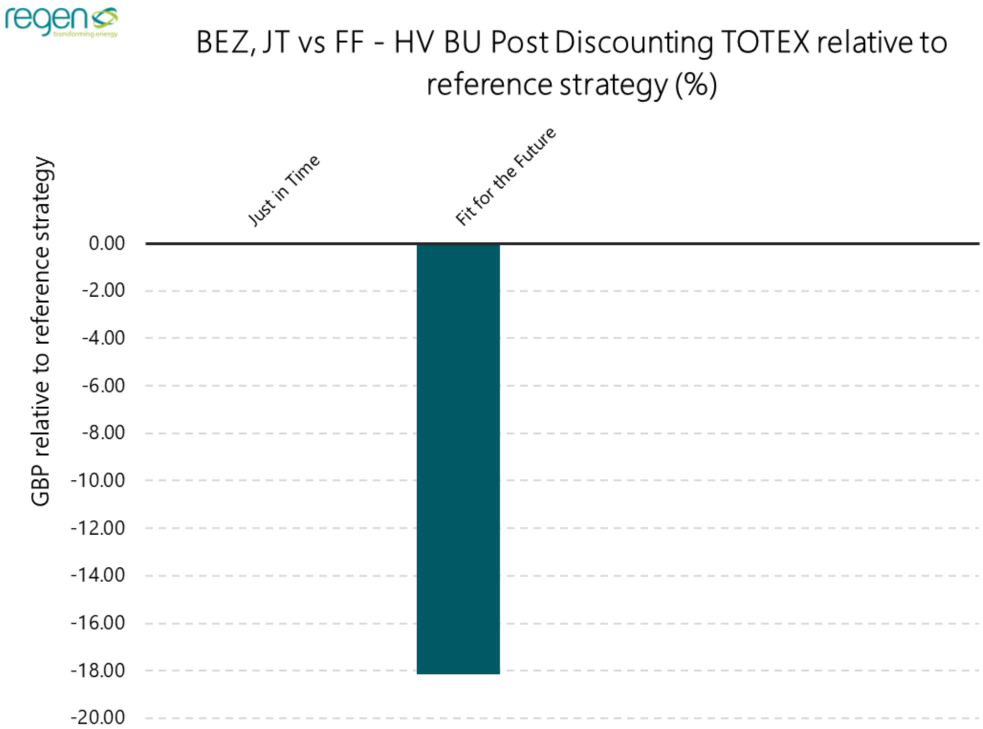

Figure 32: Total Post Discounting HV TOTEX by 2050 on the Dorchester St primary

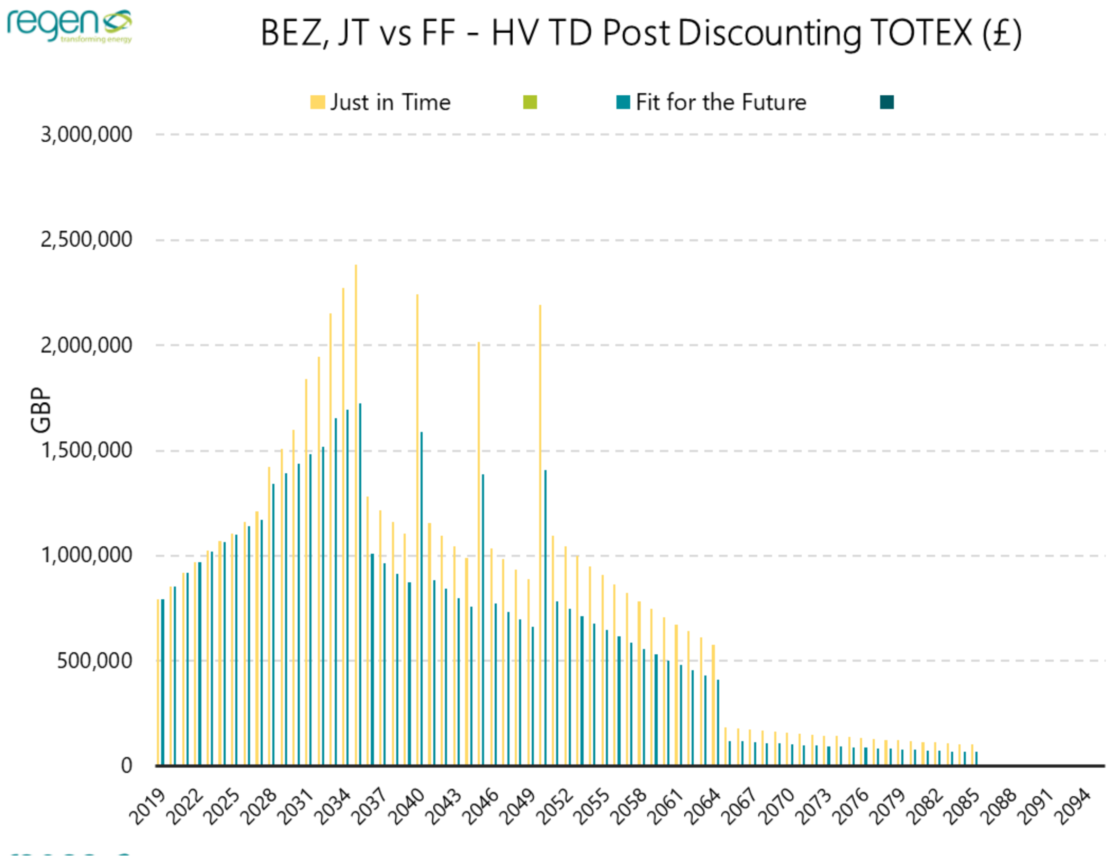

Figure 33: Post Discounting HV TOTEX by year on the Dorchester St primary, from top down analysis

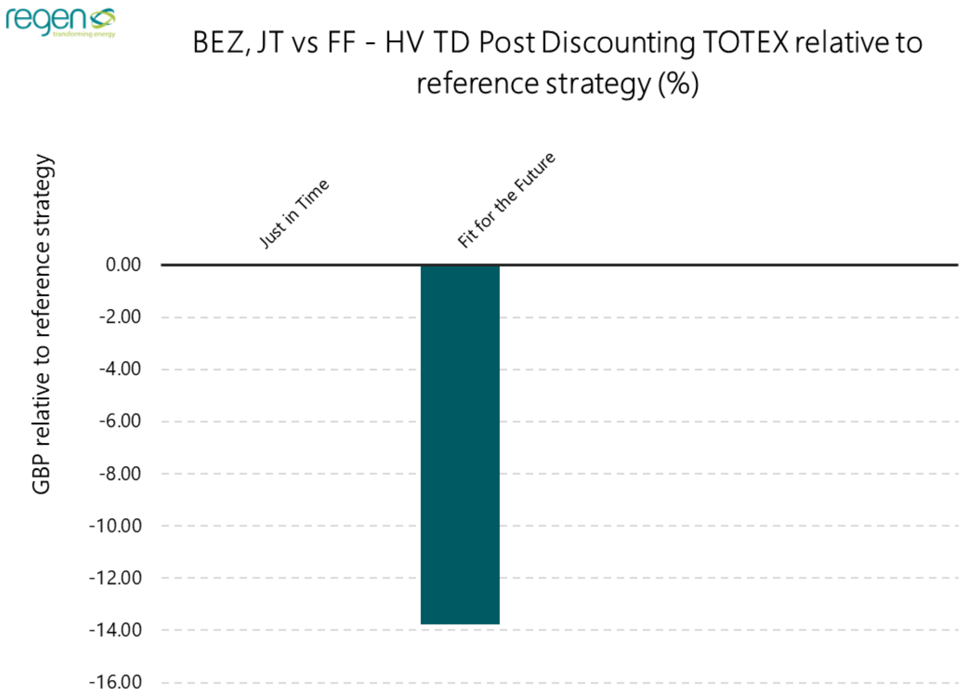

Figure 34: Total Post Discounting HV TOTEX by 2050 on the Dorchester St primary, from top down analysis

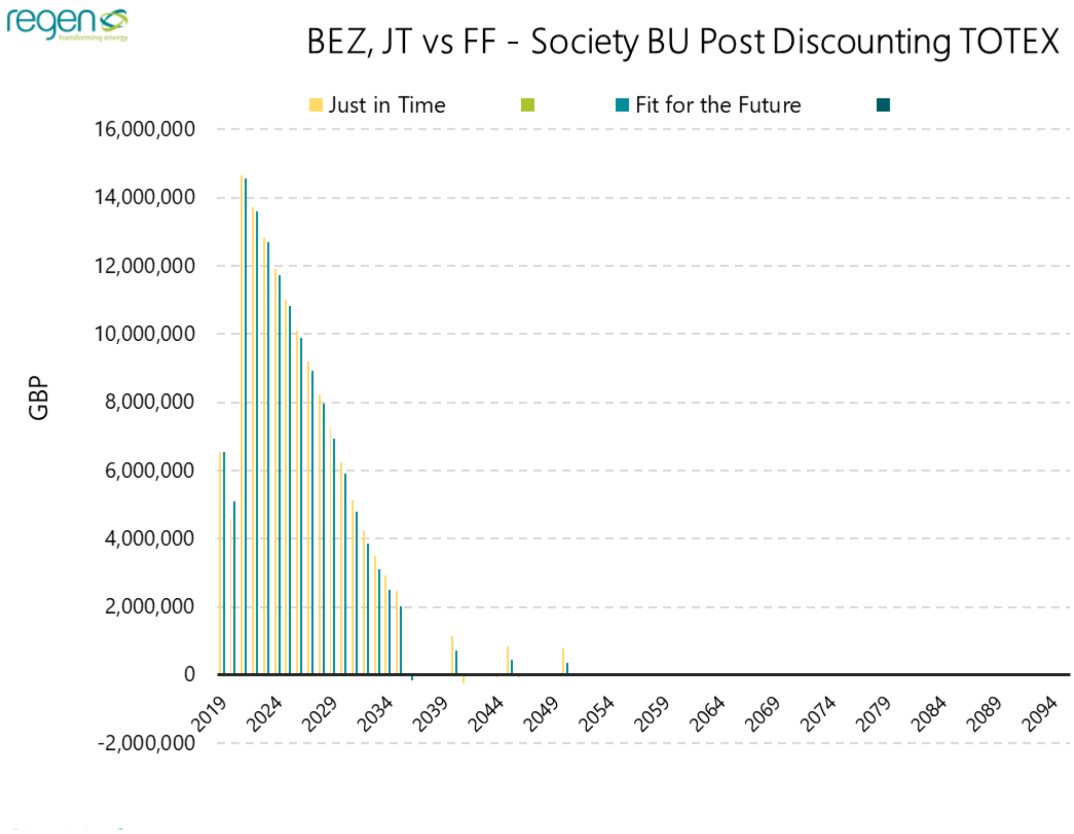

Figure 35: Societal Post Discounting TOTEX by year on the Dorchester St primary

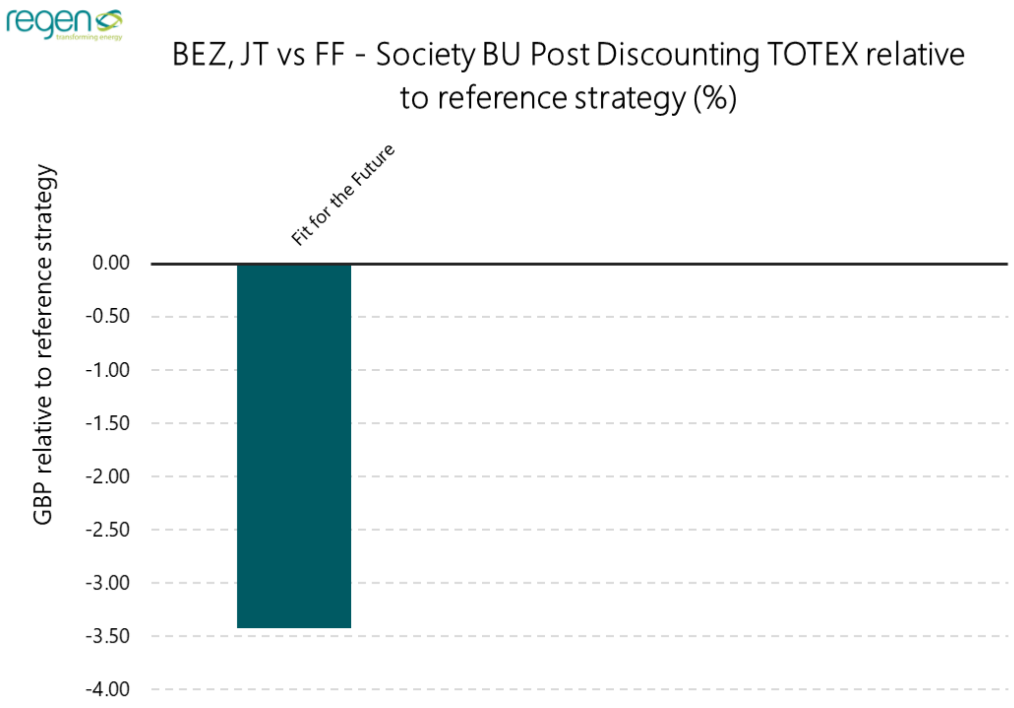

Figure 36: Total Societal Post Discounting TOTEX by 2050 on the Dorchester St primary

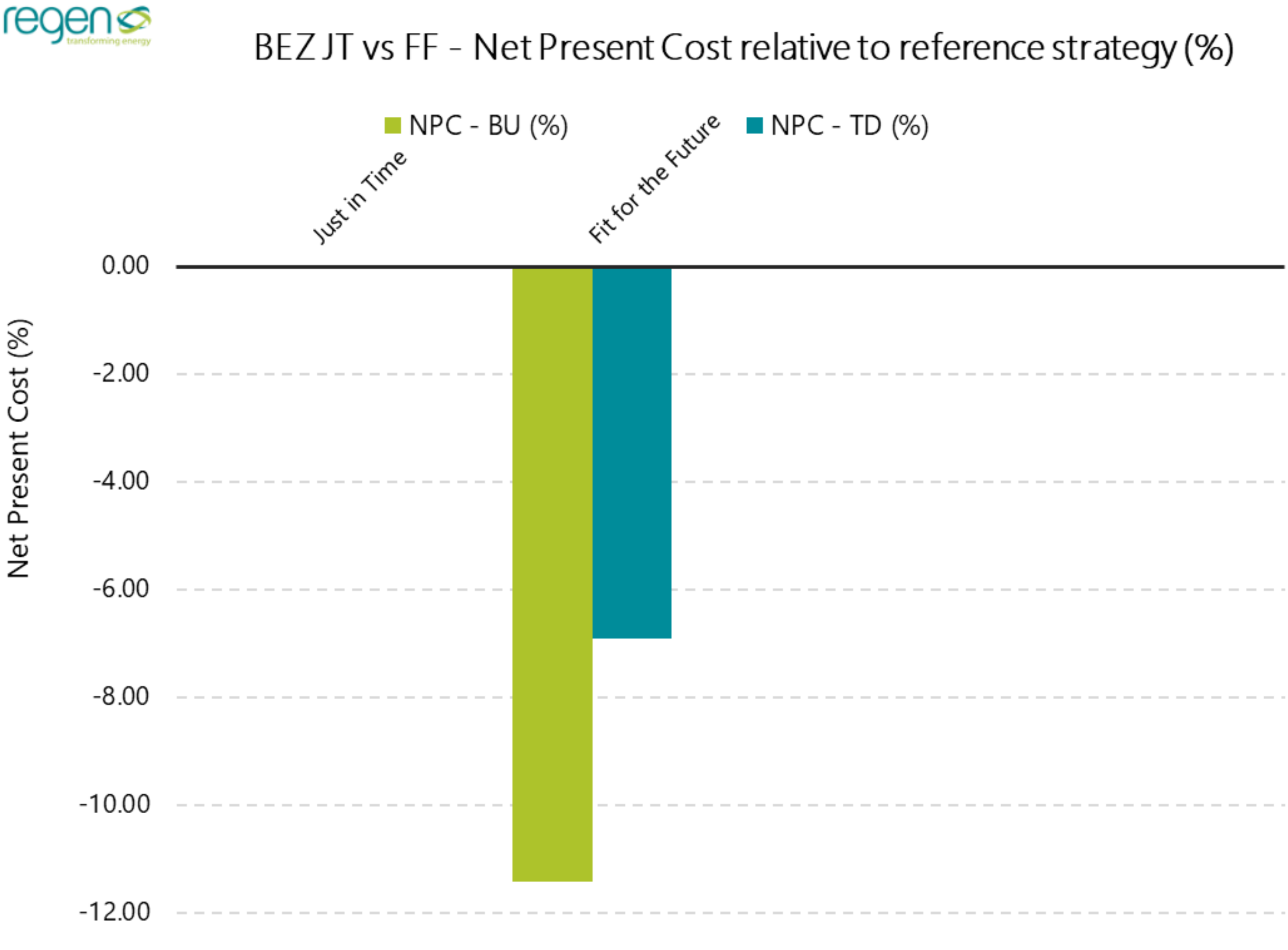

Figure 37: Total Whole Systems Net Present Cost by 2050 on the Dorchester St primary

7. APPENDIX 2: Cribbs Causeway significant results

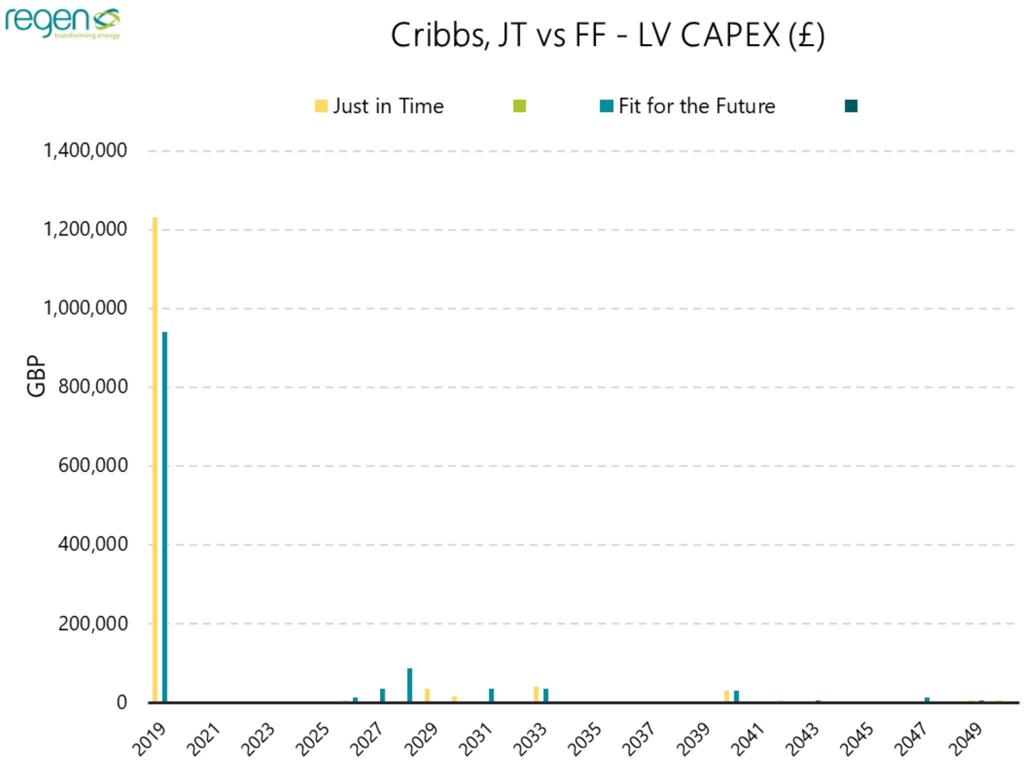

Figure 38: LV CAPEX by year on the Cribbs Causeway primary

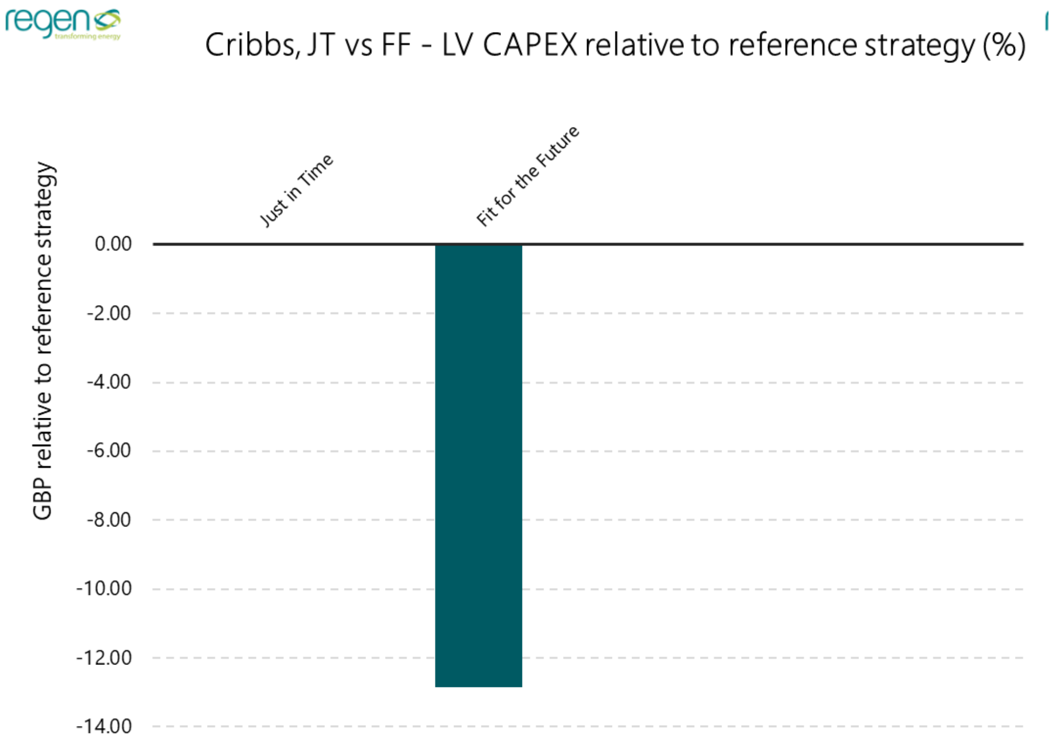

Figure 39: Total LV CAPEX by 2050 on the Cribbs Causeway primary

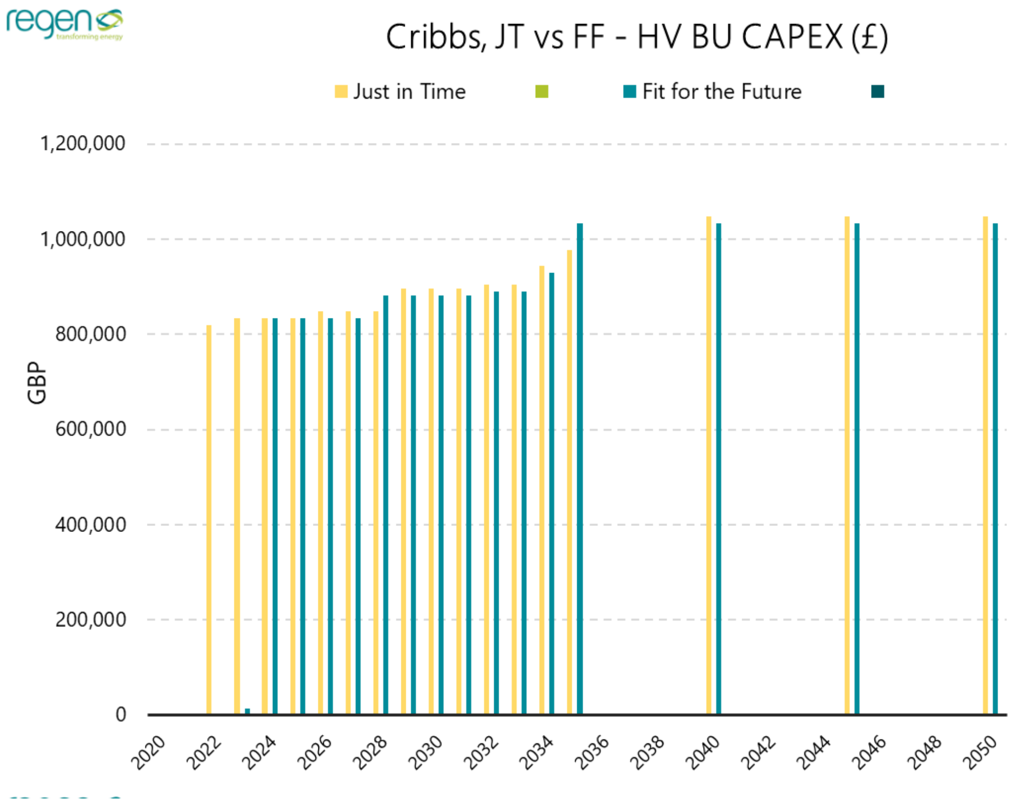

Figure 40: HV CAPEX by year on the Cribbs Causeway primary, from bottom up analysis

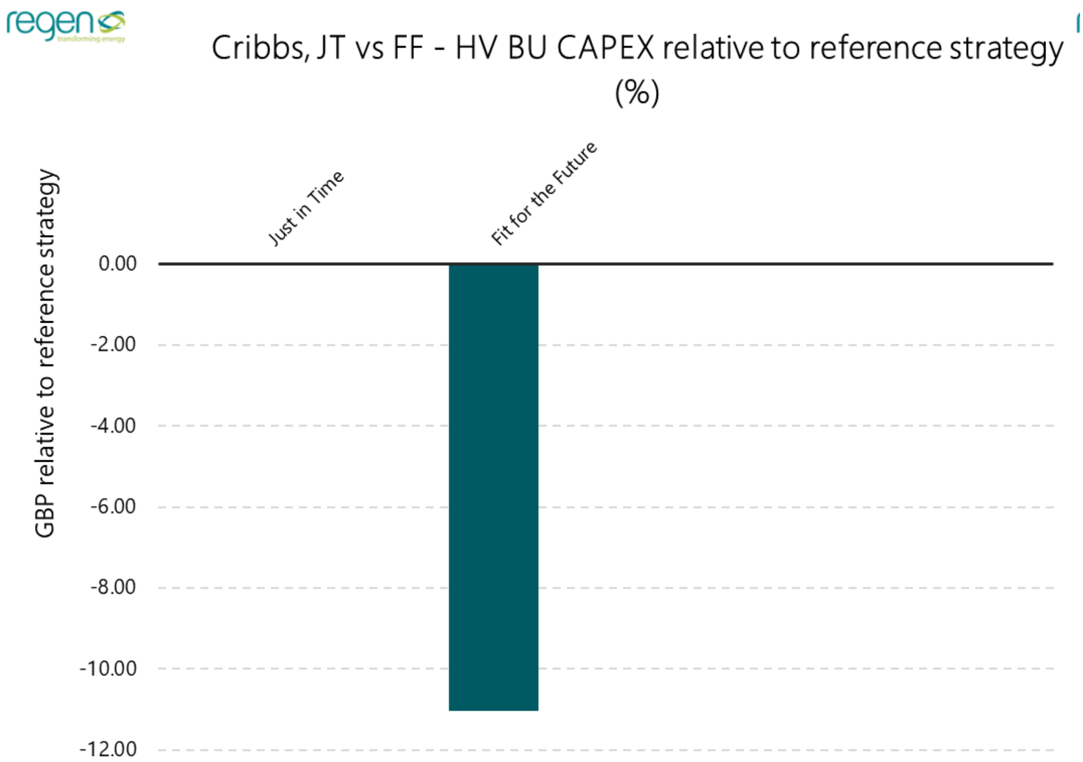

Figure 41: Total HV CAPEX by 2050 on the Cribbs Causeway primary, from bottom up analysis

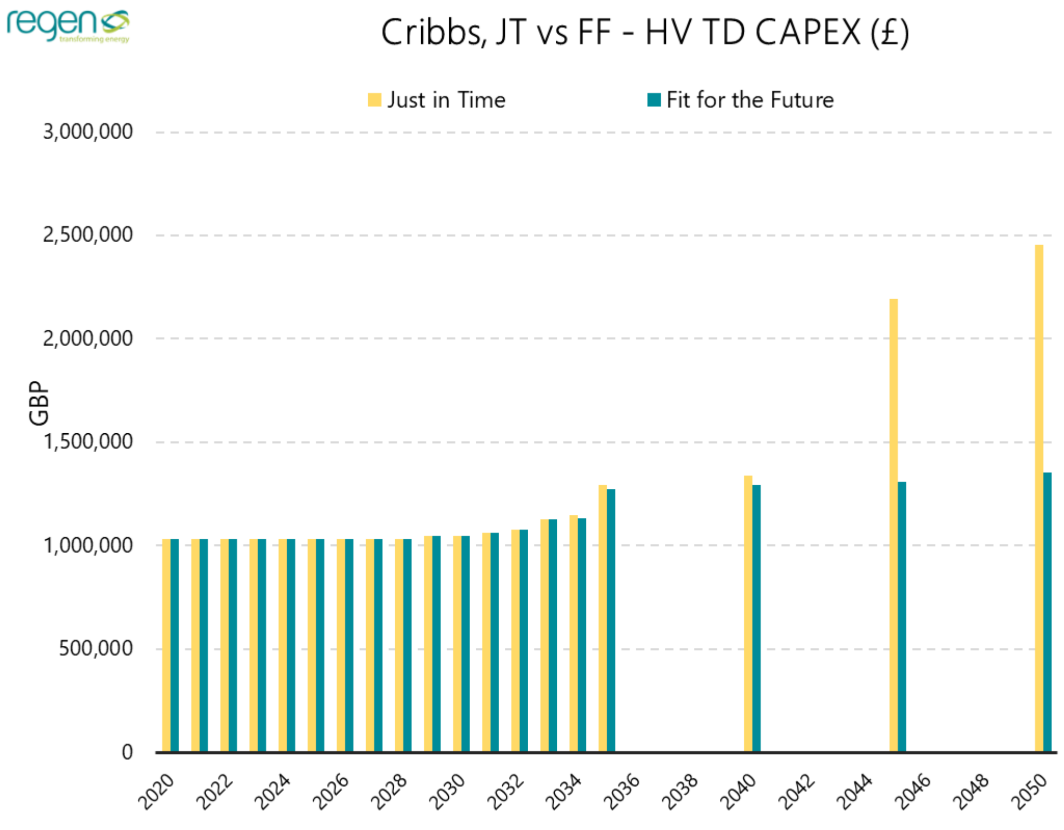

Figure 42: HV CAPEX by year on the Cribbs Causeway primary, from top down analysis

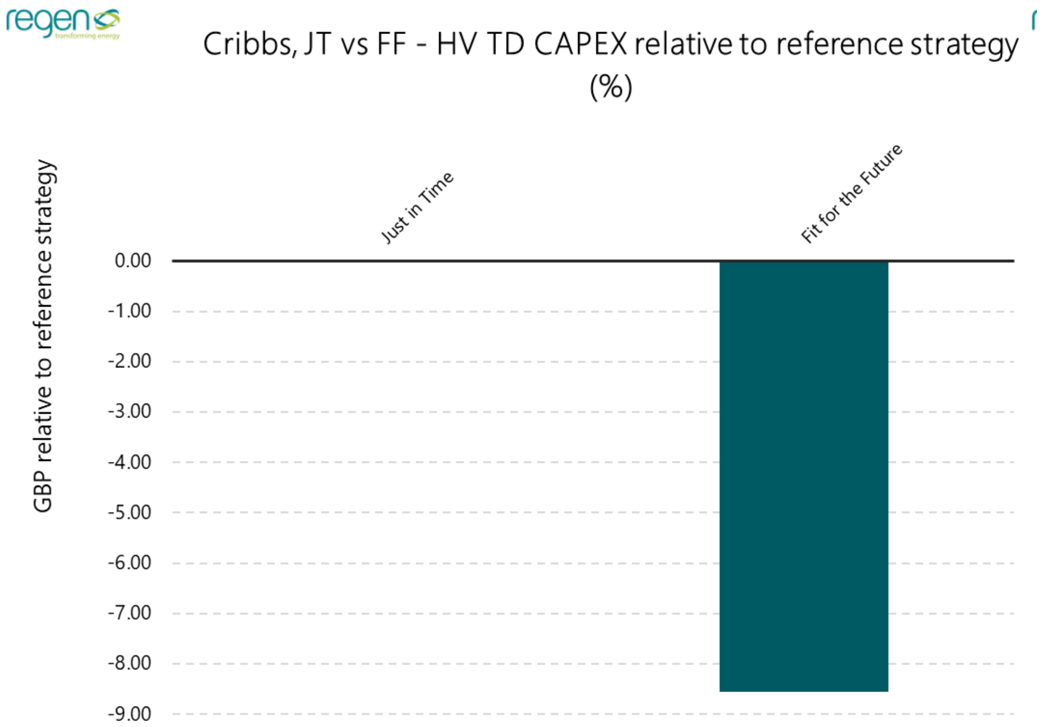

Figure 43: Total HV CAPEX by 2050 on the Cribbs Causeway primary, from top down analysis

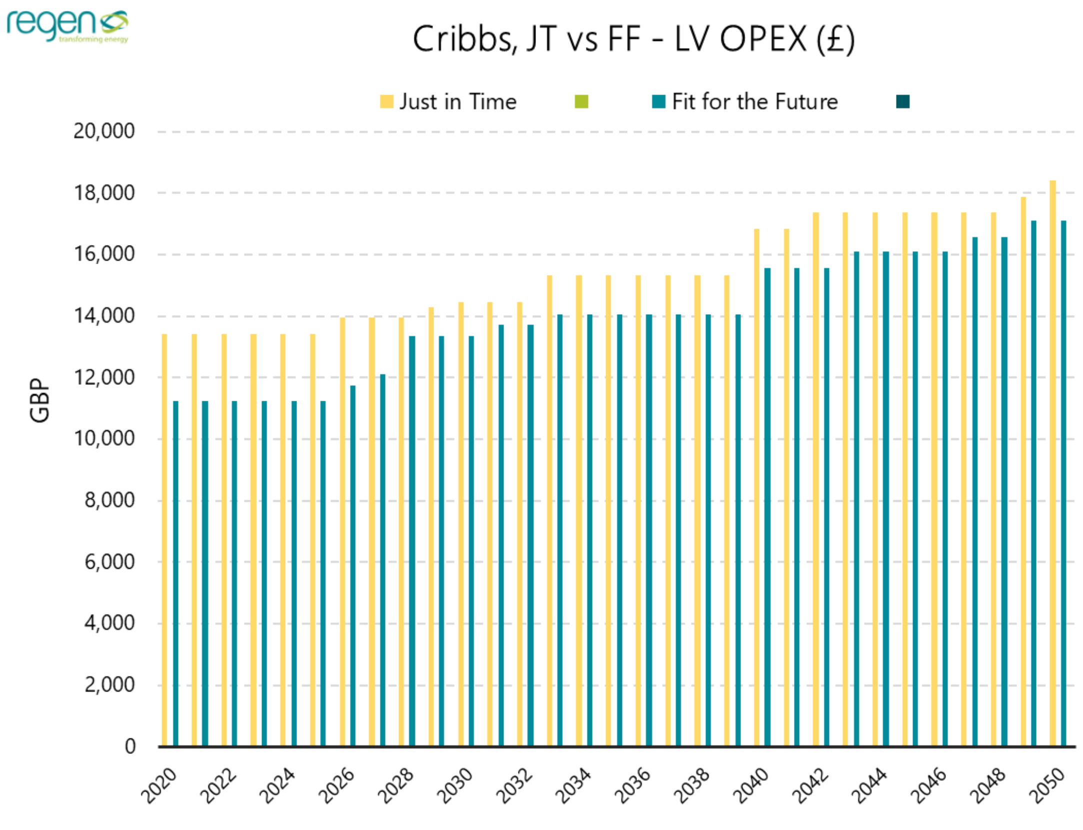

Figure 44: LV OPEX by year on the Cribbs Causeway primary

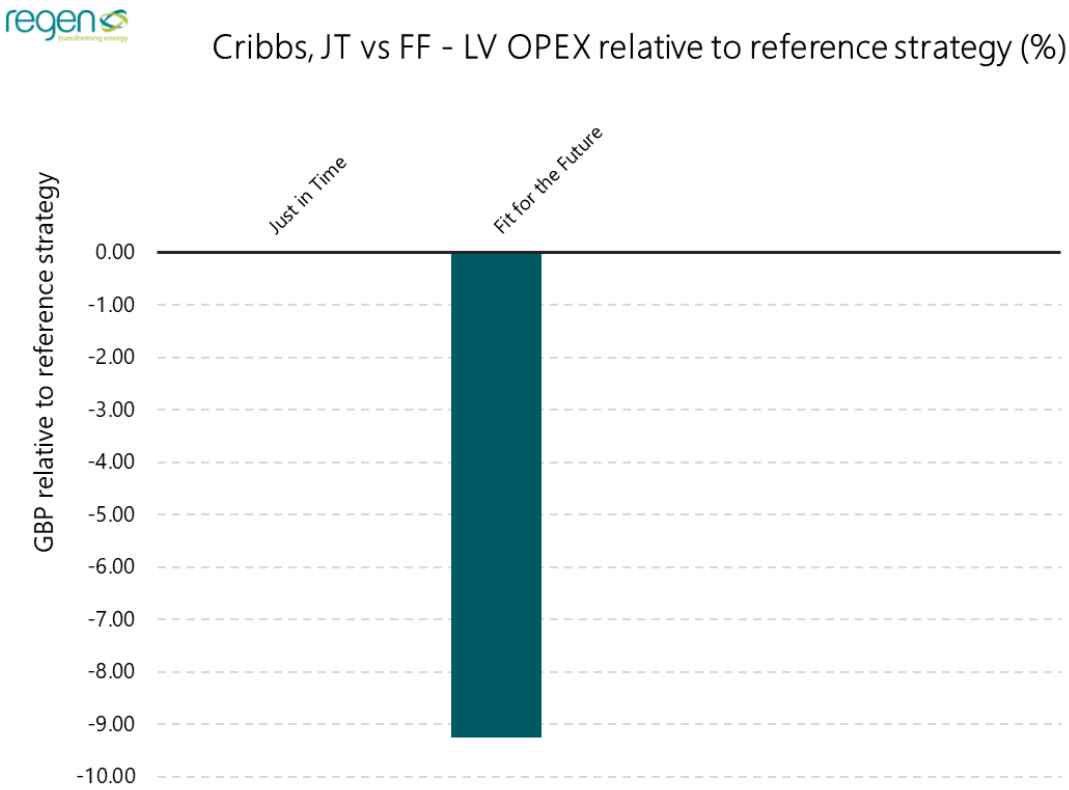

Figure 45: Total LV OPEX by 2050 on the Cribbs Causeway primary

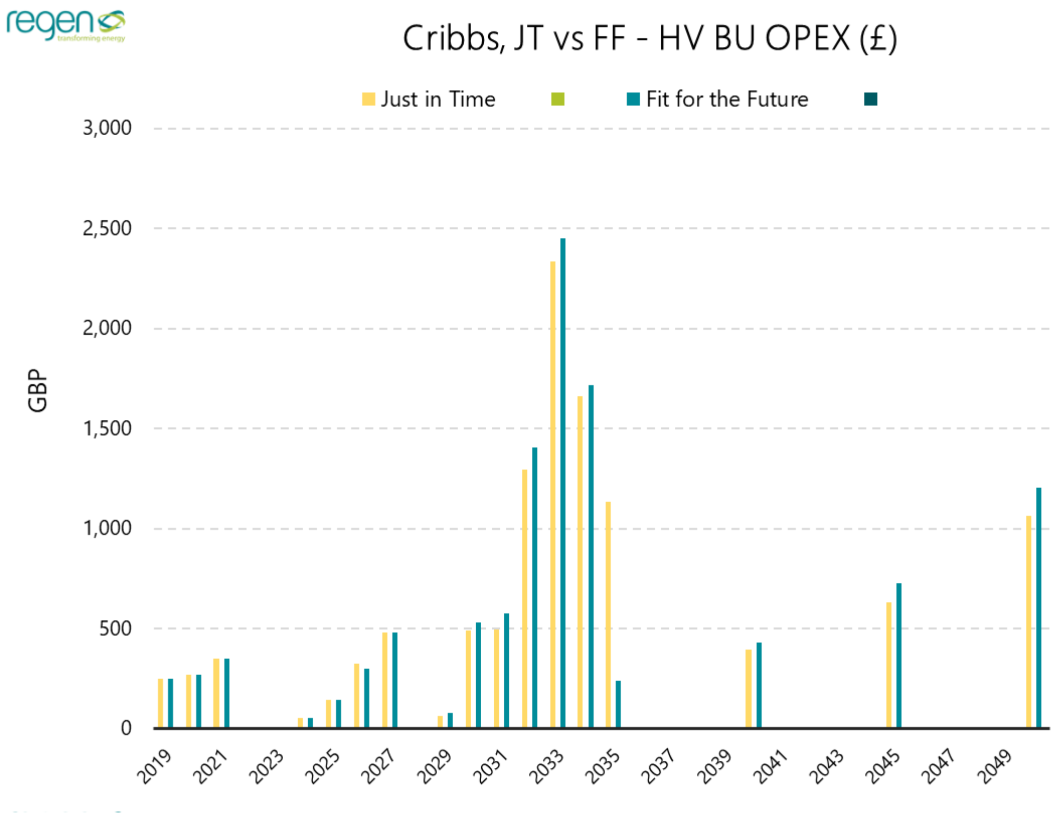

Figure 46: HV OPEX by year on the Cribbs Causeway primary, from bottom up analysis

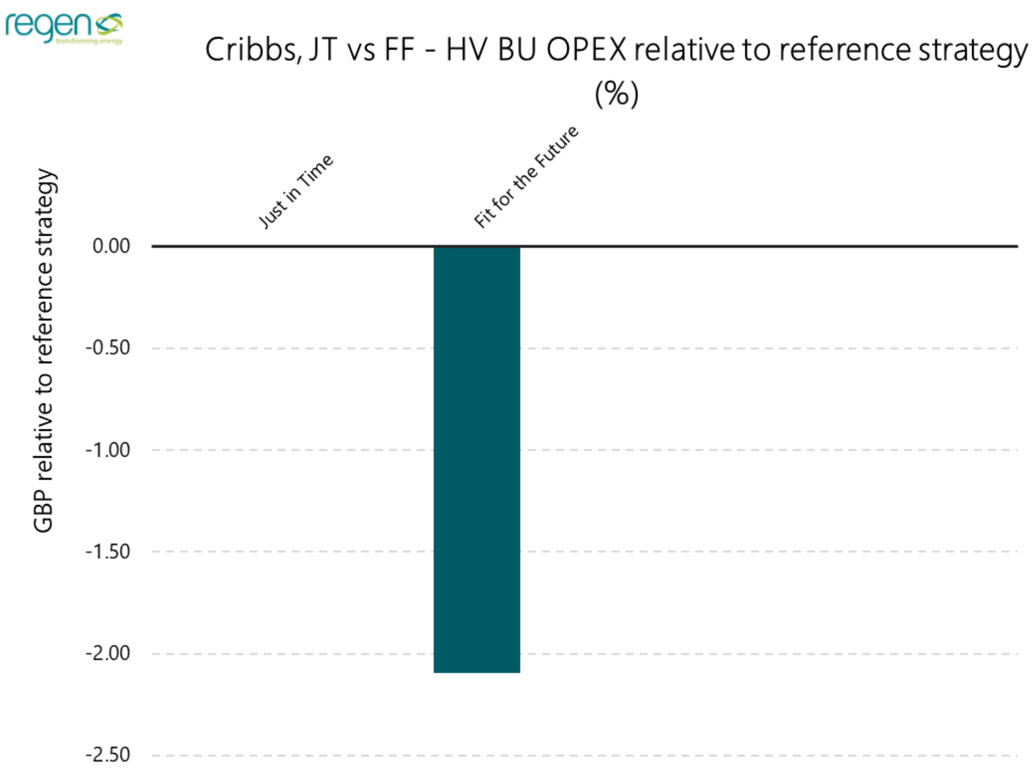

Figure 47: Total HV OPEX by 2050 on the Cribbs Causeway primary, from bottom up analysis

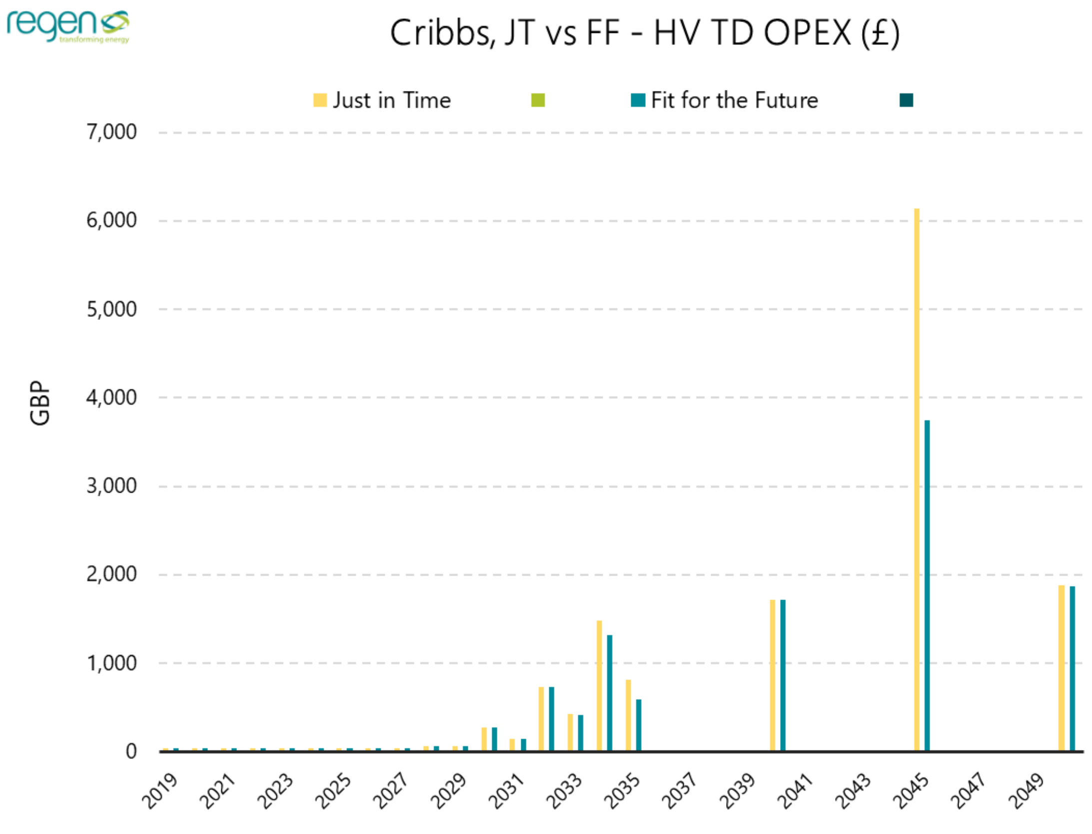

Figure 48: HV OPEX by year on the Cribbs Causeway primary, from top down analysis

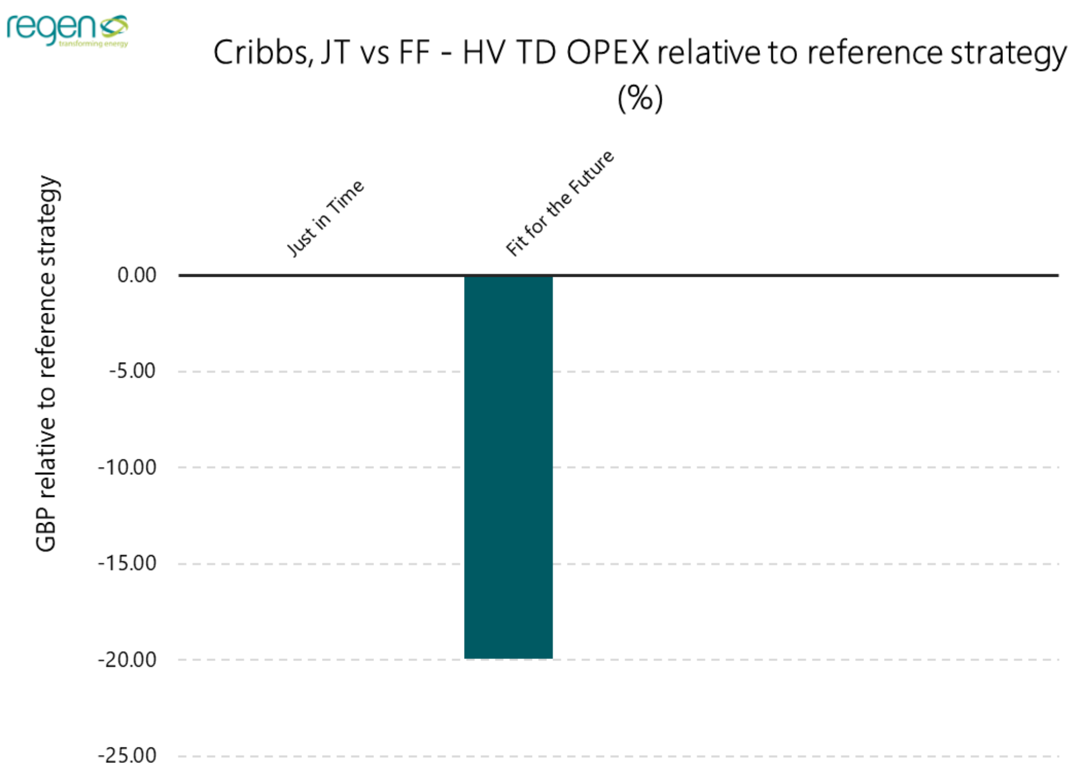

Figure 49: Total HV OPEX by 2050 on the Cribbs Causeway primary, from top down analysis

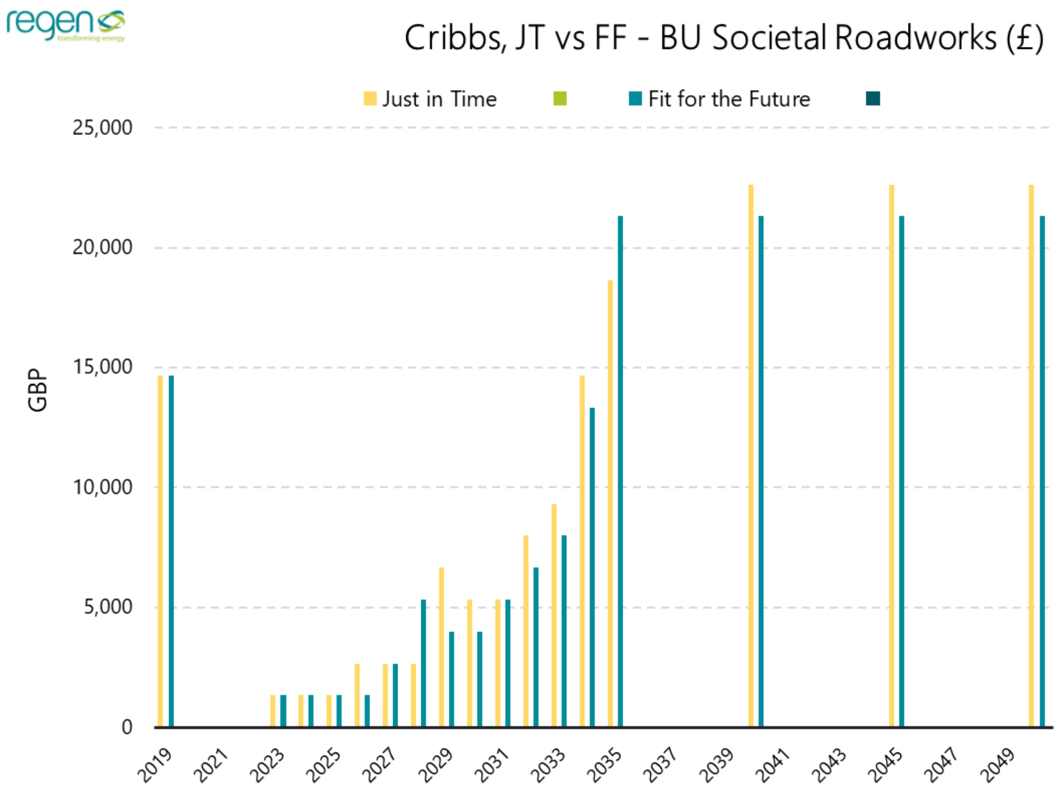

Figure 50 Societal cost of roadworks by year on the Cribbs Causeway primary, from bottom up analysis

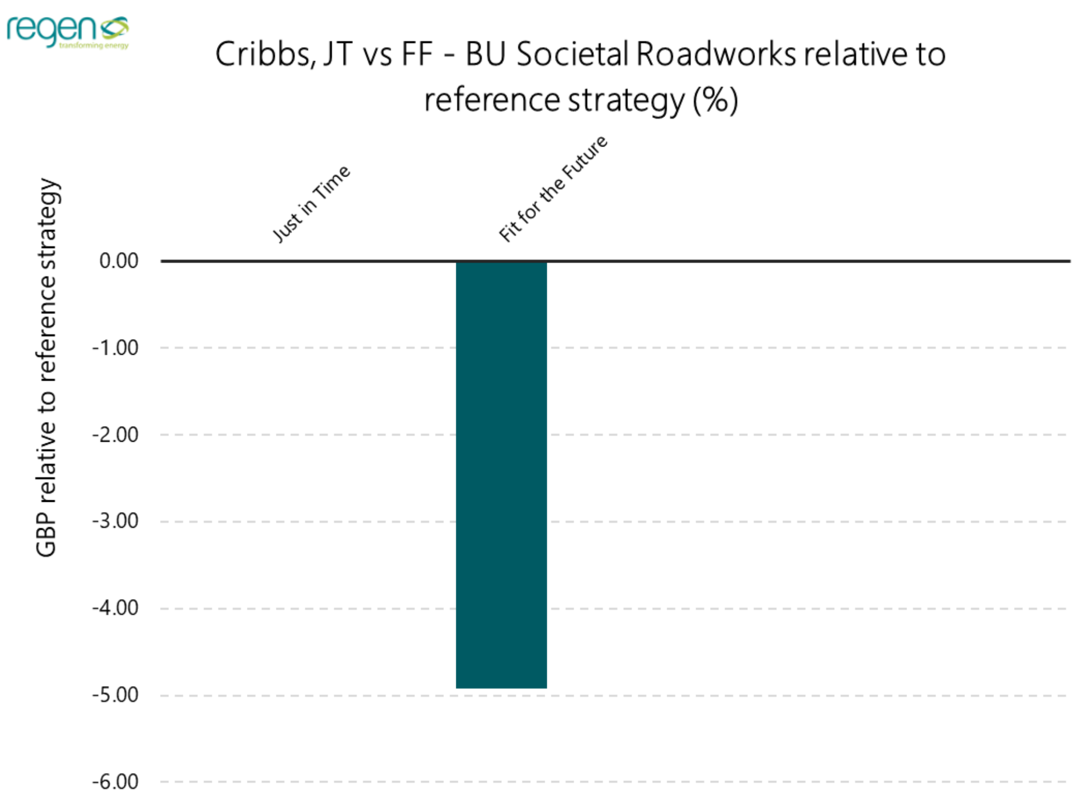

Figure 51: Total roadworks cost by 2050 on the Cribbs Causeway primary, from bottom up analysis

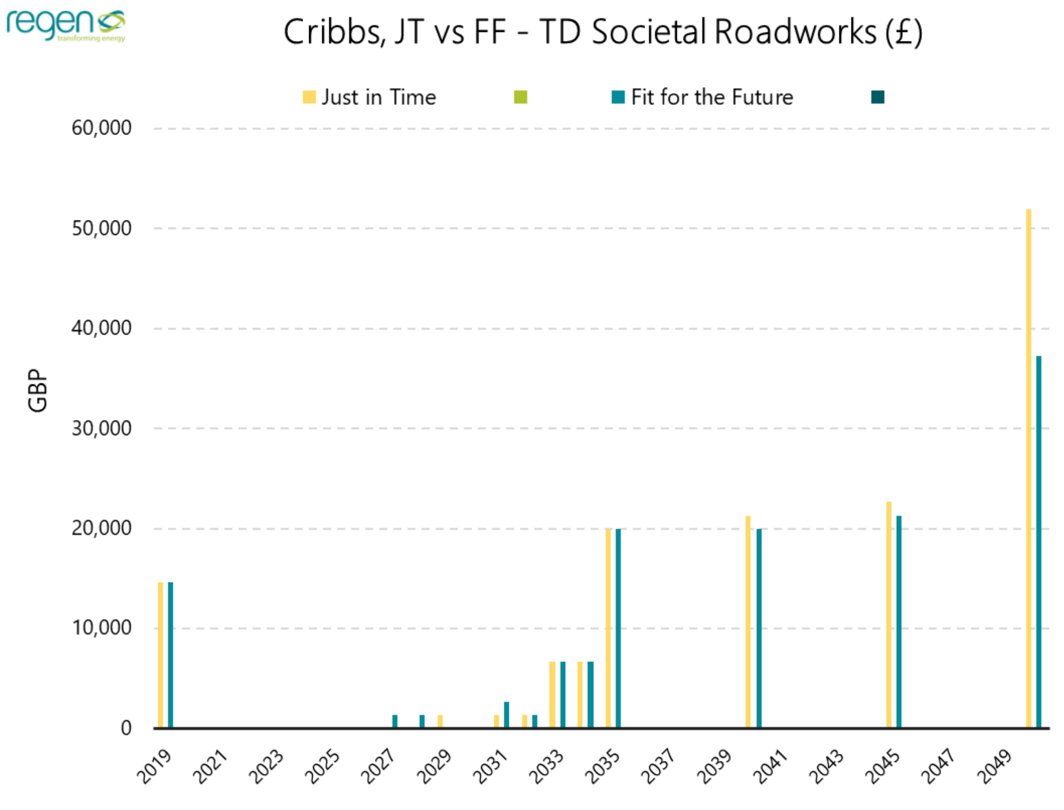

Figure 52 Societal cost of roadworks by year on the Cribbs Causeway primary, from top down analysis

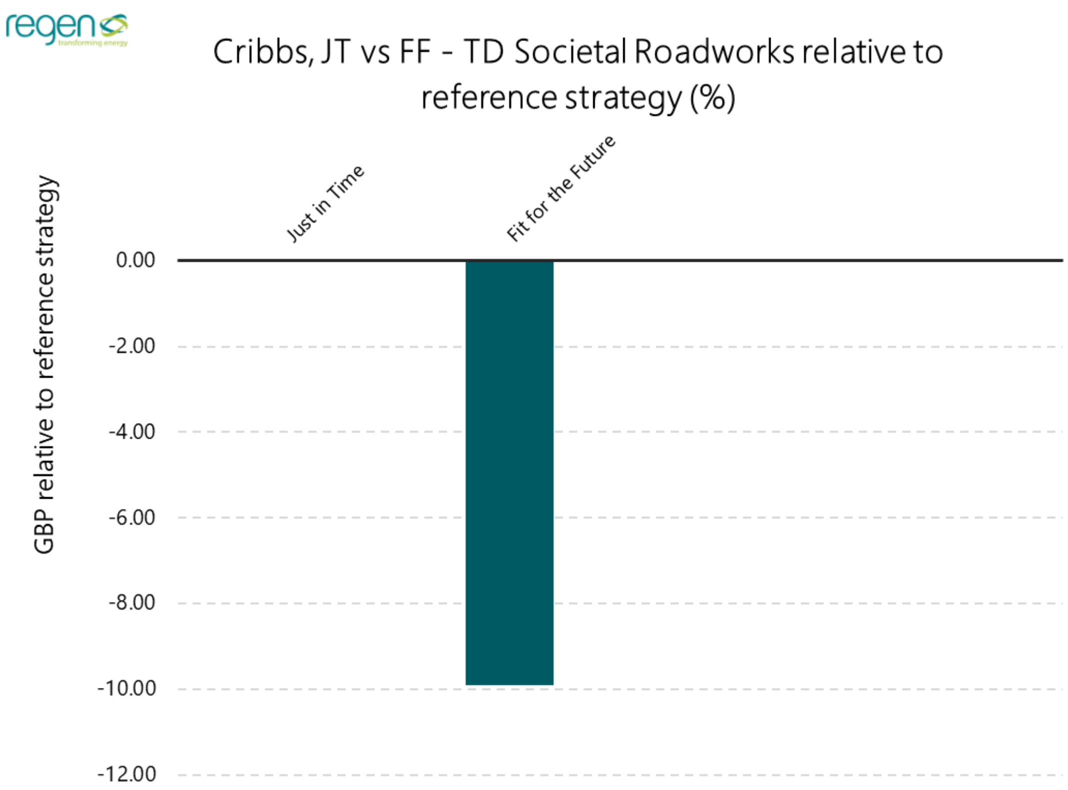

Figure 53: Total roadworks cost by 2050 on the Cribbs Causeway primary, from top down analysis

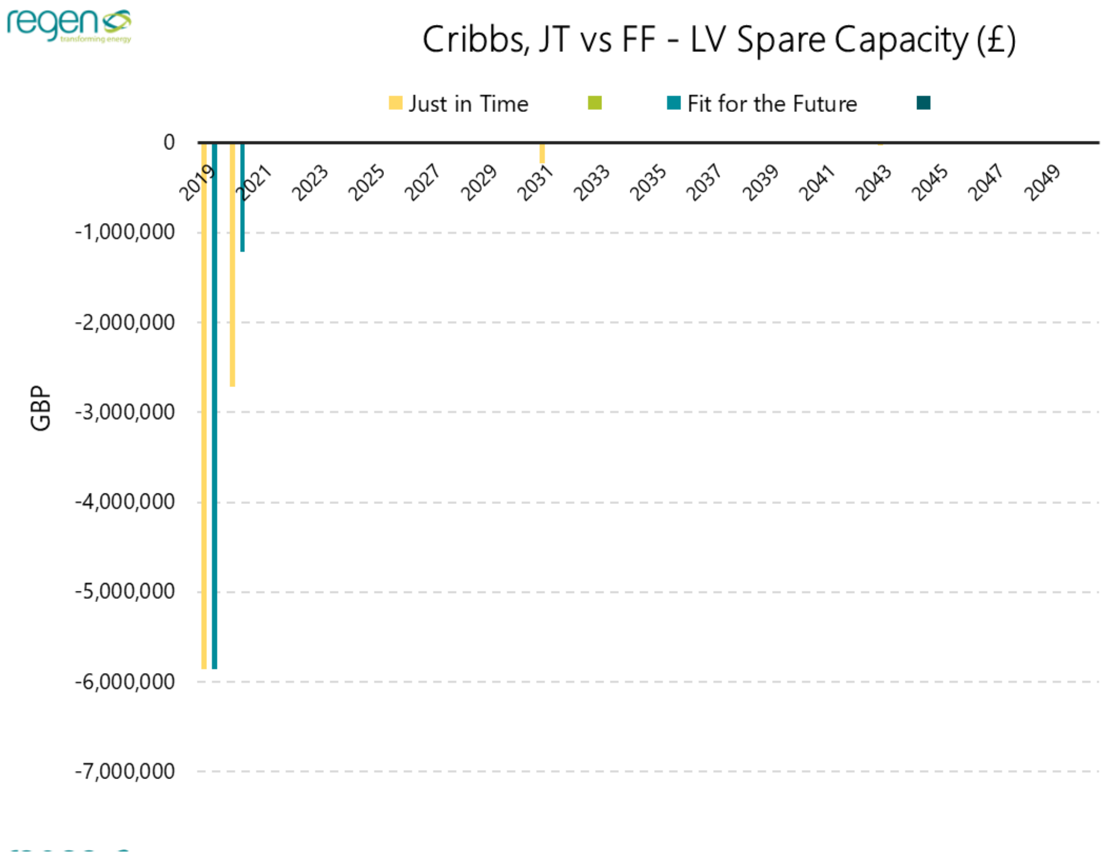

Figure 54: Monetised LV Spare Capacity by year on the Cribbs Causeway primary

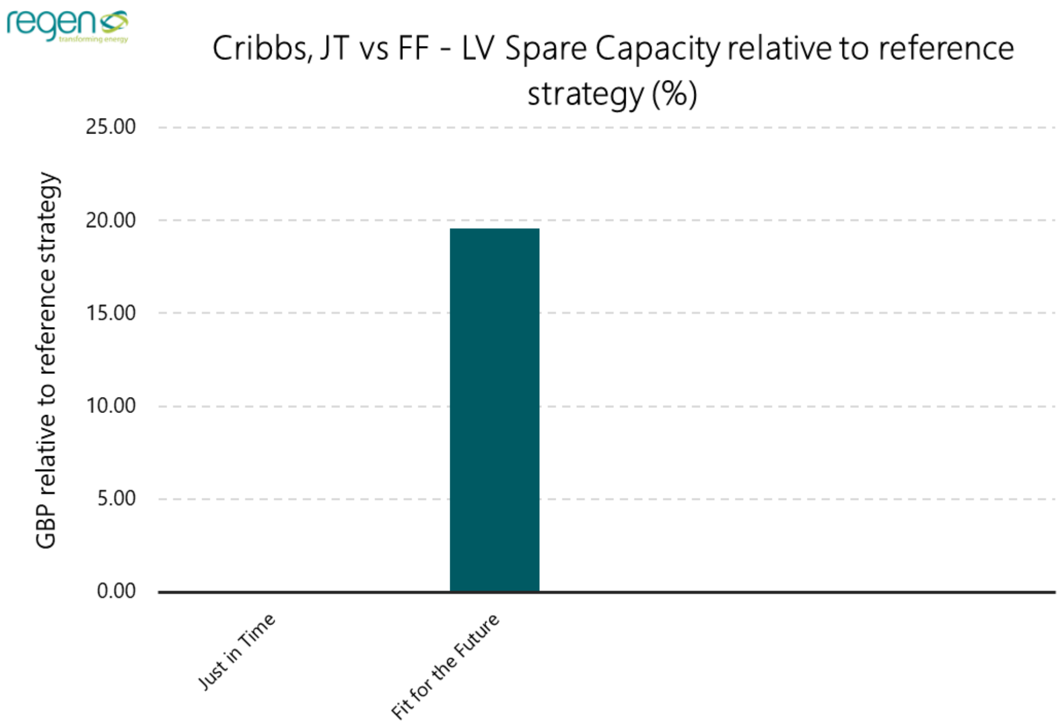

Figure 55: Total monetised LV spare capacity by 2050 on the Cribbs Causeway primary

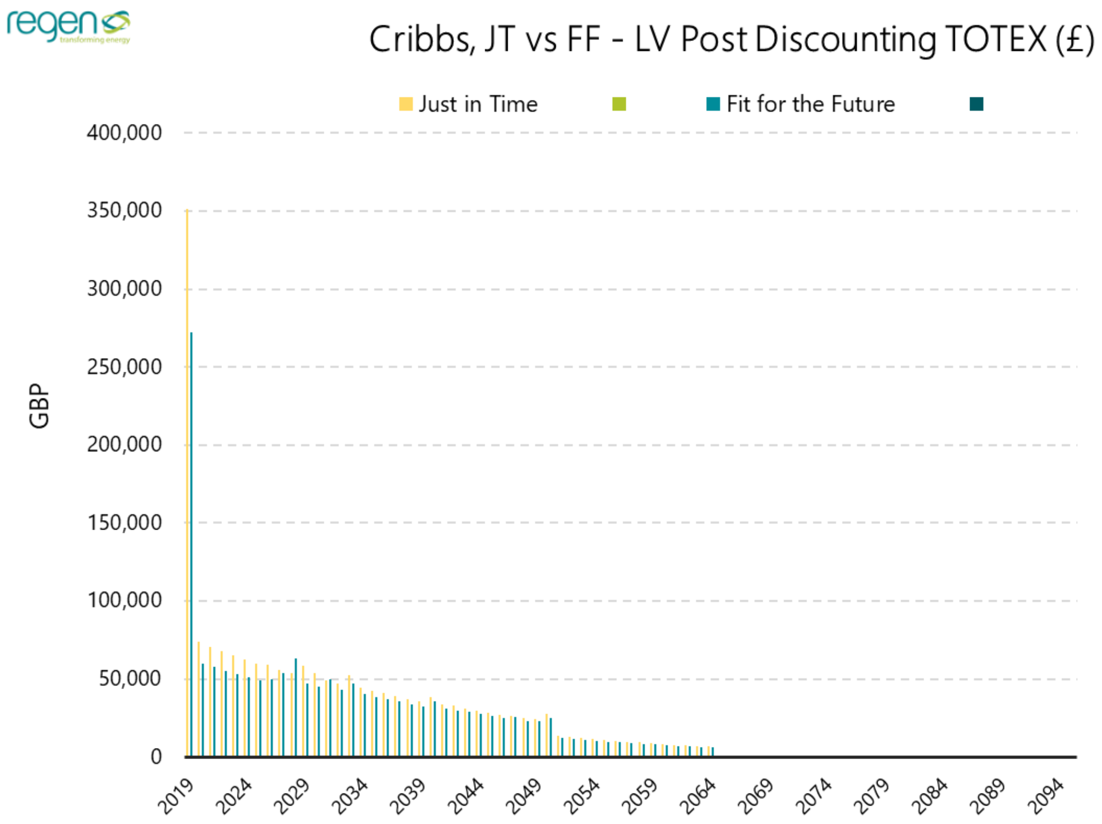

Figure 56: Post Discounting LV TOTEX by year on the Cribbs Causeway primary

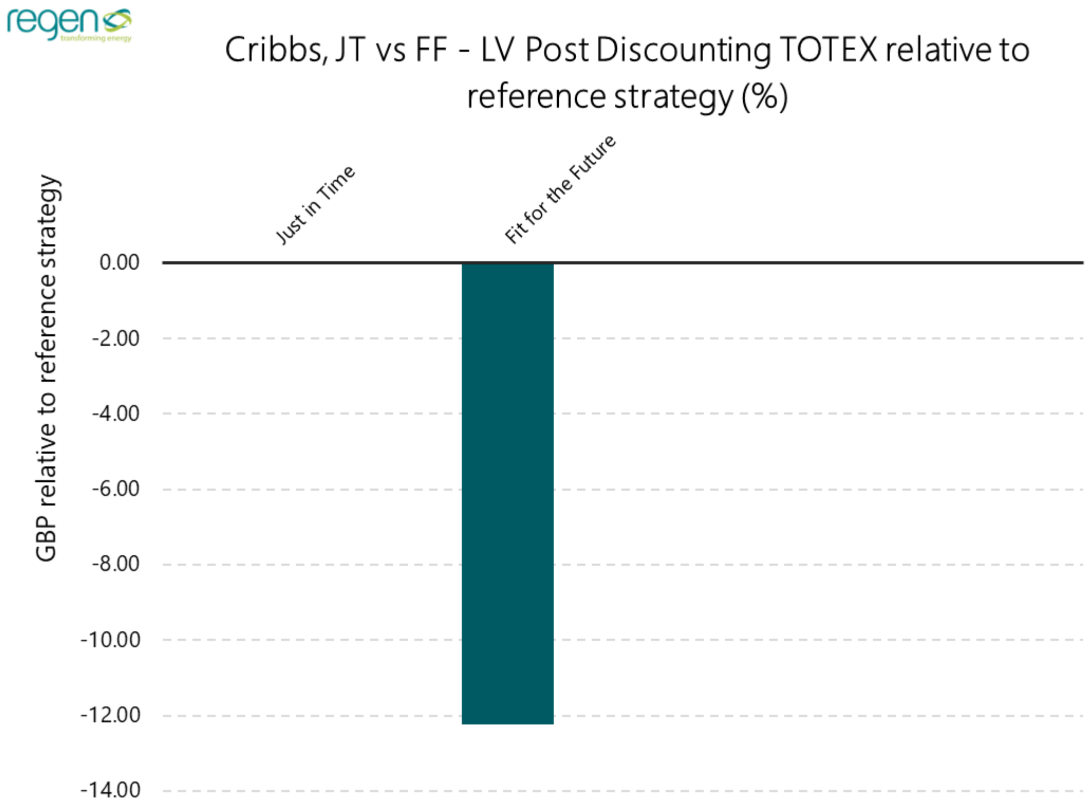

Figure 57: Total post discounting LV TOTEX by 2050 on the Cribbs Causeway primary

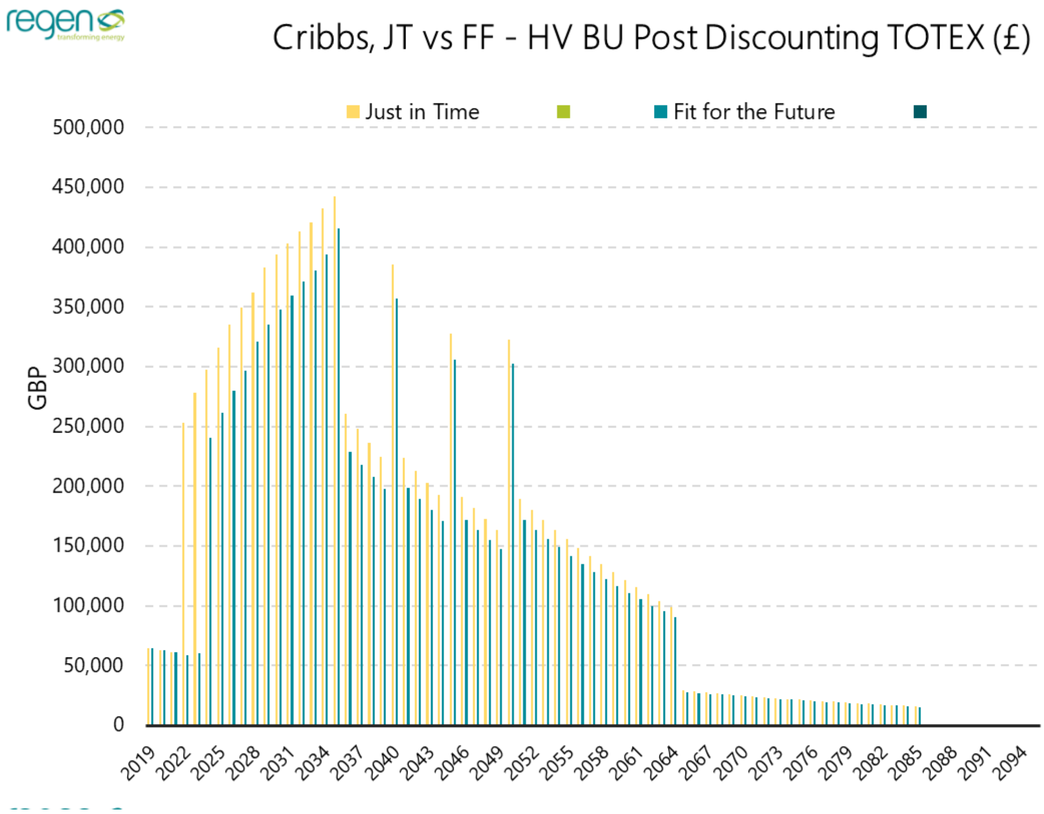

Figure 58: Post Discounting HV TOTEX by year on the Cribbs Causeway primary, from bottom up analysis

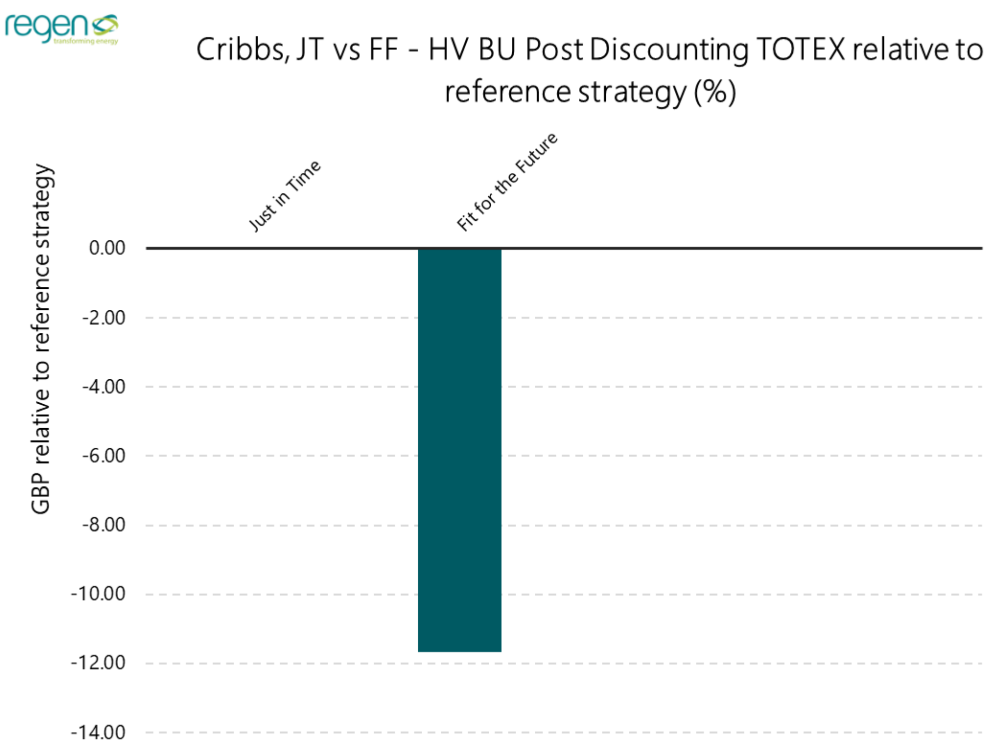

Figure 59: Total Post Discounting HV TOTEX by 2050 on the Cribbs Causeway primary, from bottom up analysis

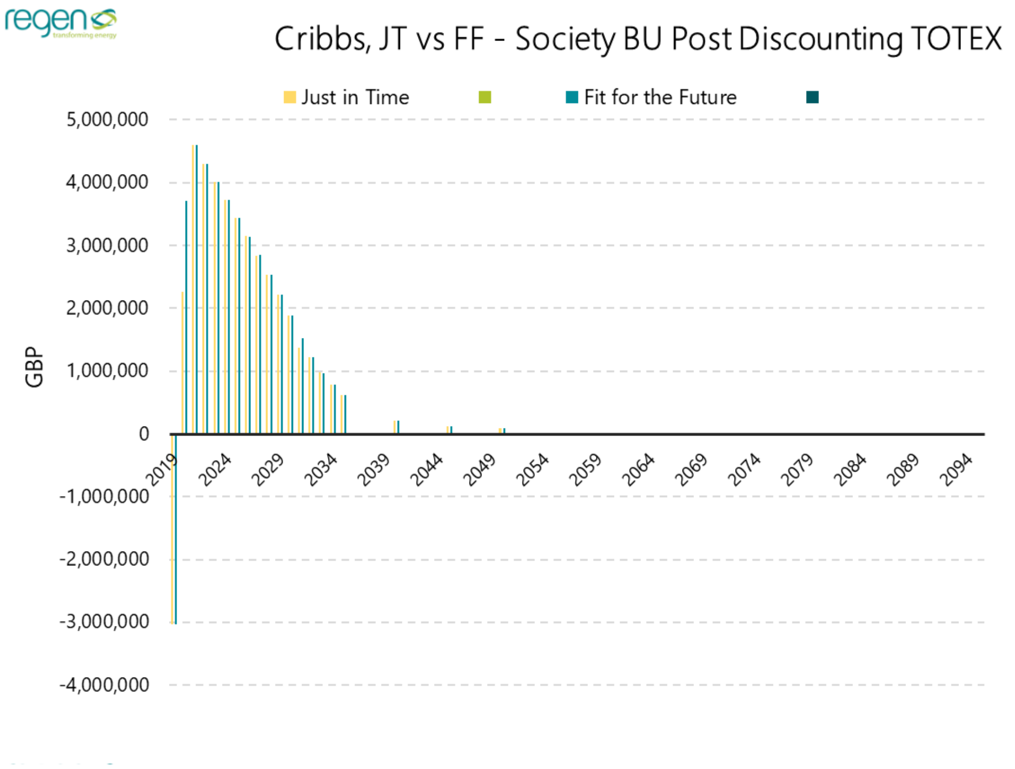

Figure 60: Societal Post Discounting TOTEX by year on the Cribbs Causeway primary, from bottom up analysis

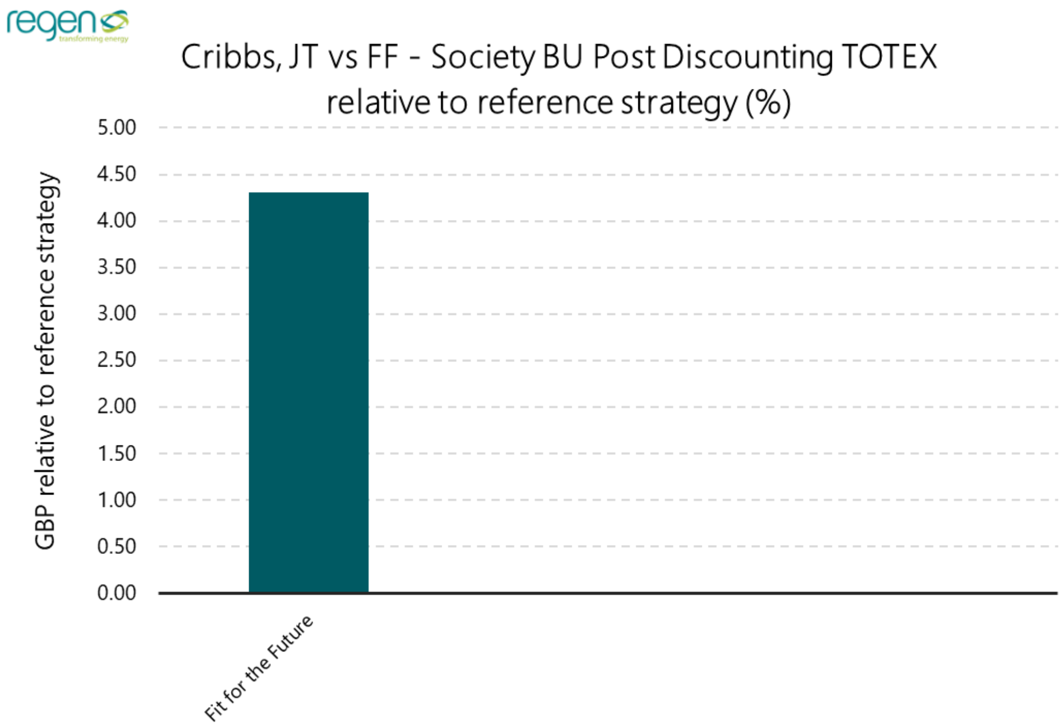

Figure 61: Total Societal Post Discounting TOTEX by 2050 on the Cribbs Causeway primary, from bottom up analysis

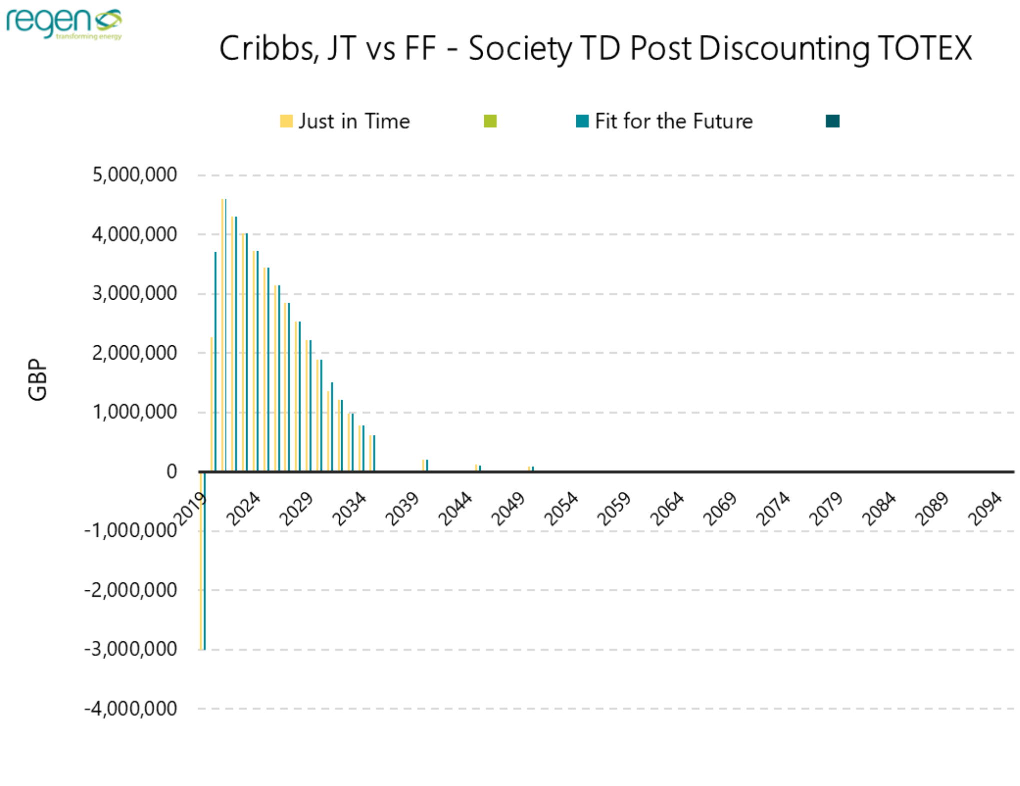

Figure 62: Societal Post Discounting TOTEX by year on the Cribbs Causeway primary, from top down analysis

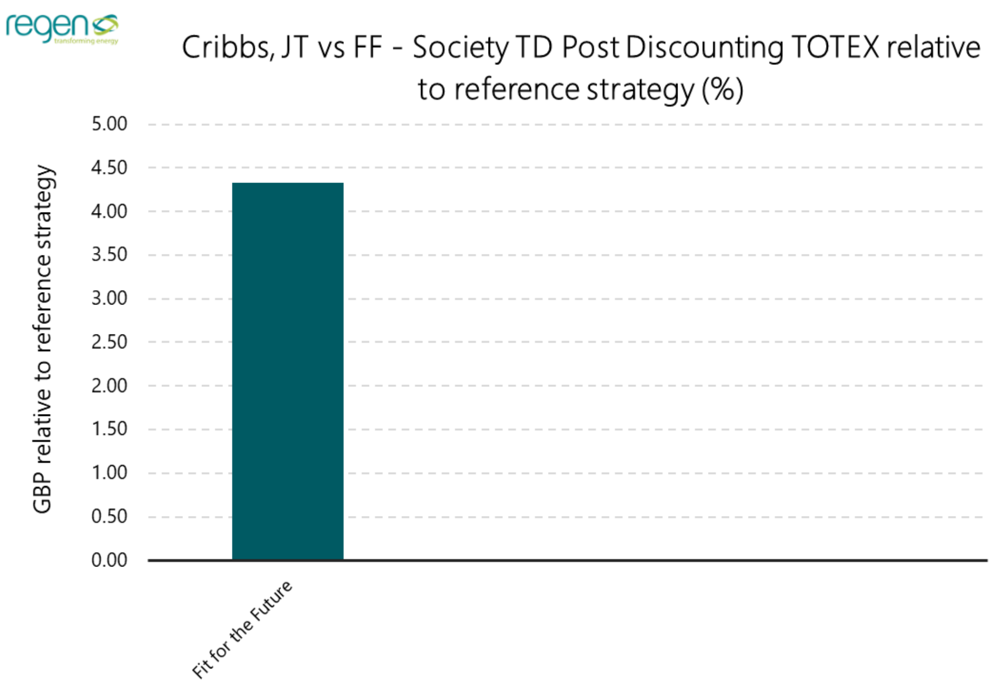

Figure 63: Total Societal Post Discounting TOTEX by 2050 on the Cribbs Causeway primary, from top down analysis

8. APPENDIX 3: Nailsea significant results

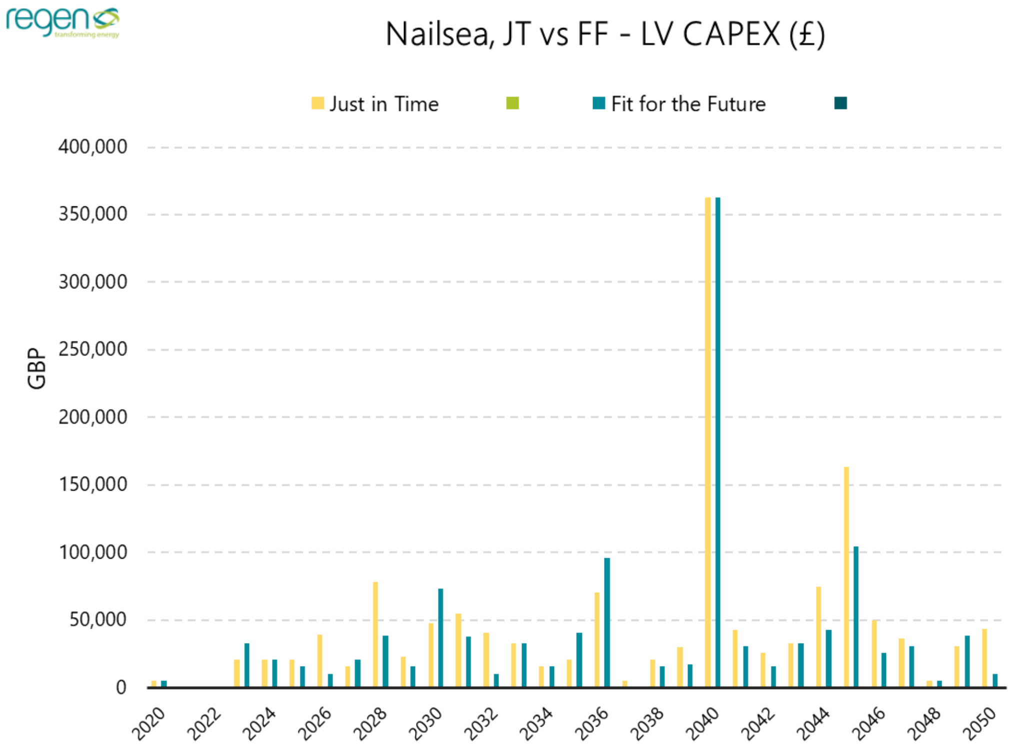

Figure 64: LV CAPEX by year on the Nailsea primary

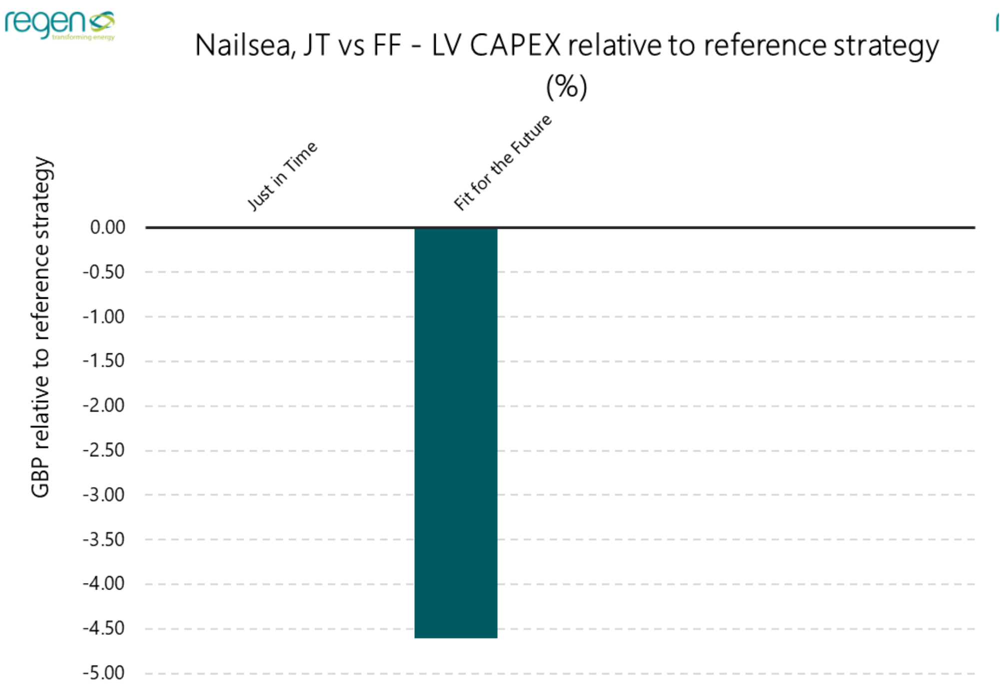

Figure 65: Total LV CAPEX by 2050 on the Nailsea primary

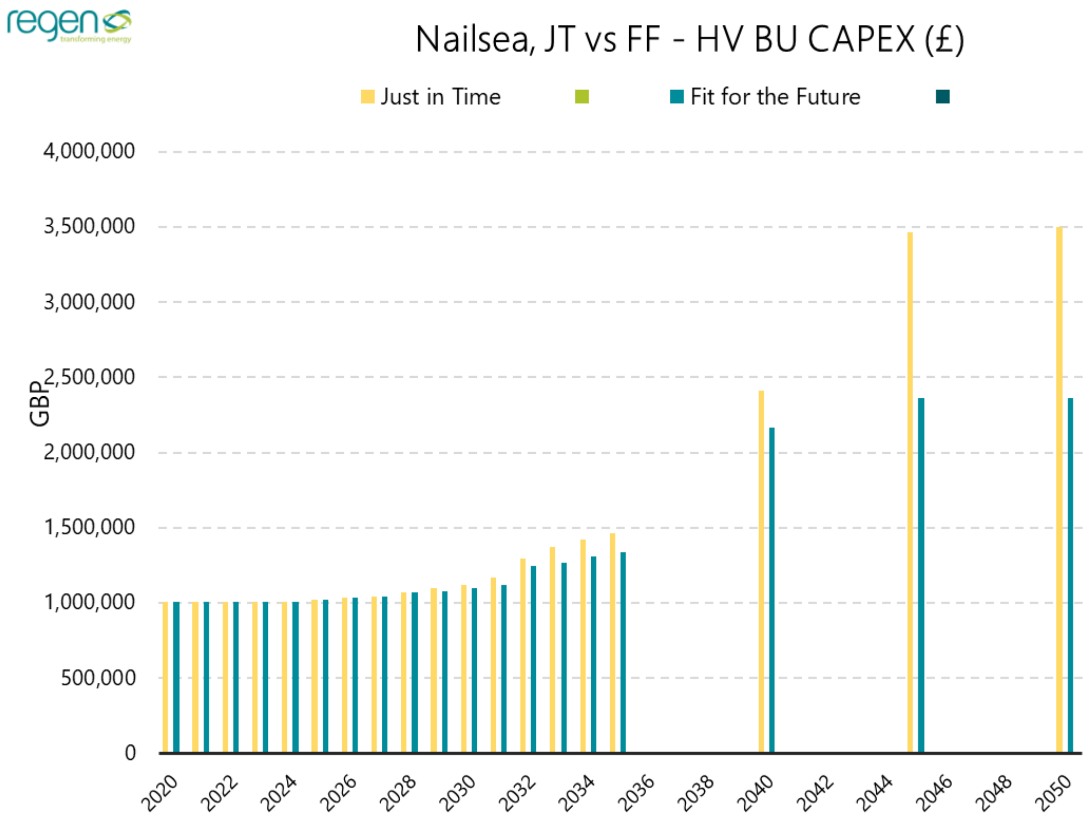

Figure 66: HV CAPEX by year on the Nailsea primary, from bottom up analysis

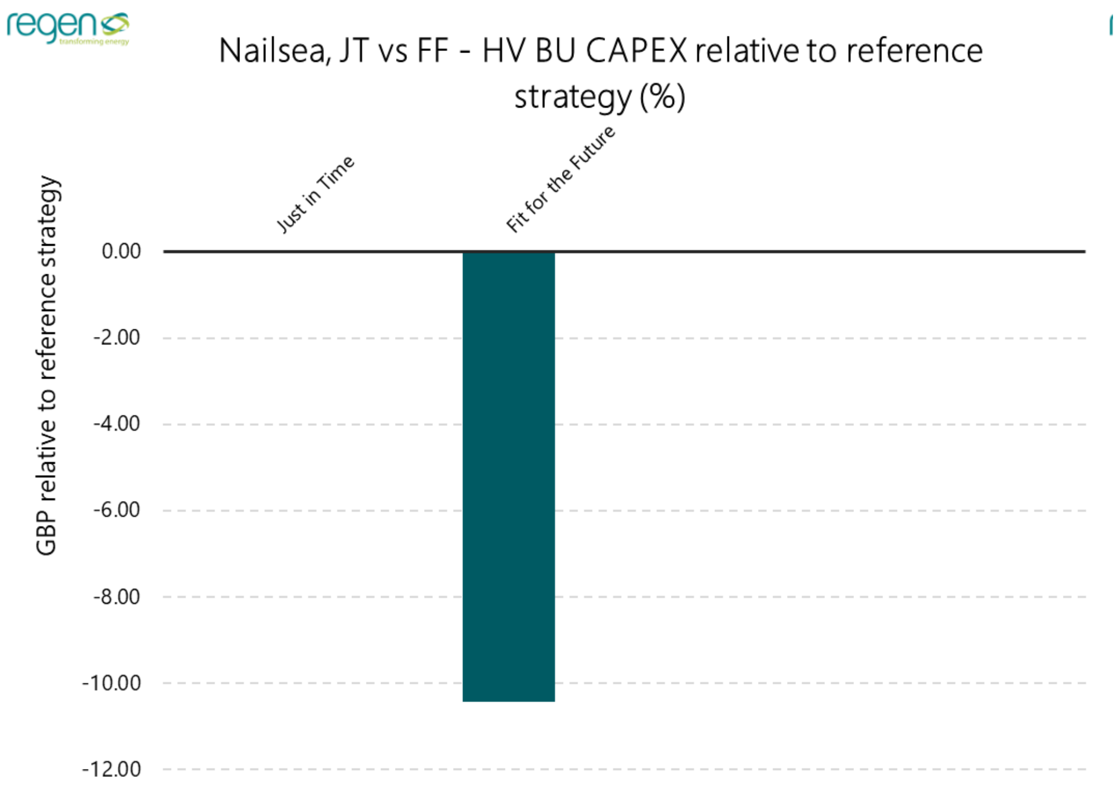

Figure 67: Total HV CAPEX by 2050 on the Nailsea primary, from bottom up analysis

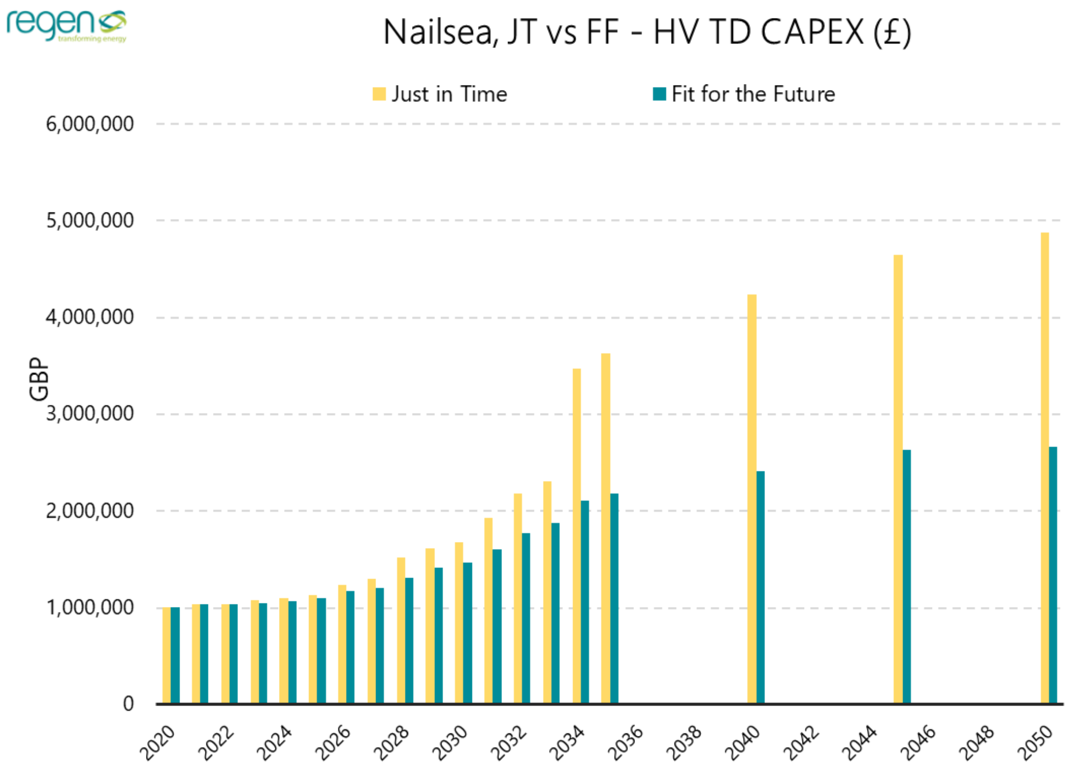

Figure 68: HV CAPEX by year on the Nailsea primary, from top down analysis

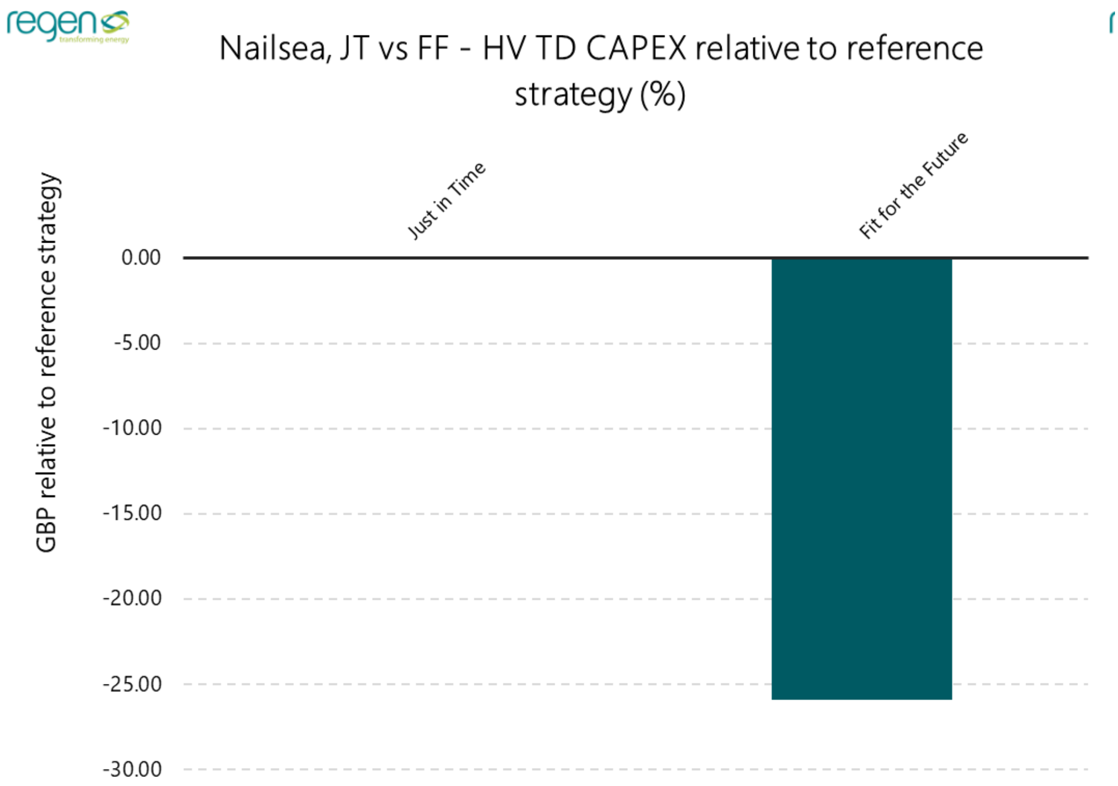

Figure 69: Total HV CAPEX by 2050 on the Nailsea primary, from top down analysis

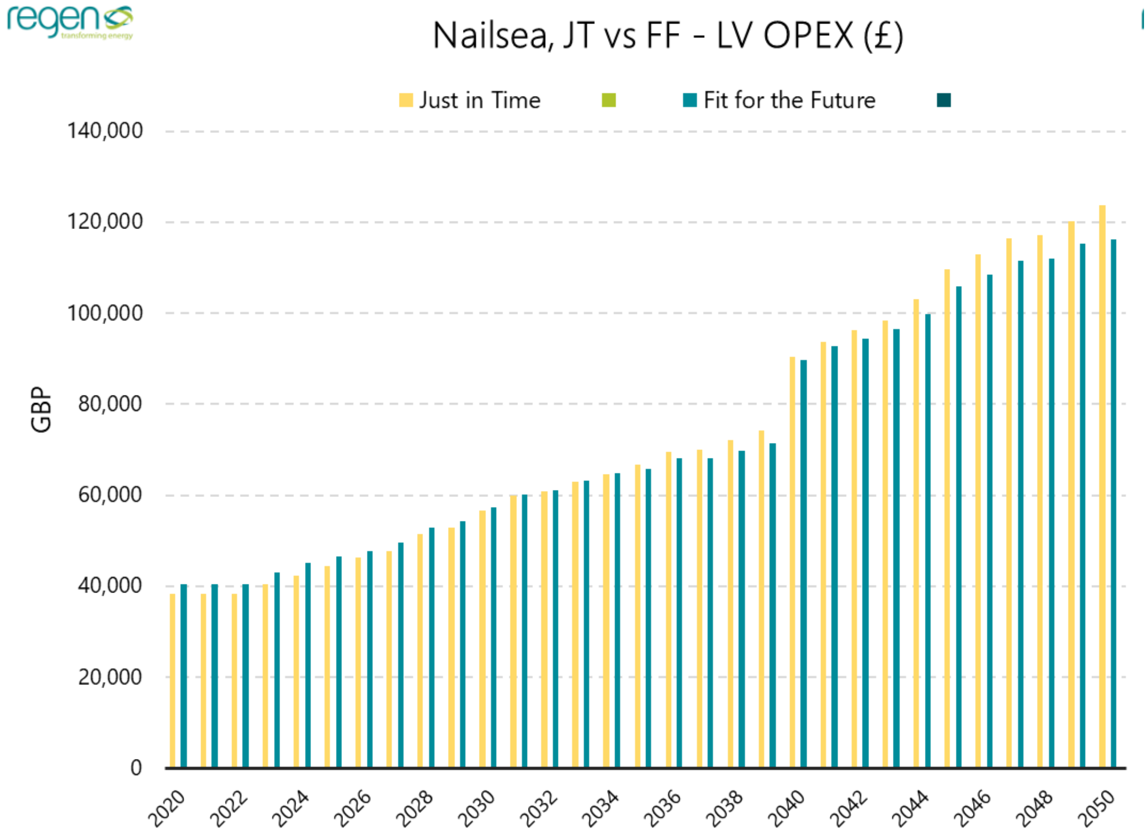

Figure 70: LV OPEX by year on the Nailsea primary

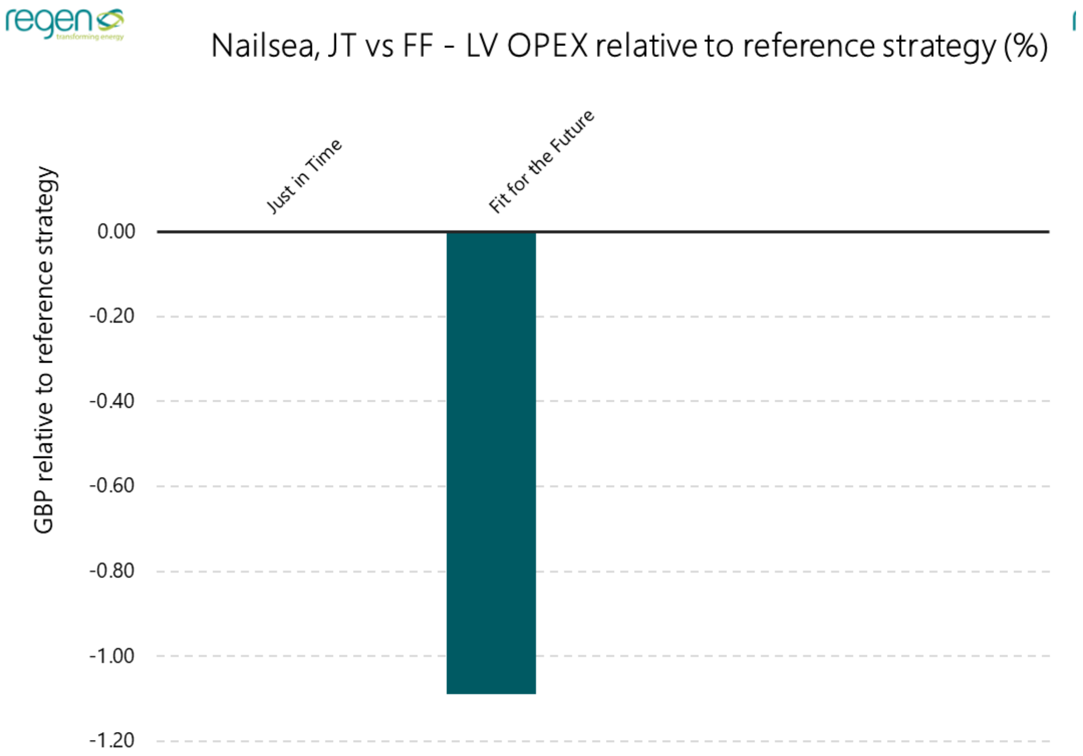

Figure 71: Total LV OPEX by 2050 on the Nailsea primary

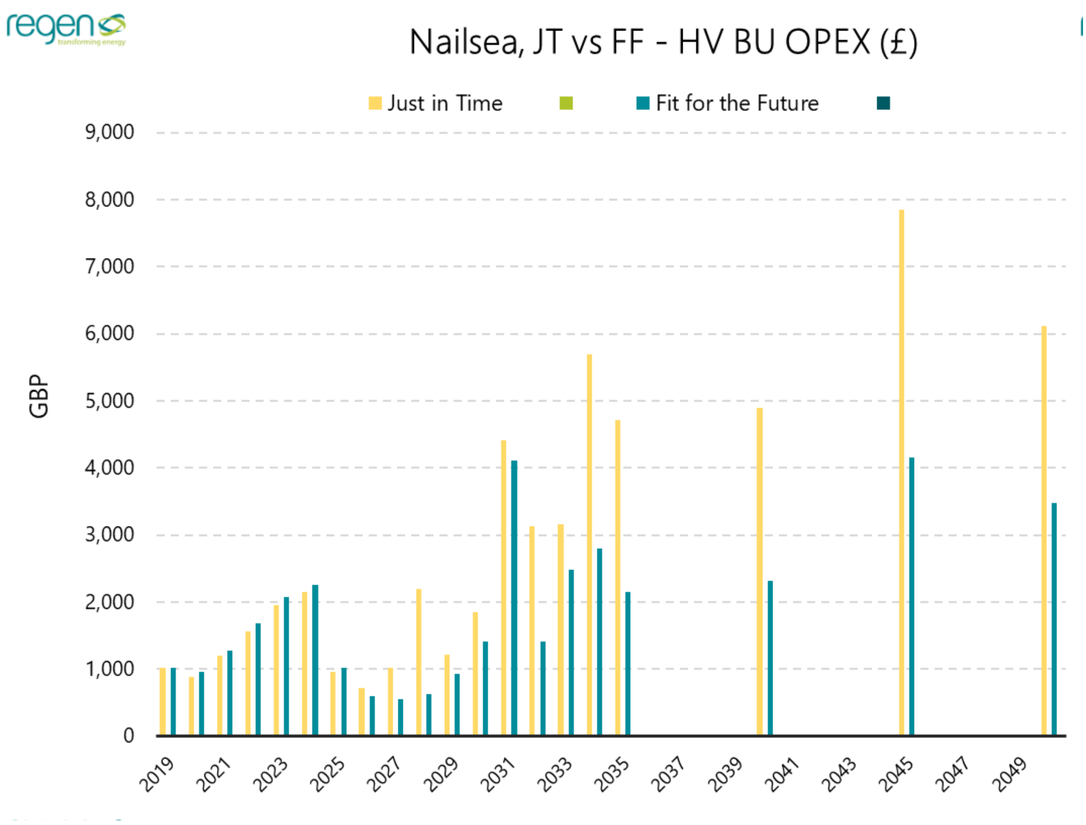

Figure 72: HV OPEX by year on the Nailsea primary, from bottom up analysis

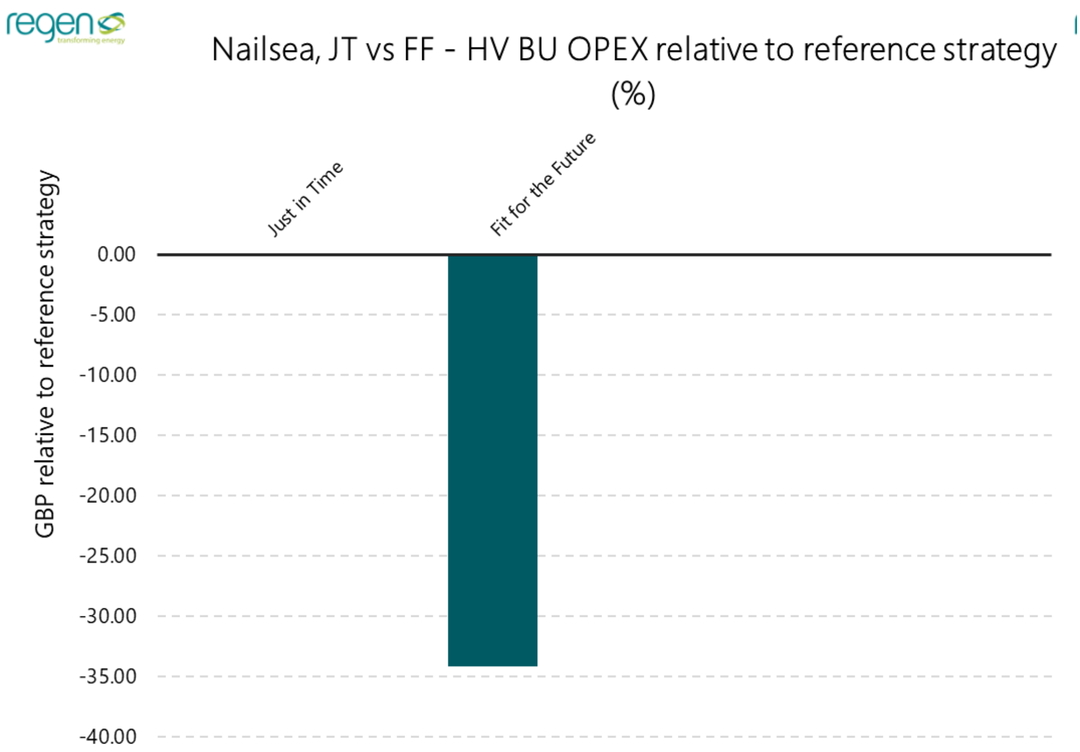

Figure 73: Total HV OPEX by 2050 on the Nailsea primary, from bottom up analysis

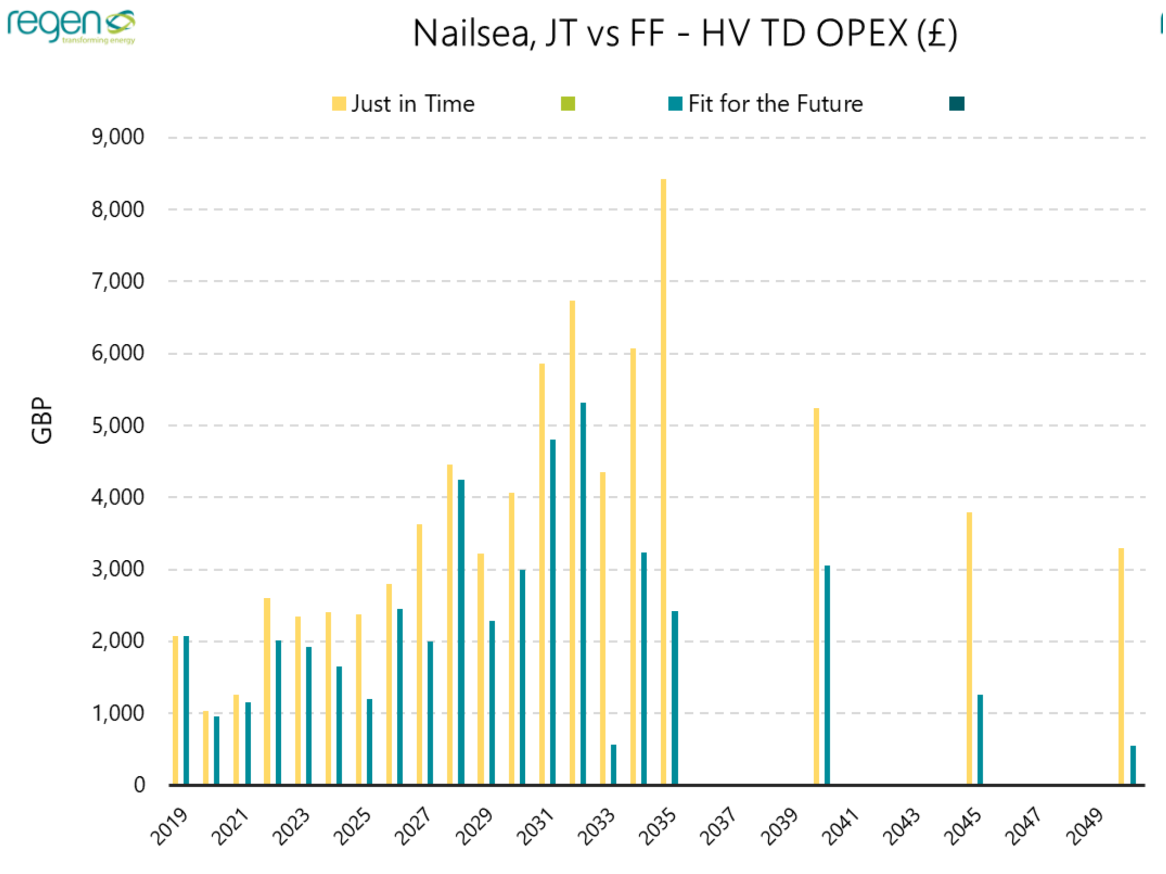

Figure 74: HV OPEX by year on the Nailsea primary, from top down analysis

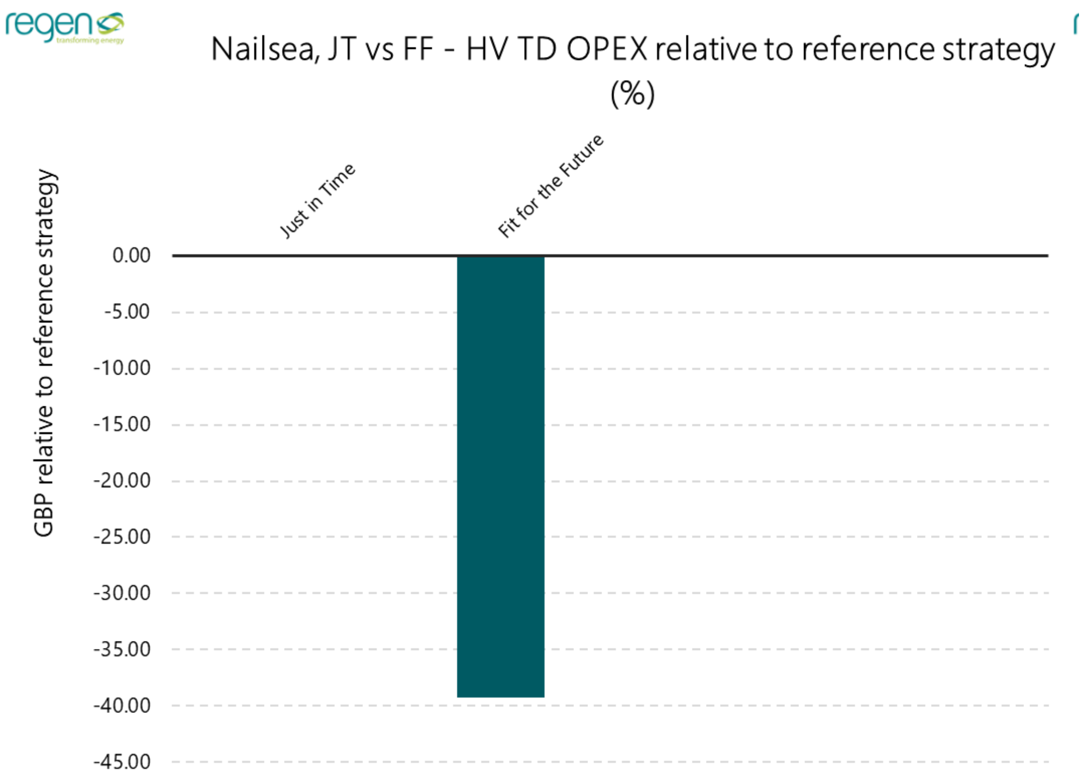

Figure 75: Total HV OPEX by 2050 on the Nailsea primary, from top down analysis

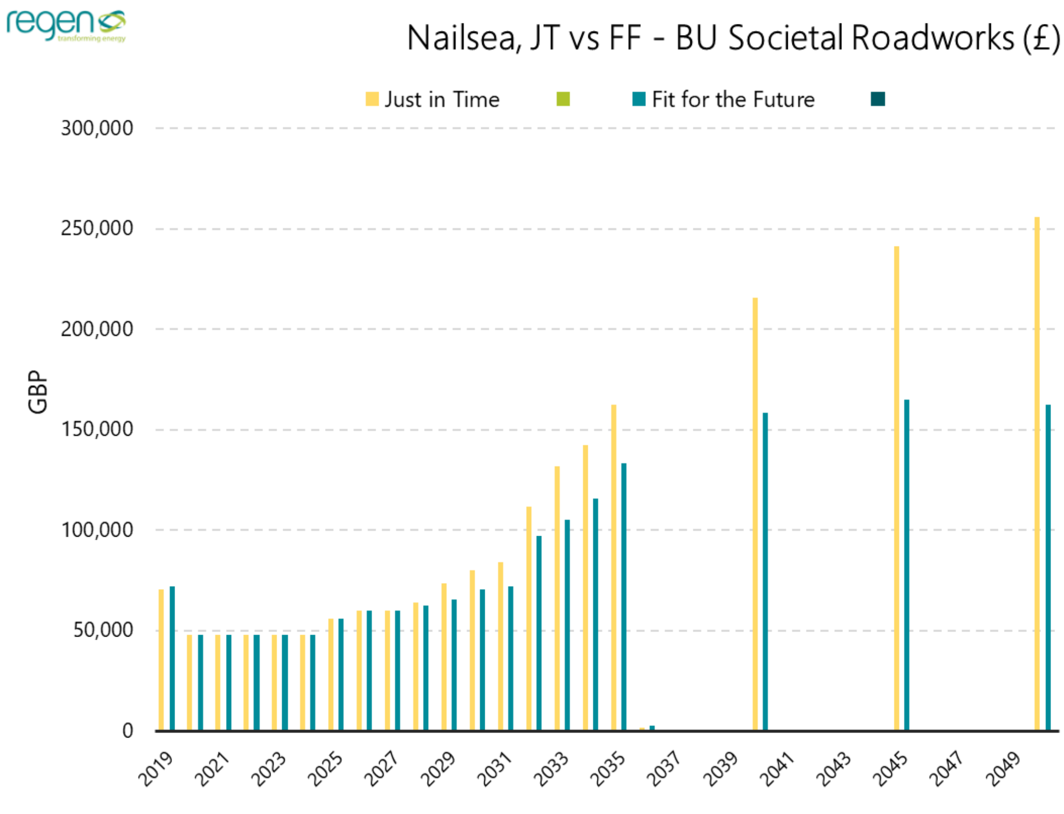

Figure 76 Societal cost of roadworks by year on the Nailsea primary, from bottom up analysis

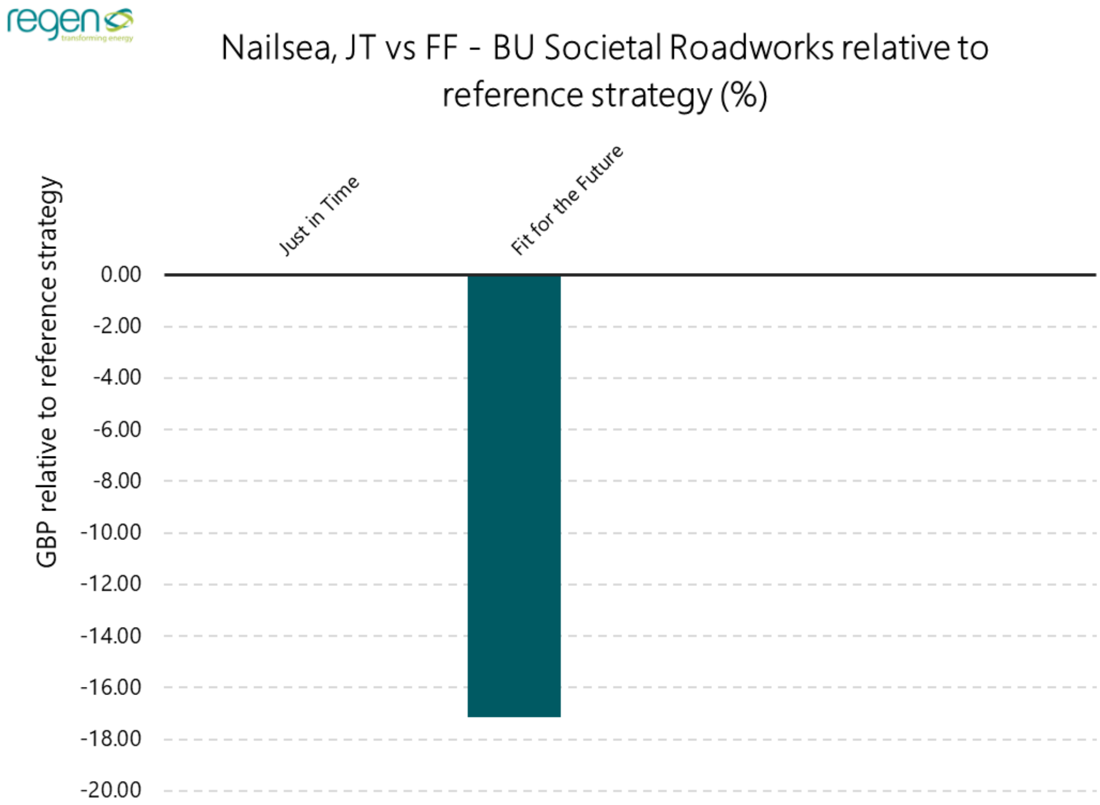

Figure 77: Total roadworks cost by 2050 on the Nailsea primary, from bottom up analysis

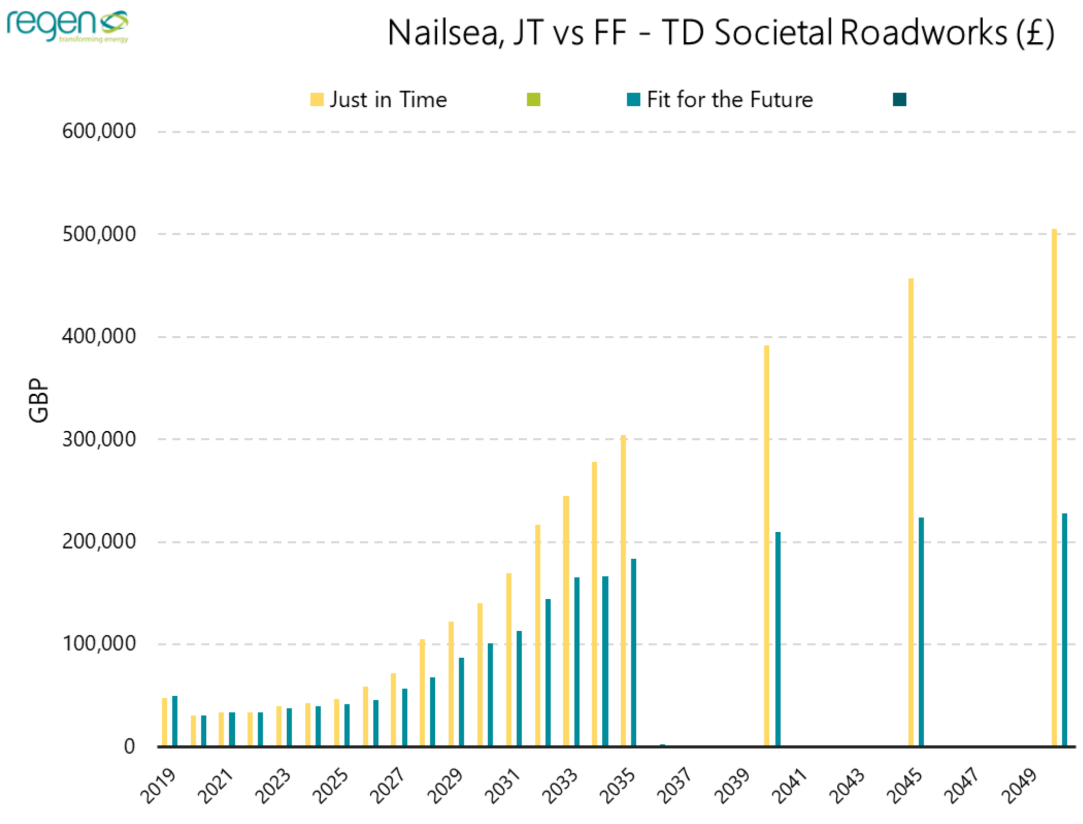

Figure 78 Societal cost of roadworks by year on the Nailsea primary, from top down analysis

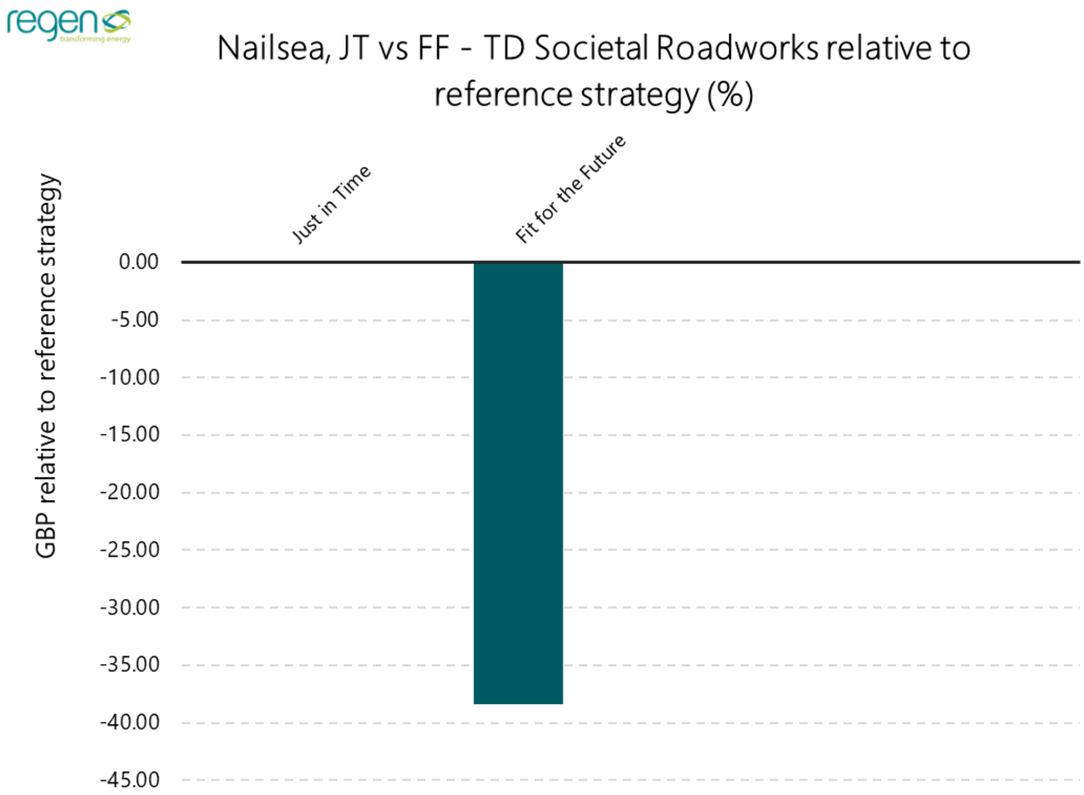

Figure 79: Total roadworks cost by 2050 on the Nailsea primary, from top down analysis

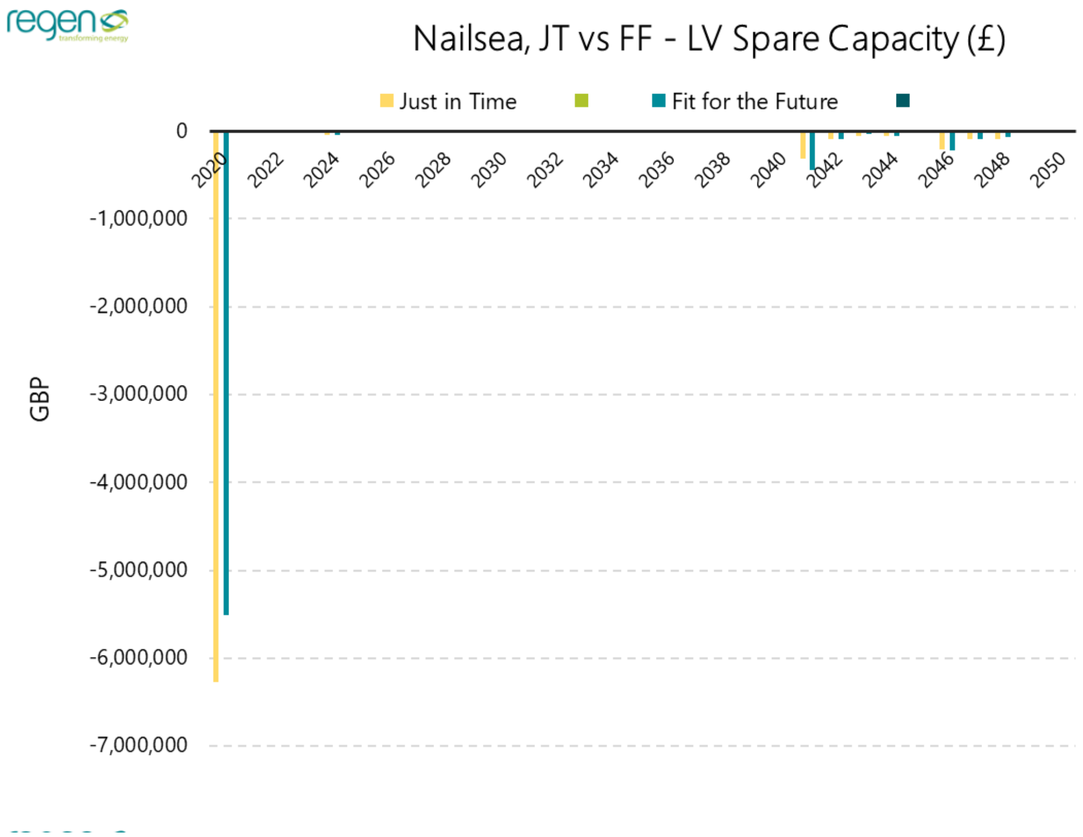

Figure 80: LV Spare Capacity by year on the Nailsea primary

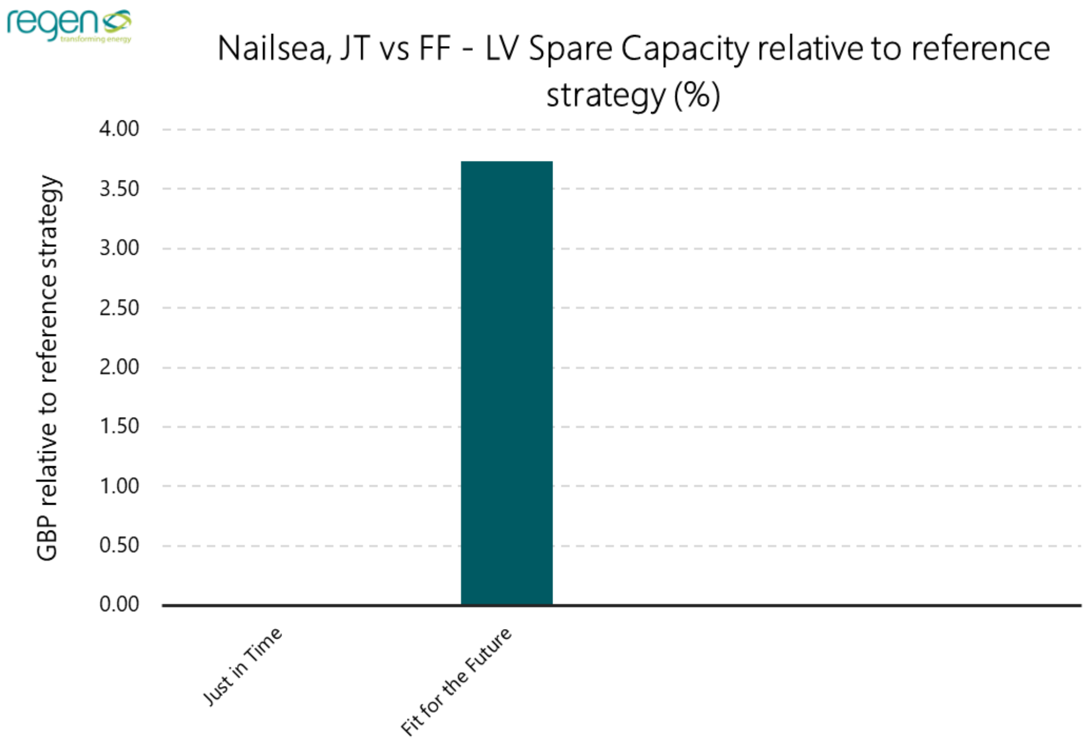

Figure 81: Total monetised LV spare capacity by 2050 on the Nailsea primary

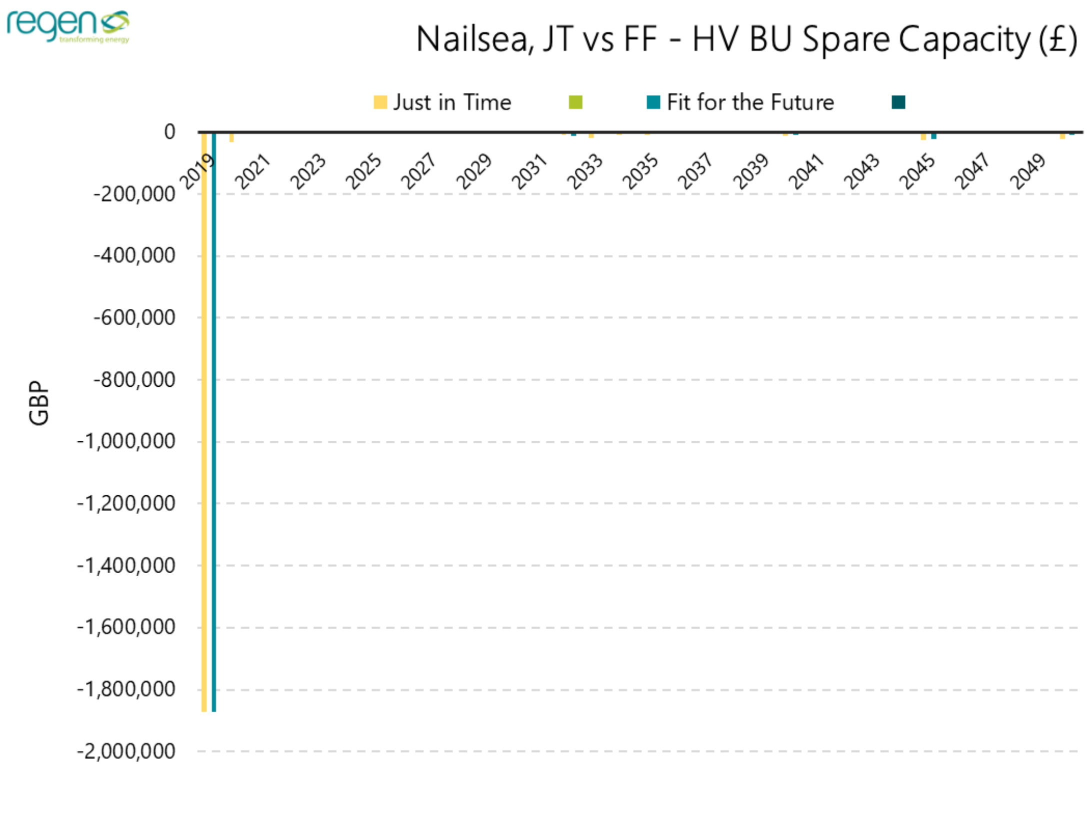

Figure 82: Monetised HV spare capacity by year on the Nailsea primary, from bottom up analysis

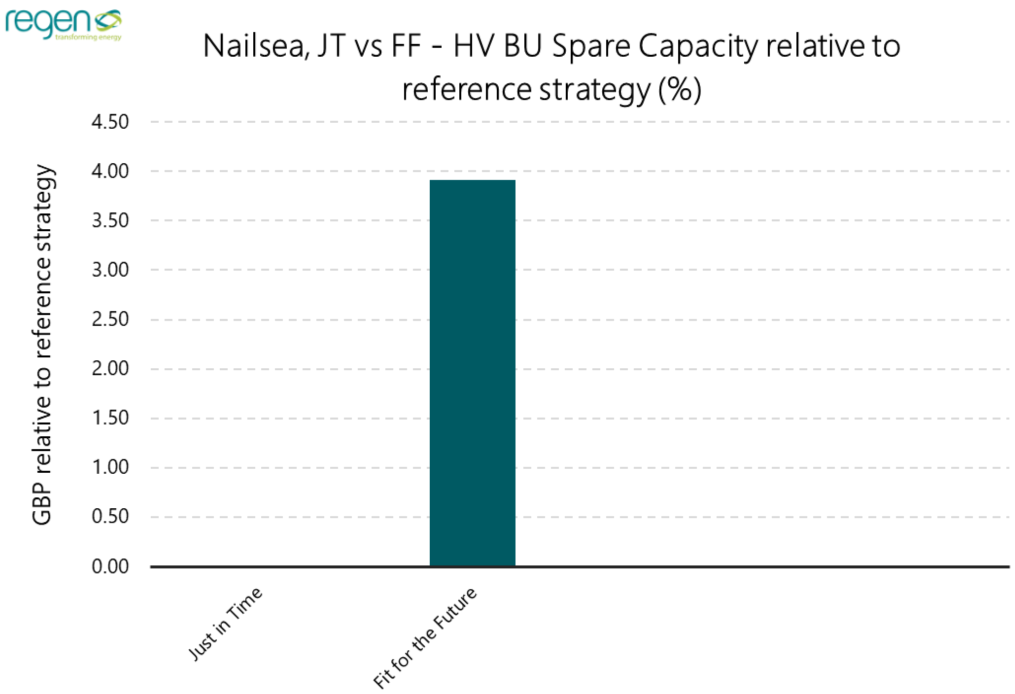

Figure 83: Total monetised HV spare capacity by 2050 on the Nailsea primary, from bottom up analysis

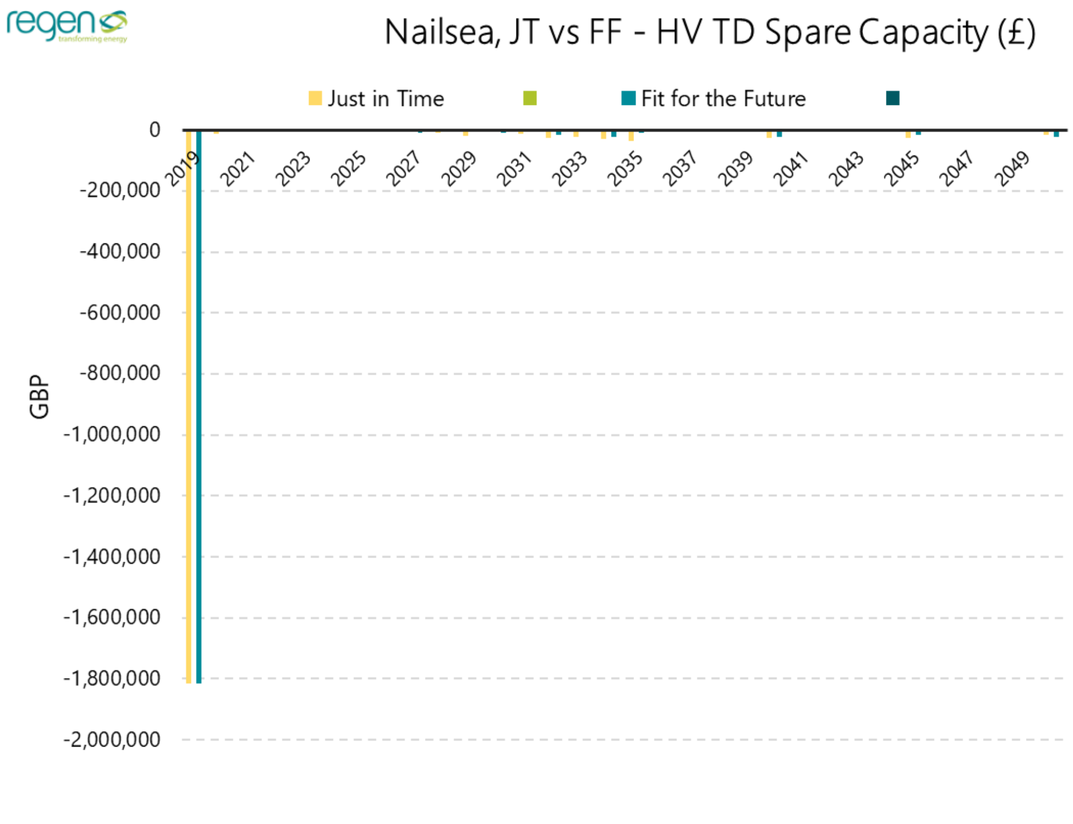

Figure 84: Monetised HV spare capacity by year on the Nailsea primary, from top down analysis

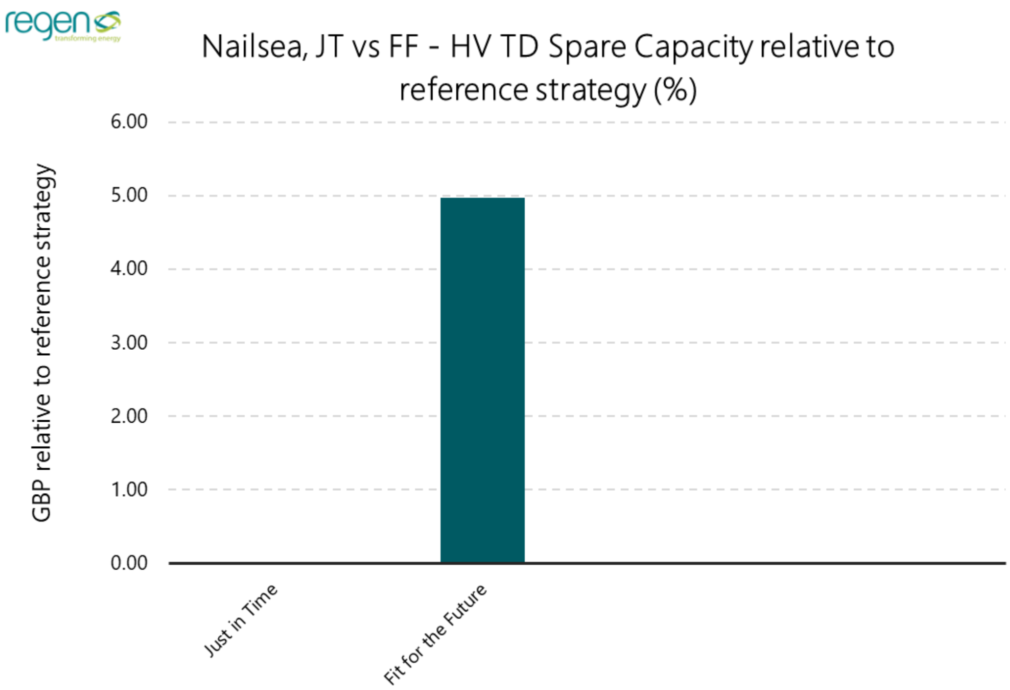

Figure 85: Total monetised HV spare capacity by 2050 on the Nailsea primary, from top down analysis

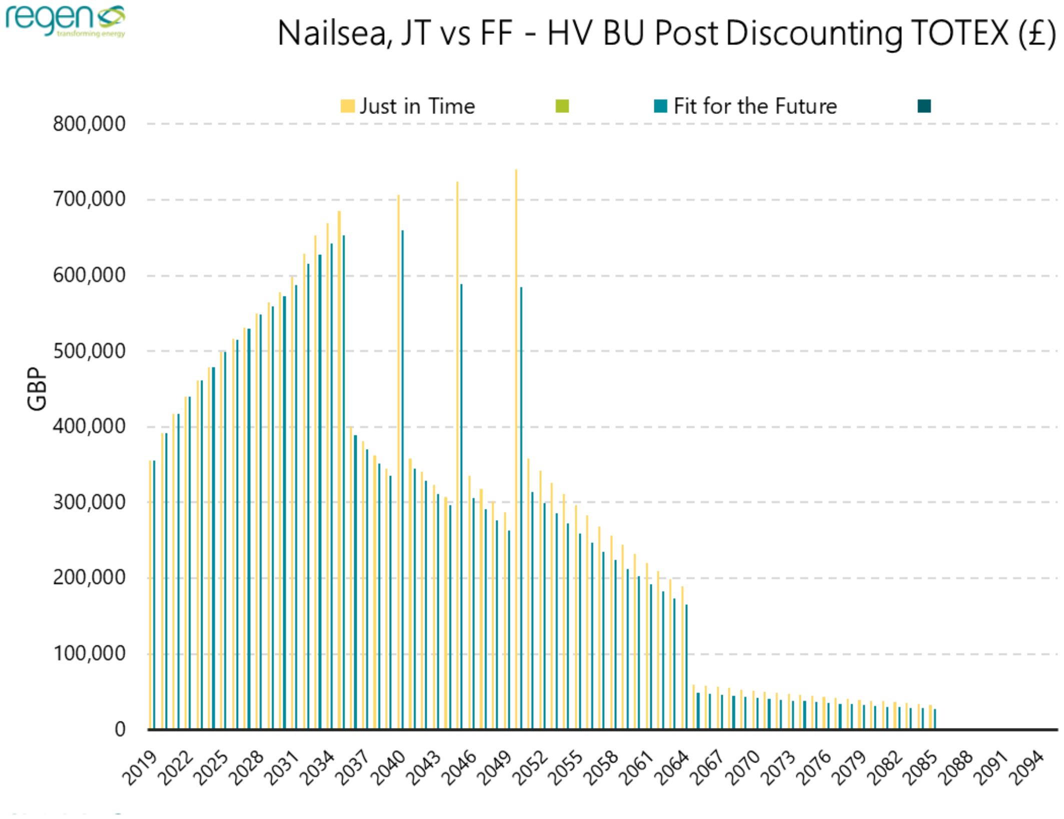

Figure 86: Post Discounting HV TOTEX by year on the Nailsea primary, from bottom up analysis

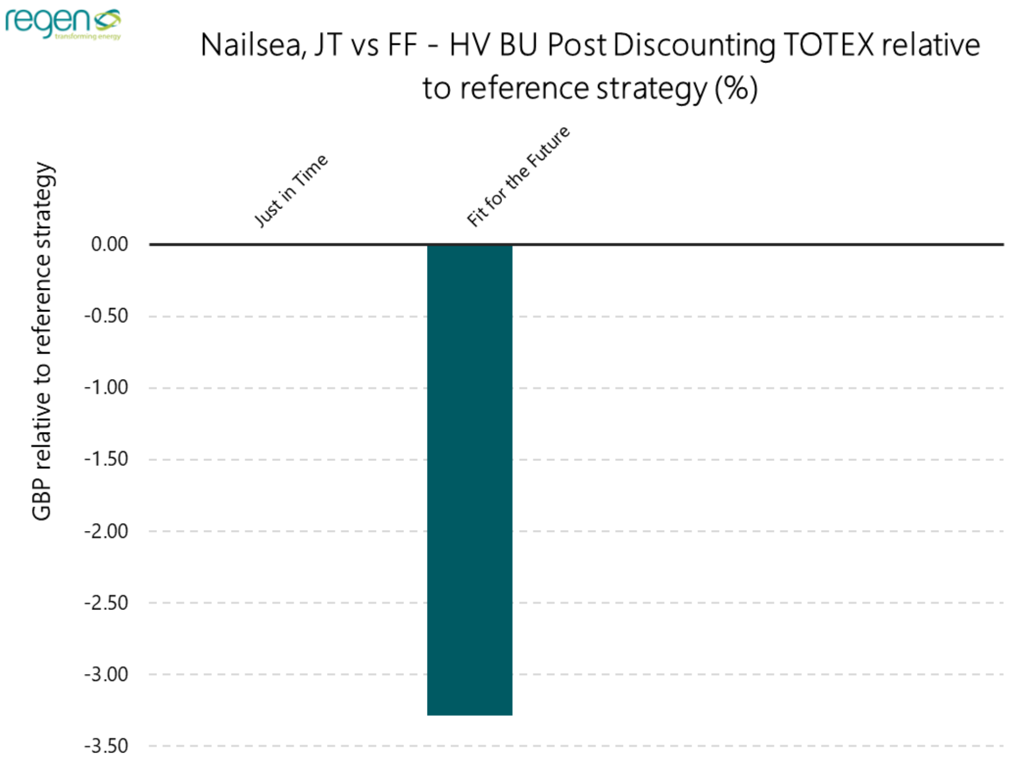

Figure 87: Total Post Discounting HV TOTEX by 2050 on the Nailsea primary, from bottom up analysis

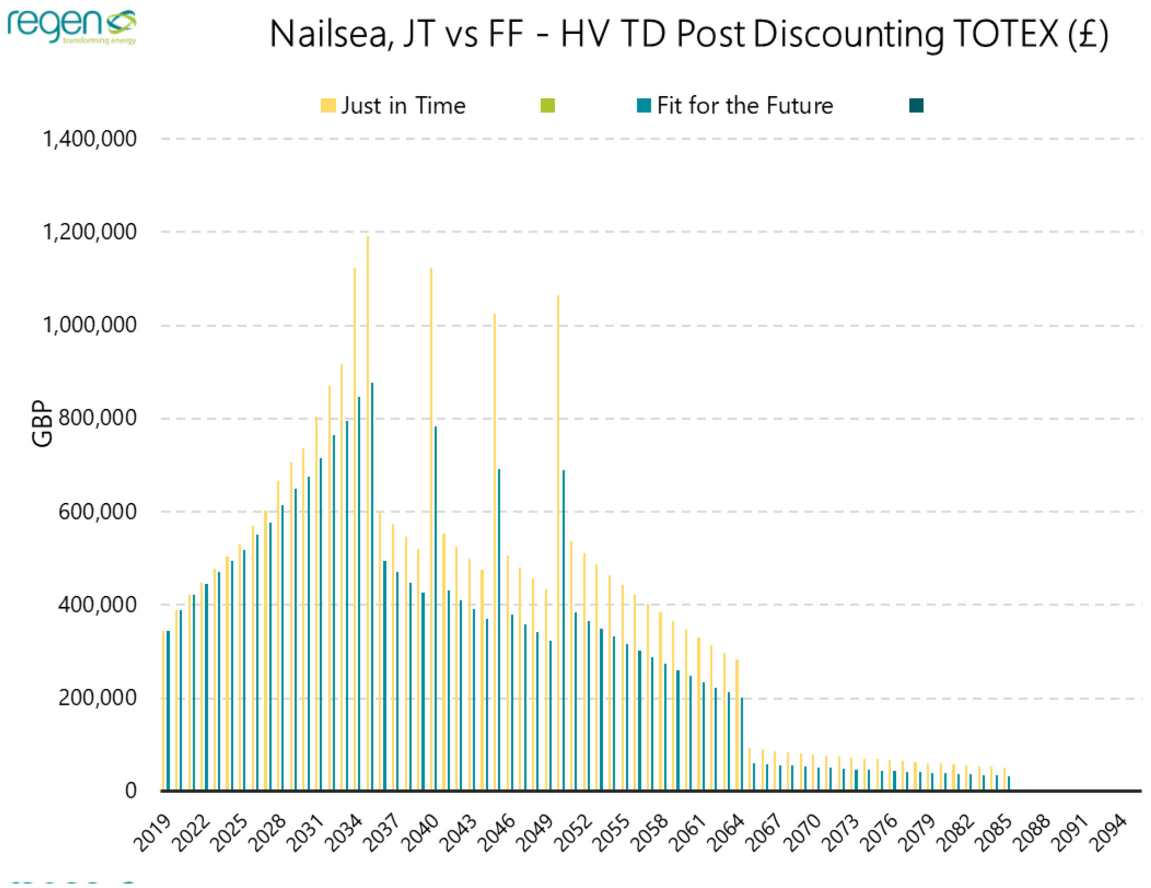

Figure 88: Post Discounting HV TOTEX by year on the Nailsea primary, from top down analysis

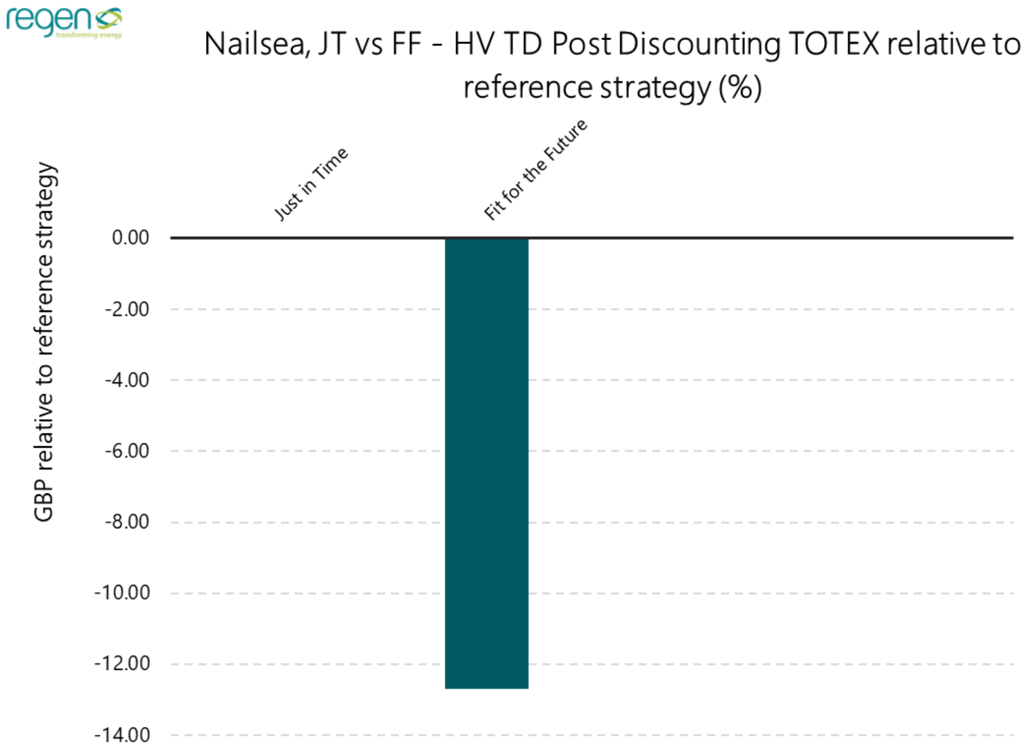

Figure 89: Total Post Discounting HV TOTEX by 2050 on the Nailsea primary, from top down analysis

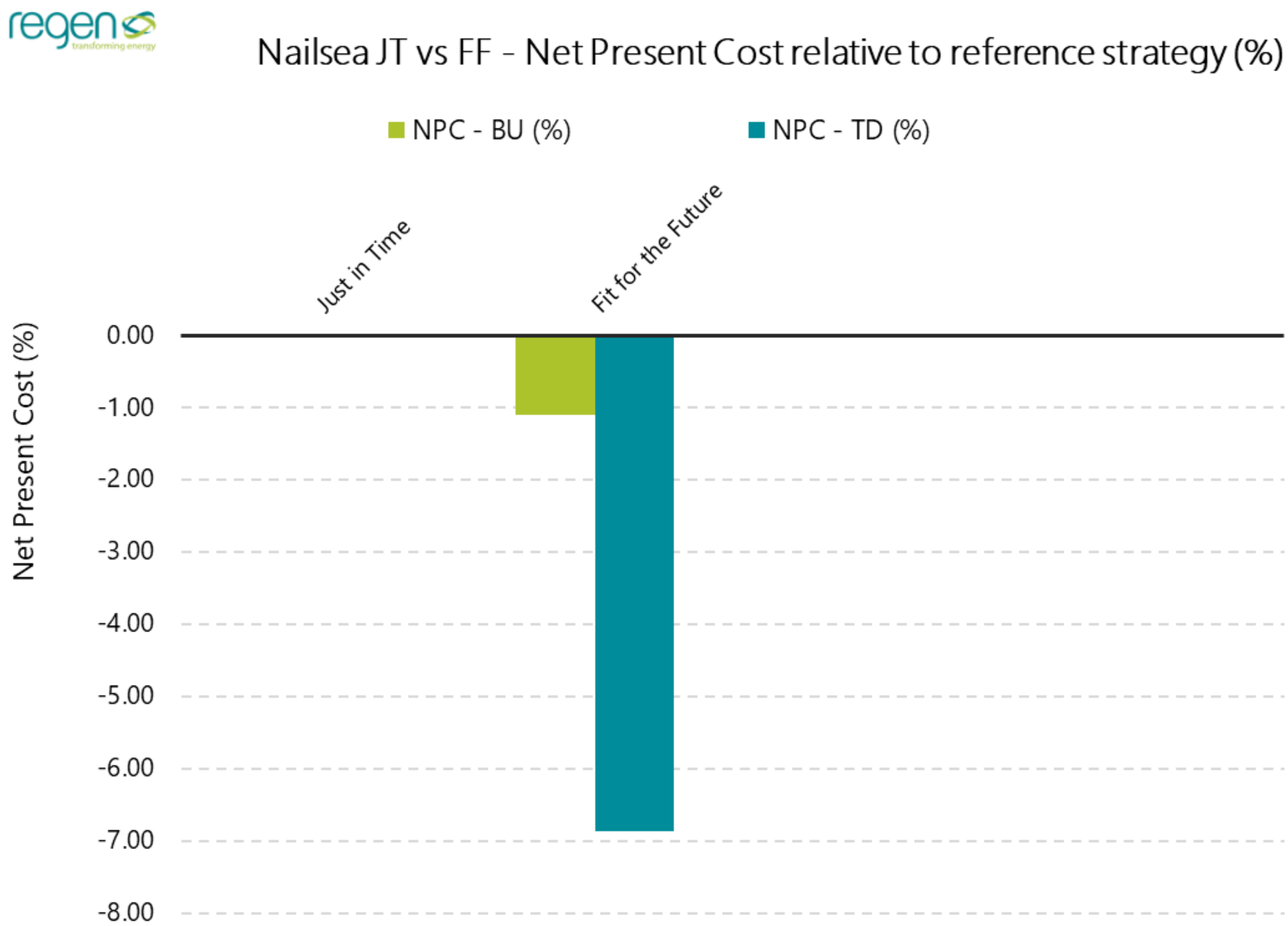

Figure 90: Total Whole Systems Net Present Cost by 2050 on the Nailsea primary