REFCL cost-benefit analysis

Energy Safe Victoria

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nous

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Executive summary

Nous Group (Nous) has been engaged by Energy Safe Victoria (ESV) to assess the incurred and projected costs of the Rapid Earth Fault Current Limiters (REFCLs) deployment program in the electricity distribution system in Victoria's highest bushfire risk areas. Nous also assessed the REFCLs demonstrated and expected benefits in reducing bushfire starts.

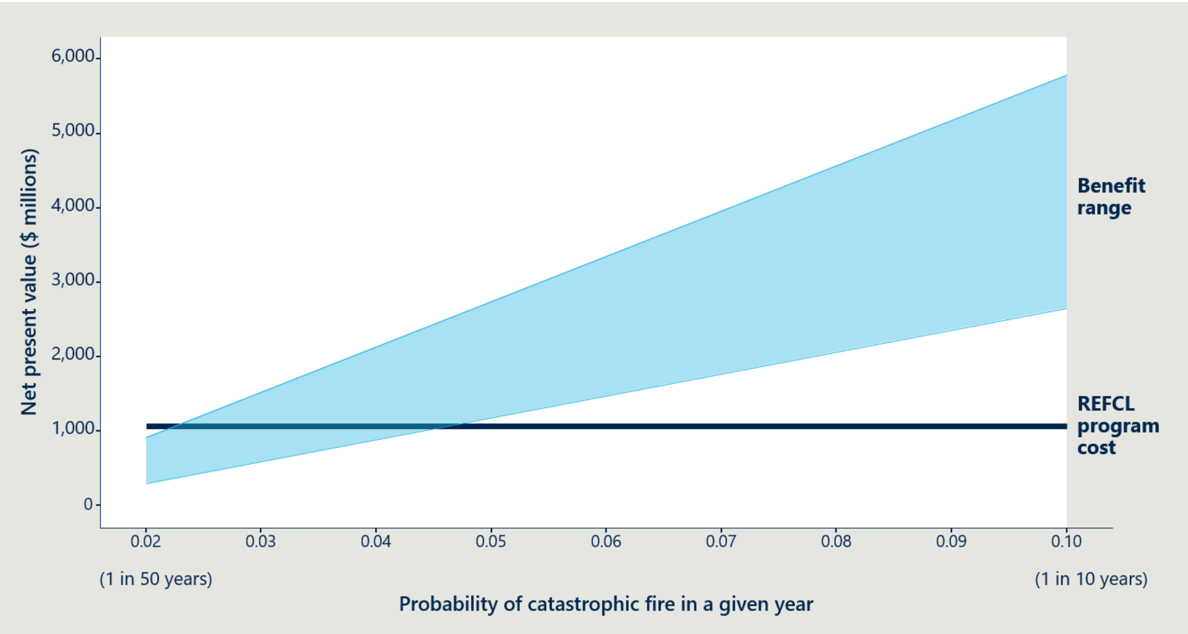
There has been a considerable increase in the costs of the REFCL program, compared to the estimates in the 2015 Regulatory Impact Statement, which supported the regulations under which the REFCLs are required to be deployed. Although Nous was not engaged to explore the reasons for the increase, significant technical causes were revealed through our work and are summarised in the body of the report.

These causes reflect the unprecedented application of REFCLs to bushfire mitigation in rural networks, which meant that initial cost estimates could not draw on experience. Thus the actual costs, which have been driven by exacting performance standards aimed at preventing fires in extreme conditions, were fully revealed during implementation. It will take many years to gather statistically significant evidence that might have justified lower cost performance requirements, so a staged and adaptive rollout would have required more time and significantly increased bushfire risks.

The future benefits of any bushfire mitigation program can only be estimated with a high level of uncertainty. Instead of putting forward a single figure, we have estimated a range of benefits using the cost of Black Saturday as a proxy for a future catastrophic fire event – one that is triggered by weather conditions that make powerline faults (with the potential to cause fires) likely.

We have chosen upper and lower bound estimates for key input parameters with which we convert the proxy cost to a plausible range of estimates of the benefits of the REFCL program. This is shown below in Figure 1.

Figure 1 | REFCL program costs and benefits



We have included intangible benefits in estimates of the total benefit of preventing a catastrophic fire event. Earlier estimates of Black Saturday's costs limited intangible costs to loss of human life, so made no provision for the impact of the fire on mental health, the environment, or other factors.

The benefit estimates are subject to considerable uncertainty and caveats that we detail in the report. However, our judgement is that the REFCL program is likely to be a prudent investment in mitigating future catastrophic fire damage caused by powerline failures in extreme conditions. This conclusion will be reviewed and adjusted as the program continues and experience is gained with the use of REFCLs.

For the future, we recommend that ESV improve its monitoring of REFCL performance through more comprehensive annual reporting of the impacts of the REFCL program to inform its active and adaptive management.

1 Context for our engagement

In May 2020 Energy Safe Victoria (ESV) engaged Nous Group (Nous) to analyse the actual and forecast costs and benefits of the Rapid Earth Fault Current Limiter (REFCL) deployment program. This section explains the history of the REFCL program over the last decade as context for our engagement, before explaining the scope and limitations of this report.

Background to the REFCL program

The Powerline Bushfire Safety Taskforce (PBST) was established in 2010 to consider how the Victorian Government should implement the recommendations of the 2009 Victorian Bushfires Royal Commission to reduce the number of fires caused by electricity assets.

Both the Royal Commission and the PBST recommended reducing the risk of fires from powerline faults without the wide-scale and preventive disconnection of rural powerlines on high fire risk days (as has been implemented in California and South Australia). A key recommendation of the PBST was that REFCL technology be deployed at specific network locations across Victoria.

Figure 2 | What is a REFCL?

> REFCLs limit energy released when an electrical fault occurs on a powerline; reducing fault current to very low levels more rapidly than traditional protection systems can, to cut off supply, while maintaining supply on unaffected circuits.
>
> REFCLs have been used in Europe for 30 years to improve supply reliability and electrical safety, but Victoria is the first jurisdiction to adopt the technology to prevent fires starting from fallen powerlines.

In 2011, the Victorian Government accepted this recommendation and initiated a Powerline Bushfire Safety Program (PBSP) for the purpose of reducing the risk of bushfires caused by electrical assets. The PBSP included several elements in addition to the REFCL program, such as selective undergrounding of powerlines. A research program was funded by the Victorian Government to assess the fire prevention potential of different REFCL types.[1]

Under the PBSP, the *Electricity Safety (Bushfire Mitigation) Regulations 2013* ('the regulations') were amended in 2016[2], requiring Major Electricity Companies (MECs) to install REFCLs at 45 zone substations (ZSSs) supplying a total area representing approximately 90 per cent of Victoria's highest bushfire risk areas. The Regulatory Impact Statement ('the RIS') on the proposed regulations concluded that the REFCLs would produce benefits (i.e. reductions in bushfire risks) that would significantly outweigh the deployment costs.[3]

The regulations require the installation of REFCLs that meet specific and exacting performance standards in three tranches, for completion by 1 May 2019, 2021, and 2023 respectively.

Tranche 1 has been delivered and Tranche 2 is underway, with REFCLs installed in high risk ZSSs such as Wangaratta and Eaglehawk. AusNet Services, Powercor, and Jemena have already done extensive planning for the third tranche.

[1] Marxsen Consulting REFCL Trial: Ignition tests 2014, available here: https://www.energy.vic.gov.au/__data/assets/pdf_file/0021/41718/REFCL-Trial-FINAL-report-Exec-Summary-plus-Ch-1-3-140804.pdf
[2] Electricity Safety (Bushfire Mitigation) Regulations 2013.
[3] ACIL Allen RIS 2015, available here: https://acilallenconsulting.com.au/uploads/files/projects/166/ACILAllen_BushfireMitigationRIS_2015.pdf

Implementation of the REFCL program has proven more technically challenging and expensive than was envisaged in the RIS. Considerable works have been required including; extensive network hardening to manage voltage rises on un-faulted power phases when REFCLs are triggered, and re-engineering of network operations. High voltage (HV) customers directly connected to REFCL networks are impacted by over-voltages when REFCLs compensate for faults, which has required those customers to harden or isolate their electrical networks at considerable expense.

The first significant in-service test of REFCL performance occurred in 2019/20, when the Tranche 1 REFCLs were operational and the first half of Victoria's summer produced unusually high fire risks. The Total Fire Ban day on 21 November 2019 was a particularly significant in-service test because this was the first Code Red day declared since 2010.

Scope and limitations of our engagement

The growing cost of the REFCL program became one focus of an independent review of ESV by Dr Paul Grimes in 2017.[4] Recommendation 27 of the Grimes Review requires annual implementation reports on the deployment of REFCLs, including:

- information on the costs and risk reduction benefits in light of actual experience
- an assessment of emerging issues that may require adjustments to program timing or technical requirements.

Nous was engaged as part of the implementation of recommendation 27, but not specifically to acquit the reporting obligations under the Grimes review. Specifically, Nous was engaged to:

- Establish program costs incurred by MECs and HV customers, including initial capital expenditure, operational expenditure, and avoided costs.
- Analyse the performance of REFCLs, determine the risk reduction benefits based on evidence to date, and forecast the likely risk-reduction benefits when the full program is deployed.

In parallel, ESV commissioned Power Systems Consultants (PSC) to do an engineering assessment of the performance of deployed REFCLs, covering:

- an investigation of REFCL performance when responding to different fault types
- advice on emerging issues that may cause the program timing or technical requirements to be adjusted
- advice on unexpected benefits that have arisen following deployment of REFCLs.

Nous has conferred with PSC throughout our review, however our reporting date is earlier than PSC's so their advice to us has been preliminary rather than final.

It should be noted that the full performance and impact of REFCLs – their availability, capacity to prevent fires, and impact on network reliability – will become progressively clearer over coming years. Only one tranche of REFCLs has been deployed, for only one fire season. It is not currently possible to draw firm conclusions about their performance. This report has been written to establish a framework for future evaluations as more REFCLs are deployed and more operational experience is gained.

Our assessment of benefits and costs represents our best judgement at this time, and there is enough emerging evidence to draw initial conclusions on the value of the program, noting that future analysis may alter those conclusions.

[4] The 'Independent Review of Victoria's Electricity and Gas Network Safety Framework' or Grimes Review, available here: https://engage.vic.gov.au/electricity-network-safety-review

2 Our approach

This section describes the approach Nous took to this engagement and the information sources draw on.

We conducted a nuanced cost-benefit analysis

As with any traditional cost-benefit analysis (CBA), Nous identified the impacts, attached monetary values to them over a defined time period, and discounted the future costs and benefits to obtain present values, before calculating two headline results:

1. Net Present Value (NPV) – The difference between the present value of total benefits and the present value of total costs.
2. Benefit/Cost Ratio (BCR) – The ratio of the present value of the total benefits to the present value of total costs.

A positive NPV and a BCR above one are useful indicators that an investment is justified. However, as explained in Section 3, Nous adopted a modified CBA framework because the cost and probability of catastrophic bushfires is subject to such uncertainty that the calculation of a single BCR is an exercise in false precision.

Instead an estimated 'benefits range' has been used; a two-dimensional field of avoided costs and probabilities – and compared those to the expected cost of the program, which is more precisely known.

Nous recognises that government's decisions on the REFCL program will not be based on whether the estimated benefit-cost ratio exceeds a specified threshold. Benefit-cost analysis can provide some useful insights into the value of the program, but the expectations and values of society properly have a larger influence on government's judgement and decisions.

We drew on multiple information sources

Nous engaged with numerous bodies to refine cost estimates, understand REFCL performance, and assessed the program's possible benefits. The list of organisations which were prepared to be disclosed in a public report is in Table 1. Nous would like to thank all stakeholders for their willingness to meet and share information.

Table 1 | Consultation

Category	Stakeholders
Government	1. Australian Energy Regulator (AER)
	2. Department of Environment, Land, Water and Planning (DELWP)
	3. Commonwealth Scientific and Industrial Research Organisation (CSIRO)
MECs	4. AusNet Services
	5. Powercor
	6. Jemena
	7. United Energy
	8. Lower Murray Water

	9. Department of Transport
	10. Department of Health and Human Services
HV Customers[5]	11. Coliban Water
	12. Deakin University
	13. Melbourne Water Corporation
Consultants	14. Power Systems Consultants (PSC)

Nous also drew on a range of quantitative and qualitative data. The key sources included:

- Documentation provided by ESV and other sources about the history of the REFCL program, research on adapting REFCLs for bushfire mitigation, electrical network safety, and fire and fault data.
- Previous assessment of bushfire costs, such as the Bureau of Transport Economics' quantification of historical bushfire costs (pre-2000), the ACIL Allen RIS and Deloitte Access Economics' estimates of Black Saturday socioeconomic costs.
- Information from MECs and HV customers on their incurred and projected costs.
- Information from MECs on REFCLs' impacts on supply reliability.
- The MECs' bushfire mitigation plans.
- The AER's Contingent Project Application documents, including the MEC's projected REFCL costs and their associated REFCL models.
- The MEC's regulatory information notices submitted to the AER.
- CSIRO's risk modelling of each zone substation, and their associated REFCL risk reduction rate.
- Several recent studies documenting the impact of climate change on bushfire risk.

[5] Barwon Region Water Corporation was approached but received no reply. However, we have included the best available estimate of its costs, which were provided by DELWP and are not material to our conclusions. The costs of those HV customers that asked not to be publicly identified have been included in the aggregate figure.

3 Findings

Section 3 provides Nous' assessment of costs and benefits and explains the assumptions and methodology we applied in attaining these results.

3.1 Key parameters

The estimates of costs and benefits are based in part on key parameters. Table 2 explains the key parameters and others are explained through the remainder of Section 3.

Table 2 | Key parameters

Assumption	Explanation
40-year time period	We have forecast costs and benefits over a 40-year time period, for each delivery tranche. This is based on the nominal average REFCL asset life of 40 years. It would be immaterial to forecast beyond this period and it is too far away to predict what replacement costs would be incurred.
Four per cent real discount rate	The real discount rate is a benchmark or threshold return on investment which is used to estimate the net present value (NPV) of the costs and revenues of an investment. A positive NPV shows that the project meets the threshold or target rate of return. We applied a real discount rate of 4.0 per cent per annum, based on published guidance by the Victorian Department of Treasury and Finance for projects where benefits can be articulated but are not easily translated to monetary values.[6]
Two per cent inflation	When dealing with incurred cost information in the years prior to 2020, we accounted for inflation by using relevant escalation indices drawn from the Reserve Bank of Australia's online calculator. This was approximately 2 per cent per annum.
Base case of no REFCL installation	We reviewed the base case assumption in the RIS that electricity distributors would install one REFCL every two years in the absence of the amended Bushfire Safety Regulations that are driving the current program. We concluded that no REFCLs that meet the regulated performance standards are likely to have been installed without a regulatory requirement, because of the technical challenge and cost. Although United Energy installed REFCLs without a regulatory requirement, it chose not to meet the performance standards that apply to the regulated program.

All figures are in 2020 Australian dollars unless otherwise stated.

3.2 Costs

Projected and incurred costs of the REFCL program sit under two main categories:

3. **The MECs' costs of installing and maintaining REFCLs**, with avoided costs subtracted (to reflect the remaining life of equipment for which replacement has been brought forward by the REFCL program).
4. **HV customers' costs to harden or isolate** their electrical installations against the voltage increases that occur on un-faulted phases when a REFCL operates.

[6] Department of Treasury and Finance (Vic), Economic Evaluation for Business Cases Technical guidelines, available here: https://www.dtf.vic.gov.au/investment-lifecycle-and-high-value-high-risk-guidelines/stage-1-business-case

The estimates of these costs are summarised in Table 3 below, which shows overall expenditure for the scheme of in excess of $1 billion.

Table 3 | REFCL costs (PV $m)

MECs' costs (with avoided costs removed)	$888
HV customers' costs	$180
Total costs	**$1,068**

These costs are discussed in more detail below. We also conclude this section with a brief comparison between these costs and those reported in the RIS.

3.2.1 MECs' installation and ongoing costs

Under the regulations, MECs are required to install REFCLs at the 45 highest risk ZSSs across Victoria. AusNet Services and Powercor each are required to install REFCLs in 22 ZSSs, while Jemena is required to do so in one.

AusNet Services and Powercor have already completed Tranche 1, and all three MECS are advanced in the delivery of Tranche 2 and planning of Tranche 3. As highlighted in Section 1, the REFCL program has proven technically challenging to implement, and its costs will be much higher than estimated in the RIS.

Context

To provide context for our assessment of projected and incurred costs, this subsection explains the AER's approval of REFCL costs and resultant impact on electricity consumers' bills, and ESV's consideration of applications for exemptions from the regulations.

AER approval process

AusNet Services and Powercor have sought funding for the REFCL installation program through Contingent Project Applications (CPAs).[7] The AER has approved most of the costs sought by the MECs, although funding was reduced for reasons including:

- High costs for the design, installation, land acquisition, testing, and commissioning costs of works to harden or isolate HV customers' electrical installations in Tranche 1.
- A change to the Electricity Distribution Code in 2018 that transferred responsibility for hardening or isolating HV customers' installations from the MECs to the customers for Tranches 2 and 3.
- High labour rates for replacing surge arrestors and HV regulators.

Table 4 overleaf, compares the costs sought by the MECs in their CPAs with those approved by the AER.

[7] The CPAs and the AER's assessments of them can be found at https://www.aer.gov.au/networks-pipelines/determinations-access-arrangements/contingent-projects

Table 4 | Comparison of CPA costs and AER-approved costs (PV $m)

	Contingent Project Application	AER approved	Reduction
AusNet Services – Tranche 1	$119	$105	12%
AusNet Services – Tranche 2	$150	$134	11%
AusNet Services – Tranche 3	$119	$103	13%
Powercor – Tranche 1	$104	$93	11%
Powercor – Tranche 2	$146	$120	17%
Powercor – Tranche 3	$179	$127	29%
TOTAL	**$817**	**$682**	**17%**

Impact on consumer bills

The AER's CPA decisions (which cover the majority of the REFCL rollout) will increase average distribution network prices as follows.

For Ausnet Services:

- in 2018 by 1.18%, 2019 by 1.68% and 2020 by 1.68% in Tranche 1
- in 2019 by 1.5% and in 2020 by 1% in Tranche 2
- in 2020 by 0.11% in Tranche 3.

For Powercor:

- in 2018 by 1.13%, 2019 by 1.63% and 2020 by 1.63% in Tranche 1
- in 2019 by 2.2% and 2020 by 2.5% in Tranche 2
- in 2020 by 0.21% in Tranche 3.

Nous has approximated this impact on consumer bills using the AER's estimated impact of its Tranche 2 decisions as a benchmark.

- For an Ausnet Services residential customer's annual bill, this corresponds to a $8 increase in 2018, a $21 dollar increase in 2019, and a $19 increase in 2020.
- For an Ausnet Services small business customer's annual bill, this corresponds to a $16 increase in 2018, a $45 increase in 2019 and a $41 increase in 2020.
- For a Powercor residential customer's annual bill, this corresponds to a $5 increase in 2018, a $18 dollar increase in 2019, and a $21 increase in 2020.
- For a Powercor small business customer's annual bill, this corresponds to a $11 increase in 2018, $39 increase in 2019 and a $46 increase in 2020.[8]

[8] Analysis has been approximated using the AER's estimated impact of its Tranche 2 decisions on a typical customer bill. It uses the 2018 distribution component of an annual electricity bill, and the AER's derived typical annual electricity usage of residential and small business customers as a baseline, escalated by the average increase in distribution prices noted above, to produce the resultant impact in the final customer bill.

Collectively, this results in an annual electricity bill that is approximately 2.5 per cent higher for all customers in 2020 compared to 2017. Previous customer research undertaken by the Powerline Bushfire Safety Taskforce revealed that, on average, customers were prepared to pay 8 per cent more for their electricity to reduce the likelihood of powerlines starting bushfires with no deterioration in the reliability of their electricity supply, and 2 per cent more with a deterioration in the reliability of supply.[9]

However, there has been a material reduction in reliability on feeders from REFCL ZSSs (discussed in the next section). The operation of the Service Target Performance Incentive Scheme (STPIS), which provides an incentive to MECs to improve reliability, will pass through a proportion of this reliability disbenefit as a reduction in customer bills. The Nous best estimate is that the reduction in the PV of the MEC's costs that can be passed onto customers is approximately $67 million for Powercor and $70 million for Ausnet Services. This will not have a significant impact on the total annual electricity bill of each customer.

ESV exemptions

The MECs have sought to reduce costs by applying to ESV for exemptions from the REFCL installation requirements under section 120M of the *Electricity Safety Act 1998*, particularly for Tranche 3 installations. ESV has discretion to grant an exemption if to do so would be consistent with ESV's statutory safety obligations.

ESV has granted Powercor an exemption to transfer all sections of powerlines with bushfire ignition risk to a new complying ZSS at Gheringhap (formerly Bannockburn) and exempt the powerlines within the city of Geelong from the requirement to be REFCL protected. This saves approximately $3.9 million and avoids impact on 10 HV customers.

ESV is also considering an exemption application for Jemena to construct a new REFCL-protected ZSS in the Greenvale area to supply a feeder that accounts for the majority of its bushfire risk, and not to provide REFCL protection on the remainder of the network in that area where there is less bushfire risk. This would save around $16 million and eliminate the requirement for two HV customer connections to be made REFCL-compliant.

Our cost assessment

Our cost assessment is based on the MECs' latest documentation of their incurred costs and projected costs. The material that AusNet Services and Powercor provided us substantiated their assertions that their incurred costs and projected costs are broadly consistent with their requests in the CPAs, rather than the costs approved by the AER, with the following minor adjustments:

- Reductions of Tranche 2 HV customer costs to reflect the revised Victorian Distribution Code.
- Additional expenditure to overcome technical issues at specific ZSSs, complete ICT works, and provide for ongoing regulatory compliance.

Jemena has not submitted a CPA for the REFCL installation that is required at its Coolaroo ZSS by 2023; but provided us with projected costs of $31.7 million (which will approximately increase the annual electricity bill of its residential and small business customers by $5 and $10 respectively).

Cost categories

Through consultation with the MECs and analysis of incurred and projected costs, Nous identified that the main categories of their REFCL program costs include:

- ZSS works, including REFCL installation and replacement of assets that fail during network hardening tests.
- Network balancing to reduce capacitive imbalance.

[9] Powerline Bushfire Safety Taskforce, Final Report, 30 September 2011, page 51.

- Line hardening, including the replacement of surge arrestors, to withstand increased voltages due to REFCL operations.
- Replacing Automatic Circuit Reclosers (ACRs), voltage regulators and other assets that are incompatible with REFCLs.
- Ongoing costs such as routine maintenance and testing at ZSSs.

Costs attributable to REFCL program

Nous examined the MECs' costs to identify if any replacement and augmentation expenditure that has been classified as REFCL costs in the CPAs were incidental to the REFCL program and should be excluded from this cost-benefit analysis. We identified no costs that would have been spent regardless of whether REFCLs were deployed. It is likely that augmentation works that were triggered by the REFCL program will produce ancillary benefits that were not enough to justify those works on their own.

Some expenditure is included in the REFCL CPAs and subsequent applications to the AER to reduce the negative impact of REFCLs on supply reliability, because those amounts are being spent as a direct result of the REFCL program. Nous has included those costs as REFCL program costs. Nous classified the value of the increase in load lost in the estimate of the program's benefits (i.e. as a disbenefit).

Avoided costs

Nous reduced the cost estimates of the three MECs, by the estimated present value of the deferral of future replacement expenditure which arises from the early replacement of some assets to accommodate REFCLs. In other words, the extra cost of early replacement is partly offset by savings from deferring the next replacement.

To do this, Nous obtained estimates of the average remaining asset life for each major replacement expenditure category from the MECs, which was used to value the benefit of deferral of the next replacement of those assets. The avoided costs for each MEC represented approximately 7.6 per cent of its total capital expenditure.[10]

Results

Altogether, we identified the MECs' total REFCL related costs as described in Table 5, broken down by MEC into capital expenditure, operational expenditure and avoided costs.

Table 5 | MEC costs (PV $m)

	AusNet Services	Powercor	Jemena	Total
Capital expenditure	$411	$479	$32	$922
Operating expenditure	$16	$23	-	$39
Avoided costs	$32	$38	$2	$72
Total costs	**$395**	**$464**	**$29**	**$888**

Capital expenditure is the key driver of MEC costs. Each MEC broke down their key components of capital expenditure differently, as provided below.

[10] We derived 7.6 per cent based on our analysis of Ausnet Services' avoided cost. Based on Powercor's advice that the two networks are similar in this respect, we have applied this 7.6 per cent to both MECs.

- For Ausnet Services, 71 per cent is in augmentation, 27 per cent in replacement, and two per cent in other (using the breakdown in Ausnet Services' CPA).
- For Powercor, six per cent is in design, 44 per cent in feeder works, 37 per cent in substation works, and 12 per cent in contracts (using the breakdown in Powercor's CPA).
- For Jemena, 20 per cent is in feeder mitigation works, 36 per cent in zone substation costs, 16 per cent in REFCL costs, 12 per cent in connection costs, and 15 per cent in other costs.

3.2.2 HV costs

HV customers directly connected to REFCL networks will experience voltage rises on un-faulted phases when REFCLs compensate for a phase-to-earth fault. This increased stress can lead to electrical equipment failures and potential safety risks, so HV customers' installations are required to be hardened (by replacing equipment at risk of failure at increased voltages) or isolated from the MECs' networks (through isolation transformers). The cost of making HV customers' electrical installations compatible with REFCLs was not anticipated at the time of the RIS. Isolation transformers account for the majority of the costs.

During Tranche 1, the MECs were required to pay for HV customers' costs, and cost recovery was allowed by the AER in response to the MECs' Contingent Project Applications. However, in 2018 the Electricity Distribution Code was amended to transfer responsibility for the cost of compatibility works from MECs to HV customers in Tranche 2 and 3.

To aid with these costs and recognising that it can be a significant financial burden, the HV Customer Assistance Program (HCAP) was established to provide financial assistance to HV customers in the private sector and is administered by DELWP.

A diverse group of manufacturing and other companies have been granted assistance. Public sector organisations including the Department of Transport, Department of Health and Human Services, and Deakin University have incurred costs that were funded by the MECs in respect of Tranche 1 and will be self-funded for Tranches 2 and 3.

Nous obtained information from DELWP and HV customers on the incurred or projected costs of all HV customers affected by the REFCL program. A summary is provided in Table 6.

Table 6 | HV customer costs (PV $m)

MEC expenditure	$45
HCAP	$8
Private HV Customer expenditure not covered by HCAP	$11
Public sector organisations	$115
Total costs	**$180**

3.2.3 Comparison with the cost estimates in the RIS

The first official forecast of the cost of a REFCL rollout was made by the Powerline Bushfire Safety Taskforce (PBST) in its 2011 report.[11] The PBST estimated REFCL capital costs to be $4 million per REFCL

[11] Powerline Bushfire Safety Taskforce (PBST) Final Report, available here: https://esv.vic.gov.au/wp-content/uploads/2020/01/PBST_final_report_30Sep2011.pdf

(2011 dollars, undiscounted) and assessed two scenarios: $156 million to install 39 REFCLs, and $432 million to install 108 REFCLs.

Following the PBST report, the RIS drew on CSIRO's fire loss consequence mapping to determine that 90 per cent of the bushfire risk reduction potential from installing REFCLs can be achieved by installing REFCLs in just 45 ZSSs that were included in the mandated program. This deployment scenario was costed in the RIS.

After making adjustments of the figures in the RIS to make them reasonably comparable with the cost assessment, Nous arrived at a RIS forecast cost of $302 million in 2020.[12]

While Nous was not engaged to analyse the reasons for the gap between the cost estimate made under this engagement and earlier forecasts, our consultations and analysis identified the following technical factors as significant causes:

- More complex installations (including extensive line capacitive rebalancing works, increased number of surge diverters to be replaced, conflicts with existing distribution feeder automation systems, and installation or modification of switchboards).
- The need for multiple REFCLs in some ZSSs.
- Project management, procurement of land to house additional equipment, zone substation rebuilding.
- Expenditure associated with supply reliability.
- Higher HV customer costs, due at least in part to a preference for isolation of customers' installation over hardening.

It is normal for the full and final costs of large and complex infrastructure projects to be revealed only while the works are being undertaken. Initial estimates must rely on partial data and simplified assumptions, which can only be verified or disproved when construction begins. This risk was magnified by the novelty of this program: Victoria's use of REFCLs for bushfire prevention in rural areas with long lines, difficult terrain, and high vegetation cover is a world-first, so there has been no Australian or overseas experience to rely on in installing or operating REFCLs for this purpose. Costs become particularly unpredictable when scaling up an innovative use of technology, given that these REFCLs are required to meet exacting performance standards to provide the target level of risk reduction.

It will take many years to gather statistically significant operational evidence that might have justified the adoption of lower cost performance requirements, so a staged and adaptive rollout would have introduced significant additional bushfire risk before the rollout was completed.

United Energy (UE), which installed REFCLs in its network at its own initiative, advised Nous that REFCL installations with significantly lower sensitivity and functionality than are required by the regulations could result in material savings. UE has adopted lower sensitivities because it does not supply areas with comparable bushfire risks to those which are subject to the mandated REFCL program.

UE notes, for example, that installing a second REFCL to meet the regulated sensitivity can increase the installation cost in a ZSS by 40 per cent (noting that some of the increase in cost is due to the installation of two REFCLs in one ZSS). Other savings are possible by limiting the functionality of the REFCL and the extent of hardening works. However, such savings would not comply with the regulations and may increase the risk that REFCLs will not prevent fires during faults in extreme conditions.

[12] The $302 million ($2020) reflects the total RIS estimated cost, including approximate costs for Gisborne, Kilmore South, Woodend, and Woori Yallock, which were excluded in the RIS estimates. The total RIS estimated cost was then reduced by 7.6% (in-line with our avoided cost estimation) and escalated by inflation.

3.3 Benefits

Nous identified three categories of impacts arising from the installation of REFCLs:

- Bushfire starts.
- Supply reliability.
- Electrocution.

These three categories are discussed below.

3.3.1 Bushfire starts

REFCLs can prevent bushfires from occurring when a so-called 'phase to earth' fault occurs, such as when a live powerline breaks and hits the ground, or is contacted by vegetation and creates a fault current to earth. In these circumstances, a REFCL installed at the ZSS from which the powerline runs is designed to reduce the flow of current into the ground to near-zero, quickly enough to prevent the current from starting a fire.[13]

The REFCL program was a response to Victoria's Black Saturday fires. The extreme heat and wind experienced on that day caused powerline failures that would not have occurred in most weather conditions – and had they occurred, would have resulted in much less loss of life and property. The extreme conditions that make powerline faults more likely also magnify the intensity, speed, and spread of fires.

Nous took a conservative approach in estimating the benefits of REFCLs being limited to preventing **catastrophic fires**, rather than including the prevention of **lower consequence fires**. There are two interrelated reasons for this approach:

- REFCLs are intended to reduce the possibility of catastrophic bushfires by operating as a last line of defence against fire starts due to powerlines in extreme weather conditions. 'Upstream' fire prevention measures – such as asset maintenance and upgrades, and vegetation clearance around powerlines – are most likely to prevent lower consequence fires that may occur on days with less extreme weather conditions (ie they are less likely to work effectively on days with extreme weather conditions).
- Even though REFCLs will be able to reduce the ignition likelihood of some lower consequence fires, the aggregate benefit of preventing one catastrophic fire will significantly outweigh the benefit of reducing several lower consequence fires.

Estimating benefit (avoided cost) of catastrophic bushfires – method and limitations

Estimating the benefits of REFCLs in preventing bushfires is a highly uncertain task – so uncertain that the calculation of benefit-cost ratios, as is typically done to justify large infrastructure expenditures, should be employed with considerable caution and qualification. Indeed, the calculation of a single benefit-cost ratio would convey a false sense of precision.

It is well accepted that neither the frequency nor the cost of extreme events can be reliably estimated. However, an indicative range of estimates can be made of the present-day cost of such catastrophic bushfires that the REFCL rollout is expected to prevent.

It is acknowledged that there is also potential for REFCLs to reduce the risk of lower consequence fires, however no attempt to monetise these benefits for this CBA has been made because REFCLs operate as a last line of defence against fire starts due to powerlines. The costs of the Black Saturday fires as a proxy for this purpose.

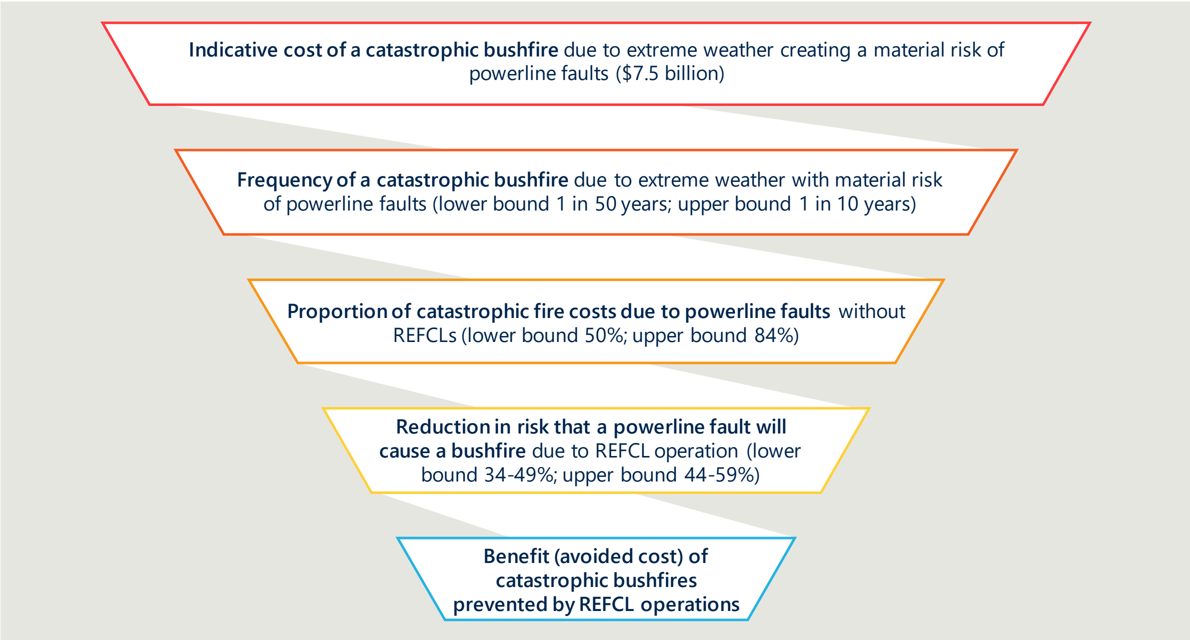
[13] Electricity Safety (Bushfire Mitigation) Regulations 2013, subsection 7(3).

For this report, this indicative cost was reduced by the proportion of fires that are expected to be caused by powerlines, then further reduced by the proportion of powerline-caused fires that are expected to be prevented by REFCLs. Upper and lower estimates of these two parameters were used to reflect uncertainty about their future values.

The resultant benefit estimates of avoiding this cost were discounted using a plausible range of the annual probability of a future catastrophic fire.

The methodology and variables are depicted visually in Figure 3. The basis of these figures is summarised in the subsections that follow and are provided in the calculated benefits in Section 4.

Figure 3 | Benefits methodology



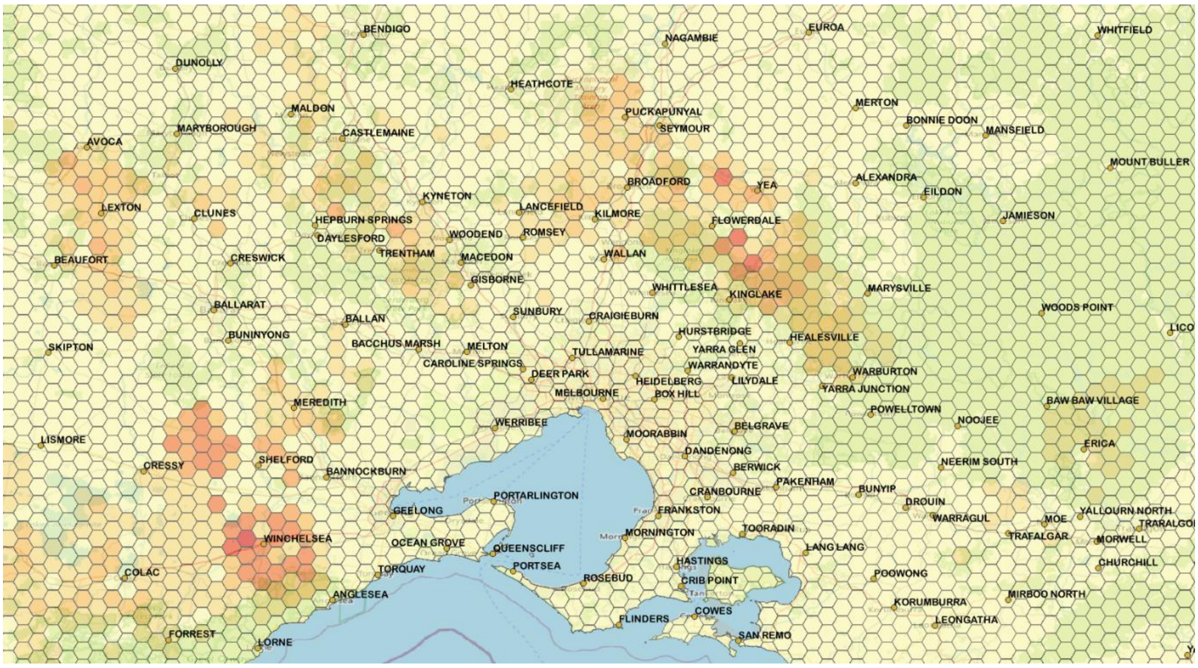
Variable 1: Indicative cost of a catastrophic bushfire

As discussed above, the cost of the Black Saturday fires was used as a proxy for the representative cost of a catastrophic fire event resulting from extreme wind and temperatures which make powerline failures a significant cause of fire starts (i.e. in the absence of REFCLs).

Estimates of the cost of catastrophes are sensitive to the choice of cost categories which are included – particularly intangible costs (i.e. costs which cannot be directly measured, such as the value of lives lost, injuries, reduced mental health, and damaged ecosystems). They are also necessarily sensitive to the method by which those intangible costs are estimated.

The scope of this engagement did not include the development of a 'ground-up' estimate, so existing studies were drawn on which have estimated the costs of Black Saturday. In choosing Black Saturday as a proxy, a worst-case example is not selected, rather a representative guide to the destruction that powerline faults can cause on days of plausible and similar severity. As evidence, CSIRO produced a 'heat map' in and around Melbourne as provided in Figure 4, with the colour intensity increasing in line with the consequence of a fire starting in that hexagon. It shows that the Black Saturday area (Broadford to Kinglake) is intense, but not as intense as the West of Geelong (Cressy to Anglesea), or the Flowerdale to Warburton area.

Figure 4 | Fire consequence heat map



To estimate the costs of Black Saturday, two key reports were thoroughly examined: the Victorian Bushfire Royal Commission's study and a paper produced by Deloitte Access Economics.[14] The estimated Black Saturday costs from these two studies are provided in Table 7.

Table 7 | Comparison of Black Saturday costs between Bushfire Royal Commission and Deloitte ($m)

	Bushfire Royal Commission	Deloitte Access Economics
Tangible costs[15]	$4,683	$3,380
Intangible costs	$811	$4,187
Total	**$5,495**	**$7,567**

Deloitte's higher estimates reflects its inclusion of a wider range of intangible costs. The Royal Commission only included a valuation of lives lost and physical injury, whereas Deloitte's estimates include additional intangible costs, including:

- Mental health – $1 billion (including post-traumatic stress disorder, depression and psychological distress).
- Alcohol and drug misuse – $210 million.
- Chronic disease - $350 million.
- Family violence - $1 billion.
- Environmental - $450 million.

[14] Victorian Bushfires Royal Commission, *Volume I: The Fires and the Fire Related Deaths*, July 2010.
Deloitte Access Economics, *The economic cost of the social impact of natural disasters*, March 2016.
[15] Note: VBRC tangibles include response costs and damage costs, which include insurance cost. DAE's tangibles include insurance costs that were escalated to total economic cost by a scaling factor.

Despite the inherent complexity of calculating intangible costs, it is our judgement that they should be included in the benefit of avoiding a catastrophic bushfire. It is well accepted that natural disasters incur costs beyond the tangible expense of emergency response and damage to property and infrastructure. Not to include plausible provision for these benefits would be a larger error than excluding them altogether.

As such, Deloitte's $7.5 billion estimate has been incorporated into our model. It is important to note that this report has not critiqued Deloitte's estimates of intangible costs or sought to produce alternative figures. The nature of intangible costs is that the validity of any estimate is necessarily debatable. Deloitte's estimates were produced for the Australian Business Roundtable for Disaster Resilience & Safer Communities, drew on academic journals and research, have not been seriously questioned to our knowledge, and have not been supplanted by more recent or rigorous estimates. We have not used a lower and upper bound for intangible costs because Deloitte did not produce such a range, and there are no studies which provide guidance as to what a reasonable range might be.

The use of Deloitte's estimates is not an implied criticism of the Royal Commission's estimates. The Royal Commission specifically stated that it sought only to gain a broad estimate of the economic costs, as a starting point and to stimulate further debate. The report states that calculating a definitive estimate was difficult due to the unavailability of data and absence of agreed methodology for calculating the various costs, even suggesting further research into the development of a methodology for costing bushfires would be valuable for policymakers and the community.[16]

Lastly, it is worth noting this report recognises that single-wire earth return (SWER) lines, not polyphase lines on which REFCLs operate, were a major cause of the costs of Black Saturday. However, this does not invalidate this approach. Black Saturday's costs are relevant because it is plausible that a catastrophic fire event of equivalent magnitude could result from polyphase lines, particularly given polyphase circuit faults are a much more common cause of electrical faults with the potential to cause bushfires. Further, it was decided that a wide range of attribution factors to account for variations in the contribution of polyphase lines to catastrophic fire costs, as discussed below.

Variable 2: Frequency of a catastrophic bushfire

A key variable is the frequency with which a catastrophic bushfire event – in which powerline failure is a significant fire cause – would occur in the absence of REFCLs. Again, the high uncertainty means that no precise estimate can be made. After considering the available evidence as set out in the following paragraphs, it was determined that a broad range is appropriate for this variable. This report has used a lower bound of 1 every 50 years (an annual probability of 0.02) and an upper bound of 1 in every 10 years (annual probability of 0.1) for the occurrence of a future catastrophic fire event in conditions which are conducive to powerline failures being a significant cause of fire starts.

The historical evidence to draw upon is unavoidably scarce. Victoria's two worst bushfire disasters (Ash Wednesday 1983 and Black Saturday 2009) were 26 years apart. There are factors that will variously increase and decrease the frequency with which catastrophic bushfires are likely to occur. Bushfire safety initiatives are designed to decrease the frequency of bushfires, which is broadly reflected in a conservative lower bound estimate of 1 in every 50 years. By contrast, climate change is predicted to further increase the frequency of catastrophic bushfires, which is more consistent with the upper bound estimate of 1 in every 10 years.

These countervailing factors are discussed below.

[16] Victorian Bushfires Royal Commission: Volume 1 Appendix A; Volume 2 Chapter 11.

Bushfire safety initiatives

Changes were made to the legislative and regulatory regime governing powerline bushfire safety following Black Saturday, with a range of initiatives since implemented to reduce fire starts. In particular MECs have:

- replaced poles, cross arms; and sections of conductor and installed armour rods, vibration dampers, and low voltage spreaders
- increased the vegetation clearance distance between powerlines and trees through line clearance practices.

The fire data from ESV and the MECs does not allow to conclusively increase or decrease our estimate of the frequency of extreme bushfires. However, the analysis indicates that while there is no overall declining trend in the number of fires per year, there appears to be a declining number of fires due to asset failures. The key results from ESV and Ausnet Services are discussed below.[17]

Table 8 | Impact of bushfire safety initiatives

ESV's 2019 Safety Performance report does not indicate a declining trend in fire-starts across the 2015-19 period. The cumulative fires in 2018-19 was lower than in 2015-16 and 2017-18, but higher than 2016-17. This is despite the 2018-19 period having a high number of total fire ban days.

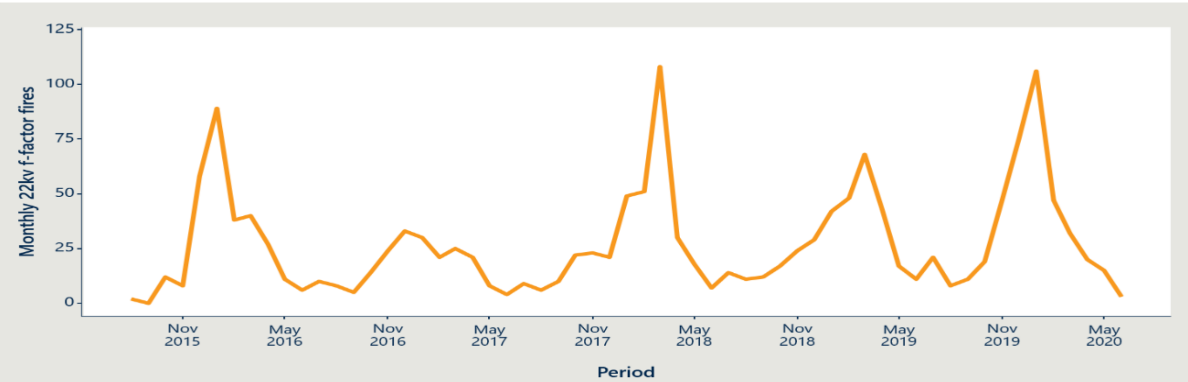
Further, the ESV's 22kV F-factor fire data was examined, which expands the period from up to 2018-19 in the Safety Performance report for 2019-20 (Figure 5). As expected, the number of fires follow a seasonal pattern with peaks in the summer and troughs in winter. The number of F-factor fires fluctuate year-on-year, being significantly higher in the summers of 2015-16; 2017-18 and 2019-20 relative to 2016-17 and 2018-19. The pattern is likely to be predominately driven by the meteorological factors in each of these years. Overall, there is no observable F-factor fire trend.

However, while there is no clear trend in the total number of fires over time, there is evidence that the number of incidents resulting from asset failures has declined.

The implementation of bushfire safety initiatives has reduced the number of incidents on AusNet Services' network with fire potential by approximately 40 per cent over the 2009-18 period.[18] They have also reduced the number of fire starts over the same period by approximately 50 per cent, with most of this reduction driven by the reduction in asset fires.

This is supported by ESV's Safety Performance report, which illustrates that the number of fire incidents resulting from asset failures across all Victorian networks in the 2018-19 period – particularly during the summer months – were well below the 2010-18 average.

Figure 5 | Monthly 22kV F-factor fires



[17] Powercor has not separately provided information on the fire start performance of its network.
[18] Information provided by AusNet Services.

Climate change

Climate change will see an increasing number of days of total fire ban where the weather conditions are conducive to potentially catastrophic fires. Critically, as discussed by the Powerline Bushfire Safety Taskforce Final Report,[19] bushfire safety measures are less likely to be effective on Code Red days than on other days. This is because powerlines are designed for a maximum loading based on temperature and wind, and they face higher stress on Code Red days due to very high temperatures, winds and loads. These days are forecast to occur more frequently given climate change.

Several recent studies support the assertion that climate change is increasing the frequency of catastrophic bushfires, as detailed in Table 9 below.

Table 9 | Research into climate change and fire risk

- DELWP's *Victoria Climate Science Report 2019* finds an increase in dangerous fire weather and length of fire season since the 1950s, including a trend in recent decades towards a greater number of very high fire danger days in Spring. It reports that the increase in the number, size, and severity of Victoria's bushfires in recent decades has meant scientists have concluded that climate change has caused heightened bushfire risk.
- 2020 research published by the *World Weather Attribution* examined whether, and to what extent, climate change has altered the likelihood and intensity of fire risk in south eastern Australia using a Fire Weather Index to measure the most intense fire risk, and Monthly Severity Rating to measure overall seasonal fire risk.
  The study found that the Fire Weather Index increased by at least 30 per cent since 1900. It also shows a significant trend towards higher fire weather risk since 1979. Compared with the 1900 climate, the probability of the index being as high as in 2019/20 has increased by more than four times. For the Monthly Severity Rating, the probability has increased by more than nine times. The study attributed part of these results to climate change.
- In 2019 in California, the *Governor's Strike Force* released a report on Californian fires and climate change, finding that the state faces a dramatic increase in the number and severity of wildfires, with 15 of the 20 most destructive wildfires occurring since 2000 and the fire season getting longer ever year.

Variable 3: Proportion of catastrophic fire costs due to powerline faults

This report has estimated that the proportion of the total costs of a catastrophic fire event that creates conditions in which powerline failures, are likely to be a significant cause. This is because REFCLs can reduce the likelihood of bushfires caused by powerlines, but not by other causes such as lightning and arson.

To use a single figure for the percentage of costs attributable to powerline failures would also represent false precision. Instead a derived two plausible estimates is used as the lower and upper bound, drawing on two different figures in the RIS:

- 50 per cent is the lower bound, representing the proportion of Victoria's last three catastrophic bushfires (those of 1977, 1983, and 2009) caused by electricity assets. On days of extreme heat and wind, powerline-caused catastrophic fires are more likely to have greater consequences. Whilst this cannot absolutely guarantee that the proportion of catastrophic fire costs due to powerline faults could never be below 50 per cent, it adds to the conservativism of our estimate.
- 84 per cent is the upper bound, being the proportion of Black Saturday costs attributable to electricity related fires starts.

[19] Powerline Bushfire Safety Taskforce (2011), Final report, available here: https://esv.vic.gov.au/wp-content/uploads/2020/01/PBST_final_report_30Sep2011.pdf

Variable 4: Reduction in risk that a powerline fault will cause a bushfire

The final key variable to calculate bushfire benefits is the reduction in risk due to the operation of REFCLs. This is applied to the sums estimated through the three prior variables. Risk reduction is modelled by CSIRO at a ZSS level. There are three factors that determine the extent of risk reduction at each ZSS:

- The number of polyphase powerlines (on which REFCLs operate) relative to SWER powerlines.
- The proportion of phase-to-earth faults (in respect of which REFCLs can prevent fire starts) relative to phase-to-phase faults.
- An assumption that REFCLs are technically effective 90 per cent of the time.

CSIRO estimates for REFCL risk reduction range between 34 to 49 per cent for specific ZSSs. This has been used as a lower bound. Given the promising performance to date of REFCLs as discussed in Table 10, an upper bound which is 10 percentage points higher has been applied, namely 44 to 59 per cent.

No evidence suggests that the risk reduction rate is below the lower bound. Rather, based on the best available evidence as described in Table 10, REFCLs appear to be operating during complex faults (phase-to-phase faults that subsequently lead to phase-to-earth faults), which was not reflected in CSIRO's rates.

For both the lower and upper bounds, an apportioned a 'risk weight' score has been used that CSIRO attributes to each ZSS. This score is based on the likelihood of faults and fire ignitions at locations based on vegetation, terrain, and other factors.

Table 10 | REFCL performance to date

ESV and Powercor's REFCL-related fire and fault data were examined.[20]

The impact of REFCLs was sought by analysing the number of fire starts due to faults on powerlines fed from zone substations before and after REFCLs were installed. For zone substations with a REFCL operating during the 2019/2020 bushfire season, there was an average of 15 fire starts per year from July 2015 to July 2019. In 2019/2020 there were 19 fire starts across the same REFCL stations.

However, this increase is an unreliable guide to the operation of REFCLs. One year's data is not statistically significant, and environmental factors can vary substantially from one year to the next, changing the probability of many fire starts which are not targeted by powerline bushfire safety initiatives. Further, some fire starts cannot be prevented by REFCLs, and on lower fire risk days the sensitivity of REFCLs is lowered to reduce the customer impact of outages. In other words, REFCLs are not operated to eliminate all fire starts.

A more useful guide to the effectiveness of REFCLs is to analyse their operation on high fire risk days. Although there is currently no formal system in place to collect data on REFCL operations that prevented a fire, Powercor has documented case studies and fault information that demonstrate REFCLs working as intended, and also operating unexpectedly to help prevent fires from complex faults.

Specifically, Powercor provided five REFCL case studies over the 2019-2020 period. In three cases, a REFCL detected a fault, operated and tripped a feeder. The REFCL was subsequently removed from service to restore supply because the fault could not be located. The restoration of supply without the REFCL in full operation resulted in a fire start in each instance. In the fourth case of a complex multi-phase fault, a large tree came down on a powerline and pushed two phases together, causing a phase to phase fault. The third phase remained active and was entangled within vegetation on the ground. A REFCL prevented a fire by limiting the fault energy and disconnecting the feeder. In the final case study, Powercor discussed how its work crew contacted a blue phase conductor multiple times over a three-minute period. The work crew was not injured due to REFCL operations.

Further, Powercor provided a list of faults on REFCL zone substations on each of the total fire ban days of 21 November 2019, 20 December 2019, 30 December 2019, and 4 January 2020. This is summarised in Table 11 below. This list of faults is split into:

[20] Ausnet Services did not provide REFCL related fault and fire data.

1. Permanent faults due to REFCL operation.
2. Permanent faults not due to REFCL operation (e.g. phase to phase).
3. Complex permanent faults that initially were not REFCL related but subsequently led to a REFCL operating.

Together, REFCL related faults on these four TFB days accounted for more than half of the total faults (18 out of 30). None of these faults resulted in a fire.[21] The large proportion of these REFCL faults, combined with the fact that any one of them could have led to a fire start in the absence of REFCLs, provide promising evidence of REFCLs' effectiveness.

It is premature to draw firm conclusions about the effectiveness of REFCLs, and a mandatory reporting system that analyses each REFCL operation is an important measure to enable this to be done in future years. However, the 21 November 2019 is very significant. Had REFCLs not prevented fires on that day, it is possible that considerable fire damage would have resulted. There is a risk that the future impact of REFCLs will be underestimated. It is harder to prove that a powerline-initiated fire was prevented than that one occurred.

Table 11 | Faults on REFCL-protected Powercor feeders - 2019/20 summer TFB days

	21 November 2019	20 December 2019	30 December 2019	4 January 2020
Permanent REFCL faults	6	4	1	-
Permanent non-REFCL faults	4	2	6	-
Complex permanent faults that led to REFCL operation	4	-	2	1

3.3.2 Supply reliability

REFCLs can impact the reliability of supply in two different ways.

- **Momentary interruptions** – the operation of REFCLs reduces momentary outages from transient faults.
- **Sustained interruptions** – REFCLs increase the impacts of prolonged power outages by increasing the number of customers taken off supply in some fault types because protection devices that are intended to confine the outage to a small number of customers cannot operate in time, so the entire feeder is tripped at the ZSS. Also, some faults can take longer to be located and repaired, so the outage not only affects more customers, it affects them for longer.

REFCLs are used in Europe to increase supply reliability and electrical safety. Based on this experience, the 2015 RIS assumed that reliability would improve from the use of REFCLs in Victoria. Subsequent analysis identified the risk that reliability would instead deteriorate.

The MECs are planning to mitigate this reduction in supply reliability. Powercor proposes to install 'Smart ACRs' that would be intended to operate more quickly than existing ACRs, compatible with the speed of REFCLs, to reduce the number of customers who lose supply in some faults. This is expected to only partly restore reliability to pre-REFCL levels. There is no existing technology that will replicate the pre-REFCL

[21] Checked against the ESV's F-factor fire data.

operation of fuses that limit the impact of downstream faults to a small number of customers. This means that supply reliability will improve but will not return to pre-REFCL levels.

It is possible that later innovations and investments may produce further gains in reliability; this will be examined by PSC in its report to ESV. However, this report has not made allowance for such an improvement because of the absence of evidence of its feasibility.

It is also expected that there will be some countervailing reliability improvements because the operation of a REFCL in a phase-to-earth fault will greatly limit fault currents, thus preventing damage to expensive upstream equipment (e.g. transformers) that would result in a sustained supply interruption to a large number of customers.

Table 12 shows that the disbenefit from increased sustained interruptions greatly outweighs the benefit from reduced momentary interruptions. The methodology for calculating these figures is outlined below. This estimate is arguably conservative, in that operational experience and modest investments have the potential to improve reliability to a greater extent over time.

Table 12 | Supply reliability benefits (PV $m)

Sustained interruptions	-$317
Momentary interruptions	$16
Total	**-$301**

Our methodology

Nous has analysed the impact of REFCLs on sustained interruptions by using Powercor's model as a benchmark.[22] Powercor has forecast an increase in sustained customer-interruptions above its five-year historical average due to the operation of REFCLs. We have valued this loss of reliability by estimating the associated loss of customer load and multiplying this by the value of customer reliability (VCR).

A consumption-weighted average value of customer reliability ($35,809/MWh) was used, which reflects the mix of residential and non-residential customers supplied from Powercor's REFCL ZSSs. This produced a sustained reliability disbenefit of approximately $0.75 million per zone substation.

Powercor estimated that Smart ACRs will limit the reliability disbenefit to approximately 50 per cent of the forecast disbenefit without Smart ACRs. The investment to install Smart ACRs is included in the REFCL program's costs. Given AusNet Services also has programs to address REFCL reliability disbenefit (such as Distribution Feeder Automation, which relies on the same Smart ACR technology), a 50 per cent reliability improvement from 2021 onwards was applied, consistent with Powercor's model.

The impact of momentary interruptions has also been analysed by examining the Momentary Average Interruption Frequency Index impact of REFCL zone substations in 2019/2020 compared to its four-year historical average, because 2019/2020 is the first full season in which several REFCLs have been in operation.

The impact of REFCLs on momentary interruptions was then converted to a benefit per substation figure using customer load (residential and non-residential) and the AER's VCR. For Jemena, we have used an average of the zone substation figures for Powercor and Ausnet Services. We assume that the beneficial impact of REFCLs on momentary interruptions will remain the same throughout the remaining life of the REFCLs.

[22] PAL MOD 4.04 – Smart ACR benefits – Jan 2020 – Public.xlsx.

As stated above, this is arguably a conservative estimate of the reliability impacts of REFCLs. Experience and operational innovation may have the potential to restore reliability close to pre-REFCL levels.

3.3.3 Risk of electrocution

The final category of benefits identified is non-bushfire related benefits, or more specifically, reduction in the risk of electrocution due to contact with powerlines fed from ZSSs equipped with REFCLs.

For context, in the 2018/19 financial year, there were two fatalities from electrocution caused by contact with a powerline. In one case, a man was electrocuted while trying to dislodge a felled tree that hit a 22kV powerline. In the other case, a vegetation worker clearing trees along a nature strip made contact with low voltage lines.

REFCLs can reduce the risk of shocks and electrocution by quickly reducing the voltage of faulted conductors following certain types of faults. However, although faults occur frequently on Victoria's distribution networks, it is rare that powerlines result in the electrocution of people, and it is unclear what impact a REFCL would have on public safety in such events.

Accordingly, we have not tried to quantify the effect of REFCLs on the risk of electrocution. Even if it transpires that the impact is favourable, the benefits will be low compared to the benefit of bushfire prevention.

4 Conclusions

There are large and inherent uncertainties involved in quantifying the benefits of the REFCL program, due to the unpredictability of the cost and probability of an extreme bushfire. There is compounding uncertainty in the risk reduction rate due to REFCLs at each zone substation, and in the proportion of future catastrophic bushfire costs that will be caused by electricity assets.

For that reason, a single benefit figure has not been calculated. This would convey a false sense of precision. Instead we have calculated a 'benefit range' in Figure 6 overleaf, which represents a plausible range of benefits. The zone reflects:

- The estimated cost of Black Saturday as a proxy for the cost of a catastrophic fire event due to conditions that are conducive to powerline failures.
- The probability of such a catastrophic fire event (ranging from 1 in 50 years to 1 in 10 years).
- The upper and lower bounds of the proportion of catastrophic bushfire costs due to electricity assets, the risk reduction rate due to REFCLs.
- The reduction in supply reliability due to the operation of REFCLs.

The benefit zone is overlaid with a solid line showing the cost of the REFCL program. It shows that for the upper bounds described above, the program is justified for almost the entire probability range. For the lower bounds, it is justified for probabilities greater than 0.05 (1 in 20 years or less). It indicates that the program remains a sound investment despite the increase in cost.

Climate change is expected to increase the benefits, reflecting the expected increase in the frequency and severity of extreme weather events. Bushfire mitigation measures other than REFCLs (other network investments, early evacuation practices, better management of vegetation and distribution assets, higher building standards, and changes to zoning laws) would reduce the benefits. There is no reliable way to assess which of these competing influences will prevail over the other.

There has been a substantial increase in the cost of the REFCL program above the estimates that were used in the 2015 Regulatory Impact Statement. There has also been a substantial increase in the estimated costs of a catastrophic fire since the RIS (hence an increase in the potential benefits of the REFCL program) due to more recent valuations of a wider range of intangible costs.

Figure 6 | REFCL program costs and benefits

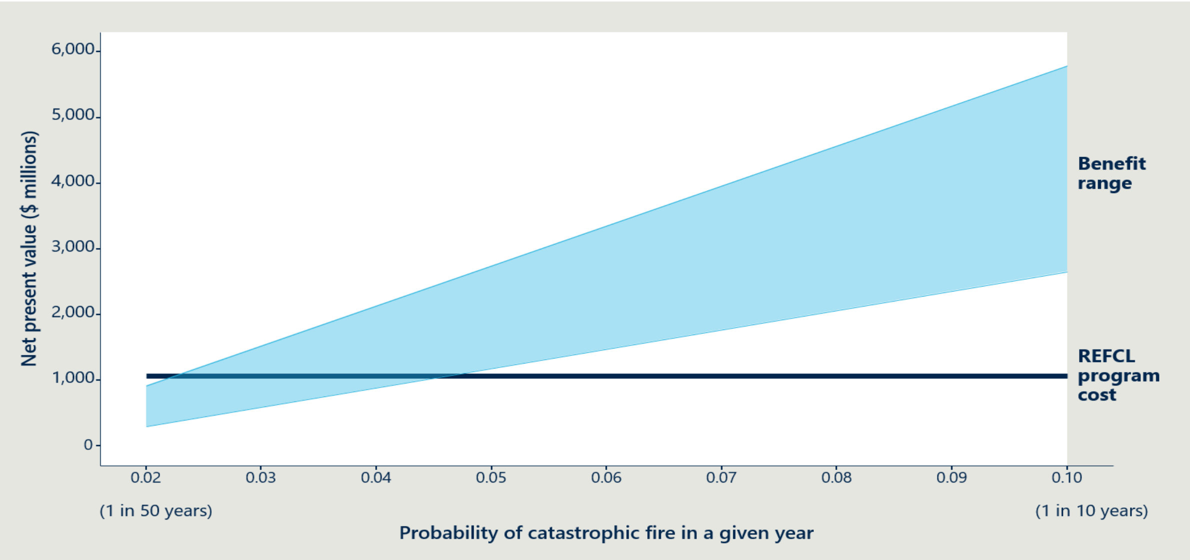


Table 13 | Headline results ($m)[23]

	Minimum probability of extreme event with low benefit assumptions	Minimum probability of extreme event with high benefit assumptions	Maximum probability of extreme event with low benefit assumptions	Maximum probability of extreme event with high benefit assumptions
PV benefits	$290	$916	$2,656	$5,786
PV costs	$1,068	$1,068	$1,068	$1,068
NPV (benefits minus costs)	-$778	-$152	$1,588	$4,718
BCR	0.3	0.9	2.5	5.4

Our judgement is that it is likely that the cost of the REFCL program will prove to be a prudent investment in mitigating future catastrophic fire damage caused by powerline failures in extreme weather conditions.

This conclusion comes with important caveats. REFCLs have been in service for only a brief period, and their operational reliability and impact can only be conclusively assessed over several years. This conclusion relies on the valuation of intangible costs which by definition cannot be directly valued. And if the probability of a fire event comparable to Black Saturday proves to be at the low end of the range we have employed, the benefits of the program would not be justified by its costs.

However, it is possible that our conclusion is conservative. The combination of climate change, the better operation of REFCLs as experience is gained, and the limitations of other mitigations on days of extreme fire risk, may make the benefits much higher than the program's cost.

Recommendation

The REFCL program is well underway, and the practical need at this stage is to maximise its benefits and minimise its costs to the greatest extent possible. To that end, Nous has identified one recommendation:

ESV should improve its monitoring of REFCL performance.

ESV already collects detailed fault and fire start data which it uses to track fire starts. The link between this data and REFCL performance could be enhanced, and we recommend that following each bushfire season, ESV seek information from the MECs for this purpose.

Data collected could include:

- instances of REFCL operation
- the type of faults operated on
- whether or not the fault became a fire
- the impact on System Average Interruption Duration Index (SAIDI) and Momentary Average Interruption Frequency Index (MAIFI).

ESV should analyse this information before sharing lessons widely, which may influence the future operation of the mandated REFCLs, and the possible future deployment of additional REFCLs and other bushfire mitigation options.

[23] The 'low' scenario represents low cost proportion of extreme event due to electricity assets, and low risk reduction rate. The 'high' scenario represents high cost proportion of extreme event due to electricity assets, and a high-risk reduction rate.