Options Evaluation Report (OER)

Panorama No.2 Transformer Refurbishment Program
OER- **N2404** revision **4.0**

Ellipse project no(s):

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Project reason: Capability - Asset Replacement for end of life condition

Project category: Prescribed - Asset Renewal Strategies

Approvals

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Change history

Revision	Date	Amendment
00	9/11/2021	Initial
01	11/11/2021	Formatting Changes
02	14/11/2021	Reissue PDF (no other change)
03	21/10/2022	Updated analysis and evaluation including: • Analysis updated with FY22 values • Amendment of environmental disproportionality factors • Removal of reputational risk • Consideration of in-situ replacement scope and technical feasibility of refurbishment
04	31/10/2022	Version history added

Executive summary

Power transformers are essential for a safe and reliable electricity transmission as they enable different voltage levels throughout the transmission and distribution networks. As part of the condition assessment and health index methodology, Panorama No.2 132/66kV transformer has been identified as reaching end of life and with an increasing risk of failure. The Need of this project is economic benefit, with risks to be considered for remediation within the 2023 – 2028 regulatory period.

Panorama 132/66kV Substation is located in TransGrid's central NSW network. It connects to TransGrid's 132 kV Wallerawang and Orange North substations. It also connects the Essential Energy 66kV distribution network which supplies industrial and residential loads in the Bathurst region.

There are two 132/66kV transformers at Panorama Substation which were both commissioned in 1981, this need only considers the No.2 transformer. The health index considers natural age, dissolved gas analysis (DGA), oil quality (OQ), Bushing DDF, defects, load and corrosive oil.

The No.2 transformer is approaching the end of its serviceable life and showing signs of deterioration due to the following key factors:

- Natural Age: The transformer was manufactured in 1980 and commissioned in 1981. The natural age of the transformer will be 43 years in 2022/23 and will be above its 45-year expected useful life by the end of 2023-2028 regulatory period.
- Aged Synthetic Resin Bonded (SRBP) Bushings: SRBP bushings are known to have a type fault which results in delamination of the bushing paper over time, resulting in catastrophic failure of the transformer. The 132kV and 66kV SRBP bushings were originally installed in 1980 are well above the 30-year useful life of high voltage bushings.
- Corrosive Sulphur: The insulating oil has corrosive sulphur, which can form conductive compounds on the insulation paper and tap changer contacts. This can cause an internal flashover and could lead to a catastrophic failure.
- Oil leaks: There are leaks from the lid hatches, pipework bushings, terminal boxes and conservator, allowing moisture ingress and oxygen into the main insulation.
- Corrosion: The paint and galvanic protection on the transformer has failed, resulting in rusting and deterioration.

These condition issues have been evaluated through the transformer health index methodology to give an effective age for the No.2 Transformer of 50 years (2022/23), which significantly above its chronological age. These condition issues, if not remediated, increase the probability of transformer failure.

The No.1 transformer at Panorama substation is in satisfactory condition with an effective age of 44 years (2022/23), which is above its chronological age by one year and not part of this need as it has been refurbished in 2018-2023 regulatory period.

These condition issues, if not remediated, increase the probability of transformer failure. The replacement of the Panorama No.2 Transformer would significantly reduce the likelihood of prolonged and involuntary load shedding in the Central region and help TransGrid manage its safety obligations.

The key economic benefits associated with addressing this need are summarised as:

- Reduction of risk as valued as a direct impact to TransGrid and consumers including:
  - Changes in involuntary load shedding
  - Safety and environmental hazards associated with a catastrophic failure.
- Avoided operating expenditure related to corrective maintenance;

Two options have been considered to address the increasing risk of failure of the Panorama Transformer, as shown in Table 1 below. These options are the complete replacement of the transformer with a new unit (option A) and refurbishment of the existing transformer involving replacement of bushings attempting to address the identified condition issues (option B).

The preferred option is the replacement of the Panorama No.2 transformer (option A). This option is technically feasible and has the highest Net Present Value. The option is optimally timed to be completed within the 2023-2028 regulatory period.

Table 1 - Evaluated options

Option	Description	Direct capital cost ($m)	Network and corporate overheads ($m)	Total capital cost[1] ($m)	Weighted NPV (PV, $m)	Rank
Option A – Replacement	Replacement of the No.2 Panorama Transformer	9.2	0.7	9.9	78.8	1
Option B – Refurbishment	Refurbishment of the No.2 Panorama Transformer	1.0	0.3	1.3	21.0	2

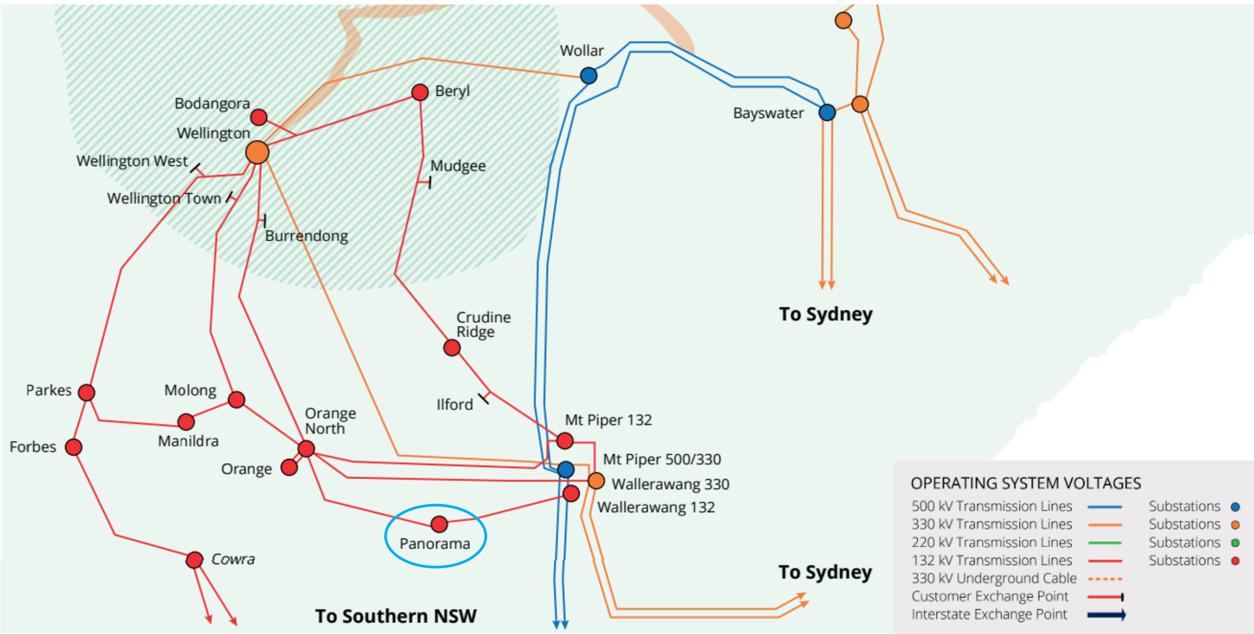
1. Need/opportunity

Panorama 132/66 kV Substation was commissioned in 1981 and forms part of Transgrid's network that serves the Central region of NSW. It connects to Transgrid's 132kV Orange North and Wallerawang substations. It also connects to Essential Energy's 66kV distribution network which supplies industrial and residential loads in the Bathurst region.

The location of Panorama Substation and transmission supply arrangements for the Central NSW network is provided in Figure 1 below.

[1] Total capital cost is the sum of the direct capital cost and network and corporate overheads. Total capital cost is used in this OER for all analysis.

Figure 1: Central NSW transmission network



Note: The 66kV Essential Energy network that Panorama No.1 and No.2 transformer supplies are not shown in Figure 1.

The Panorama No.1 and No.2 Transformers (132/66kV, 120MVA each) were commissioned in 1981 during the initial construction of Panorama Substation. The transformers at the substation plays a central role in supplying electricity to the Essential Energy distribution network.

The two transformer arrangement allows for an N-1 contingency during planned and unplanned outages. Transgrid does not have an agreed back up arrangement for the Panorama load with Essential Energy network.

Condition Assessment of the Panorama Transformers using Transgrid’s Network Asset Risk Assessment Methodology (RAM) has noted signs of deterioration, primarily due to condition issues set out in Table 2 below.

Table 2 - Condition Issues

Issue	Potential impact
Synthetic Resin Bonded Paper (SRBP) Bushings	The transformer has SRBP bushings were originally installed (1980) with the transformer. SRBP bushings are wound using resin impregnated paper and cured before being encapsulated in a porcelain housing. The paper layers in the bushing tend to delaminate over time resulting in voids and high levels of partial discharge (PD). Over time treeing can occur in the bushing, damaging the insulation system and ultimately bushing or transformer failure.

Issue	Potential impact
Corrosive Sulphur	Corrosive sulphur can form conductive compounds on insulating paper, disrupting the integrity of the paper leading to thermal insulation failure or electrical breakdown between adjacent conductors. Sulphur compounds can also attack the silver coating on selector switching contacts, creating loose sections of conductive silver sulphide. This can result in a catastrophic failure of the tap changer and/or transformer.
Loss of oil due to leaks	Flange and gasket leaks can cause loss of oil within the Transformer resulting in a catastrophic failure. Moisture and oxygen can also enter the transformer resulting in accelerated aging of the insulation resulting in failure.

If the deteriorating asset condition is not addressed by a technically and commercially feasible option, the likelihood of prolonged and involuntary load shedding in the Bathurst region will increase.

In addition, the increased risk of failure presents a safety risk which Transgrid is obligated to manage. Rectifying the worsening condition of the transformer will reduce safety risks, as well as lower planned and unplanned corrective maintenance costs.

The key economic benefits associated with addressing this need are summarised as:

- Reduction of risk as valued as a direct impact to Transgrid and consumers including:
  - Changes in involuntary load shedding
  - Safety and environmental hazards associated with a catastrophic failure.
- Avoided operating expenditure related to corrective maintenance;

2. Related needs/opportunities

- N2419 – FY24-28 Panorama Secondary Systems Renewal
- N2194 – Supply to Orange – Future load Growth

3. Options

3.1. Base case

Under the ‘Base Case’ scenario, there is no consideration for planned replacement of the transformer. This is a ‘run to fail’ scenario and will lead to an increase in the identified risks, the transformer's eventual failure, and the materialisation of the expected consequences. This case shall only be considered as a last resort should no option be deemed viable through the economic evaluation process.

Replacement of a failed transformer with a strategic spare is expensive and requires significant time to restore capacity. Key considerations against the base case are:

- Transgrid holds a similar spare for the Panorama No.2 transformer.
- Primary and secondary asset modifications will also be required at Panorama substation to adapt the spare unit.
- If the failure is catastrophic, there is substantial clean up and disposal costs and likely to take 1-2 weeks.
- As there are no spares on site, a spare transformer will need to be dismantled and transported from another depot/substation and assembled at Panorama.
- Transportation permits will likely be required due to the physical size and weight of the spare transformer.
- The spare transformer will need to undergo high voltage testing and commissioning works.

The base case assumes the failed transformer can be replaced with a strategic spare in a much shorter time frame than replacing the transformer with a new asset. Where a spare transformer is not available due to concurrent failures the design, procurement and installation time for new transformer is expected to be at least 12 months. The probability and likelihood of expected unserved energy under this scenario has been excluded from the base case risk modelling.

3.2. Options evaluated

Option A — Replacement of No.2 Transformer [NOSA 2404, OFS 2404A]

This option replaces the Panorama No.2 transformer with a new 132/66 kV 120 MVA transformer. The option will address the identified need by installing a new transformer with a very low probability of failure, associated risks and lower operating costs.

This option involves:

- Installation of a new 120MVA power transformer.
- Installation of new switch bays, gantries, busbar extension, protection and control systems (secondary systems);
- Installation of an auxiliary transformer.
- Bench extension and modification of the palisade fencing.
- Construction of new firewalls.

The new No.2 transformer will be installed in a new compound with associated bays to maintain reliability during construction. The old No.2 transformer will then be decommissioned and disposed of once the new No.2 transformer is in-service. The final transformer configuration at Panorama substation will remain as two transformers to meet the NSW Electricity Transmission Reliability and Performance Standard.

Consideration of In-Situ Replacement

Transgrid has evaluated the option of undertaking an in-situ transformer replacement at Panorama Substation. This would require a 12-16 week outage of the No.2 transformer, during this period 30 - 60 MW of load would be radial supplied via the No.1 transformer. Essential Energy have limited load transfer capability (less than 7 MVA) during non-peak demand period by energising Essential Energy's 818/2 transmission line between Essential Energy's Orange and Blayney Substations.

The outage risk of undertaking an in-situ transformer replacement is considered unacceptable as there would be significant load shedding in the event of an unplanned outage of the No.1 transformer. The transformer recall period during construction is also expected to be weeks unlike maintenance or refurbishment activities which is typically within 24-48 hours.

During the in-situ construction Transgrid would not be compliant under the obligations set out in the NSW Electricity Transmission Reliability and Performance Standard to maintain a reliability of 2 (Redundancy Level of N-1) at Panorama substation.

The estimated Capex with this option is $9.92 million with an expected asset life of 45 years. The expected project timeframe from Decision Gate 1 (DG1) is 32 months.

Option B — Refurbishment of No.2 Transformer [NOSA 2404, OFS 2404B]

This option consists of an in-situ refurbishment of the Panorama No.2 Transformer according to the recommended scope in Network Asset Condition Assessment (NACA):

- Replacement of high voltage, low voltage and tertiary voltage bushings;
- Oil treatment and/or replacement.
- Moisture removal.
- Corrosion repair, leak repair and repainting.
- Major overhaul of the tap changer.
- Conservator modifications and/or repairs.

The refurbishment is expected to result in a reduction in the effective age of seven years, limited by the natural age of the transformer.

Limitations of Refurbishment

Refurbishment is expected to improve condition issues associated with the bushings, insulating oil quality, gasket leaks and tap changer components. It cannot address or improve the quality of the paper insulation, eliminate gas generation, ageing in the core, improve winding clamping pressure or eliminate all sulphur compounds bonded to the tap changer contacts.

The natural age of the transformer at the end of the 2023-28 regulatory period is 48 years, 3 years above the useful life of a power transformer. The transformer is being refurbished within its useful life which provides the largest economic benefit and reduction in effective age provided by the option. However, refurbishment (Option B) of the Panorama No.2 transformer does not provide the highest economic value when compared to replacement of the transformer (Option A). The refurbishment option will essentially delay the transformer replacement into 2028 – 2033 regulatory period and result in a higher lifecycle capex investment.

The majority of reliability, safety and environmental risk will remain even after the refurbishment and will only be addressed by replacement.

The estimated Capex with for option is $1.31 million, with an expected improvement of asset life of seven years. The expected project timeframe from DG1 is 21 months.

3.3. Options considered and not progressed

The following options were considered but not progressed:

Table 3 - Options not progressed

Option	Reason for not progressing
Increased maintenance or inspections	The condition issues have already been identified and cannot be rectified through increased maintenance or inspections, and therefore is not technically feasible to address the need.
Elimination of all associated risk	This can only be achieved by retiring the assets, which is not technically feasible due to the requirement to maintain the existing network reliability.
Non-network solutions	Transgrid does not consider non-network options to be commercially feasible to assist with meeting the identified need.

4. Evaluation

4.1. Commercial evaluation methodology

The economic assessment undertaken for this project includes three scenarios that reflect a central set assumptions based on current information that is most likely to eventuate (central scenario), a set of assumptions that give rise to a lower bound for net benefits (lower bound scenario), and a set of assumptions that give rise to an upper bound on benefits (higher bound scenario).

Assumptions for each scenario are set out in the table below.

Parameter	Central scenario	Lower bound scenario	Higher bound scenario
Discount rate	5.5%	7.5%	2.3%
Capital cost	100%	125%	75%
Operating expenditure	100%	75%	125%
Risk costs	100%	75%	125%
Benefits	100%	75%	125%
Scenario weighting	50%	25%	25%

Parameters used in this commercial evaluation:

Parameter	Parameter Description	Value used for this evaluation
Discount year	Year that dollar values are discounted to	2021/22
Base year	The year that dollar value outputs are expressed in real terms	2021/22
Period of analysis	Number of years included in economic analysis with remaining capital value included as terminal value at the end of the analysis period.	25 years
ALARP disproportionality	Multiplier of the environmental and safety related risk cost included in NPV analysis to demonstrate implementation of obligation to reduce to ALARP.	Refer to section 4.3 for details.

The capex figures in this OER do not include any real cost escalation.

4.2. Commercial evaluation results

The commercial evaluation of the technically feasible options is set out in Table 2. Details appear in Appendix A.

Table 4 - Commercial evaluation (PV, $ million)

Option	Capital Cost PV	OPEX Cost PV	Central scenario NPV	Lower bound scenario NPV	Higher bound scenario NPV	Weighted NPV	Ranking
Option A	8.91	0.01	65.86	30.87	152.53	78.78	1
Option B	1.17	0.01	17.87	9.28	39.01	21.01	2

4.3. ALARP evaluation

TransGrid manages and mitigates bushfire and safety risk to ensure they are below risk tolerance levels or 'As Low As Reasonably Practicable' ('ALARP'), in accordance with the regulation obligations and TransGrid's business risk appetite. Under the Electricity Supply (Safety and Network Management) Regulation 2014 Section 5 'A network operator must take all reasonable steps to ensure that the design, construction, commissioning, operation and decommissioning of its network (or any part of its network) is safe.' TransGrid maintains an Electricity Network Safety Management System (ENSMS) to meet this obligation[2].

In its Network Risk Assessment Methodology, under the ALARP test with the application of a gross disproportionate factor[3], the weighted benefits are expected to exceed the cost. TransGrid's analysis concludes that the costs are less than the weighted benefits from mitigating bushfire and safety risks. The

[2] TransGrid's ENSMS follows the International Organization for Standardization's ISO31000 risk management framework which requires following hierarchy of hazard mitigation approach

[3] The values of the disproportionality factors were determined through a review of practises and legal interpretations across multiple industries, with particular reference to the works of the UK Health and Safety Executive. The methodology used to determine the disproportionality factors in this document is in line with the principles and examples presented in the AER Replacement Planning Guidelines and is consistent with TransGrid's Revised Revenue Proposal 2023/24- 2027/28.

proposed investment will enable TransGrid to continue to manage and operate this part of the network to a safety and risk mitigation level of ALARP.

Evaluation of the above options has been completed in accordance with As Low As Reasonably Practicable (ALARP) obligations. The Network Safety Risk Reduction is calculated as 1 x Bushfire Risk Reduction + 1 x Other Environmental Risks + 3 x Safety Risk Reduction + 0.1 x Reliability Risk Reduction.

Results of the ALARP evaluation are set out in Table 5.

Table 5 - Reasonably practicable test ($ million)

Option	Network Safety Risk Reduction	Annualised Capex	Reasonably Practicable?[4]
A	0.19	0.60	No
B	0.06	0.13	No

The result of the ALARP evaluation is that all options lie under the ALARP threshold.

4.4. Preferred option

The preferred option is the replacement (Option A) of the Panorama No.2 Transformer, as this is technically feasible and has the highest positive NPV. This option addresses the need by achieving the largest risk reduction. A new transformer has a relatively low probability of failure and corresponding post-investment risk.

Capital and Operating Expenditure

Opex benefits associated with avoided corrective and reduced routine expenditure have been included in the business case NPV and optimal timing evaluation.

There are no capex to opex trade-offs considered in this evaluation.

Regulatory Investment Test

A Regulatory Investment Test for Transmission (RIT-T) is required as the preferred option is above $7 million.

4 Reasonably practicable is defined as whether the annualised CAPEX is less than the Network Safety Risk Reduction.

5. Optimal Timing

The test for optimal timing of the preferred option has been undertaken. The approach taken is to identify the optimal commissioning year for the preferred option where net benefits (including avoided costs and safety disproportionality tests) of the preferred option exceeds the annualised costs of the option. The commencement year is determined based on the required project disbursement to meet the commissioning year based on the OFS.

The results of optimal timing analysis are:

- Optimal commissioning year: 2023/24. This is the earliest feasible commissioning year due to the significant lead time required to design, procure and commission a transformer replacement. The difference of one year between the manufacturing and commissioning year of the transformer has no impact to the optimal timing of the project.
- Commissioning year annual benefit: $1.75 million
- Annualised cost: $0.60 million

Based on the optimal timing, the project is expected to be completed within the 2023-2028 Regulatory Period

6. Recommendation

It is recommended that Option A for the replacement of the Panorama No.2 transformer be scoped in detail.

The total project cost is $9.92 million, including $1 million to progress the project from DG1 to DG2.

Appendix A – Option Summaries

Project Description	Panorama Transformer Renewal		
Option Description	Option A - Transformer Replacement		
Project Summary			
Option Rank	*1*	Investment Assessment Period	*25*
Asset Life	*45*	NPV Year	*2022*
Economic Evaluation			
NPV @ Central Benefit Scenario (PV, $m)	[Net Present Value (Standard - OER)] *65.86*	Annualised CAPEX ($m)	Annualised Capex - Standard (Business Case) *0.60*
NPV @ Lower Bound Scenario (PV, $m)	[Net Present Value (Upper Bound)] *30.87*	Network Safety Risk Reduction ($m)	Network Safety Risk Reduction *0.19*
NPV @ Higher Bound Scenario (PV, $m)	[Net Present Value (Lower Bound)] *152.53*	ALARP	ALARP Compliant? No
NPV Weighted (PV, $m)	[Net Present Value (Weighted)] *78.78*	Optimal Timing	Optimal timing (Business Case) *2023*
Cost			
Direct Capex ($m)	*9.22*	Network and Corporate Overheads ($m)	*0.70*
Total Capex ($m)	*9.92*	Cost Capex (PV,$m)	*8.91*
Terminal Value ($m)	*4.41*	Terminal Value (PV,$m)	*0.98*
Risk (central scenario)	Pre	Post	Benefit
Reliability (PV,$m)	Reliability Risk (Pre) *76.17*	Reliability Risk (Post) *3.34*	Pre – Post *72.83*
Financial (PV,$m)	Financial Risk (Pre) *1.04*	Financial Risk (Post) *0.39*	Pre – Post *0.65*
Operational/Compliance (PV,$m)	Operational Risk (Pre) *0.00*	Operational Risk (Post) *0.00*	Pre – Post *0.00*
Safety (PV,$m)	Safety Risk (Pre) *0.33*	Safety Risk (Post) *0.16*	Pre – Post *0.17*
Environmental (PV,$m)	Environmental Risk (Pre) *0.26*	Environmental Risk (Post) *0.13*	Pre – Post *0.13*
Reputational ($m)	Reputational Risk (Pre) *0.00*	Reputational Risk (Post) *0.00*	Pre – Post *0.00*
Total Risk Benefit (PV,$m)	Total Risk (Pre) *77.81*	Total Risk (Post) *4.03*	Pre – Post *73.78*
OPEX Benefit (PV,$m)			OPEX Benefit *0.01*
Other benefit (PV,$m)			Incremental Net Benefit *0.00*
Total Benefit (PV,$m)			Business Case Total Benefit *73.79*

Project Description	Panorama Transformer Renewal		
Option Description	Option B - Transformer Refurbishment		
Project Summary			
Option Rank	*2*	Investment Assessment Period	*25*
Asset Life	*15*	NPV Year	*2022*
Economic Evaluation			
NPV @ Central Benefit Scenario (PV, $m)	[Net Present Value (Standard - OER)] *17.87*	Annualised CAPEX ($m)	Annualised Capex - Standard (Business Case) *0.13*
NPV @ Lower Bound Scenario (PV, $m)	[Net Present Value (Upper Bound)] *9.28*	Network Safety Risk Reduction ($m)	Network Safety Risk Reduction *0.06*
NPV @ Higher Bound Scenario (PV, $m)	[Net Present Value (Lower Bound)] *39.01*	ALARP	ALARP Compliant? No
NPV Weighted (PV, $m)	[Net Present Value (Weighted)] *21.01*	Optimal Timing	Optimal timing (Business Case) *2023*
Cost			
Direct Capex ($m)	*0.96*	Network and Corporate Overheads ($m)	*0.35*
Total Capex ($m)	*1.31*	Cost Capex (PV,$m)	*1.17*
Terminal Value ($m)	*0.00*	Terminal Value (PV,$m)	*0.00*
Risk (central scenario)	Pre	Post	Benefit
Reliability (PV,$m)	Reliability Risk (Pre) *76.17*	Reliability Risk (Post) *57.39*	Pre – Post *18.78*
Financial (PV,$m)	Financial Risk (Pre) *1.04*	Financial Risk (Post) *0.87*	Pre – Post *0.17*
Operational/Compliance (PV,$m)	Operational Risk (Pre) *0.00*	Operational Risk (Post) *0.00*	Pre – Post *0.00*
Safety (PV,$m)	Safety Risk (Pre) *0.33*	Safety Risk (Post) *0.28*	Pre – Post *0.05*
Environmental (PV,$m)	Environmental Risk (Pre) *0.26*	Environmental Risk (Post) *0.23*	Pre – Post *0.03*
Reputational ($m)	Reputational Risk (Pre) *0.00*	Reputational Risk (Post) *0.00*	Pre – Post *0.00*
Total Risk Benefit (PV,$m)	Total Risk (Pre) *77.81*	Total Risk (Post) 58.77	Pre – Post *19.04*
OPEX Benefit (PV,$m)			OPEX Benefit *0.01*
Other benefit (PV,$m)			Incremental Net Benefit *0.00*
Total Benefit (PV,$m)			Business Case Total Benefit *19.05*

Approval Record

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