Supporting Document 12.1.15e
Major Project Detailed Options Report

ESS_5019 Googong Town Zone Substation - 2nd 132/11kV Power Transformer

April 2018

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1. Executive Summary

Major Project	ESS_5019 Googong Town Zone Substation - 2nd 132/11kV Power Transformer
Description	Install a 2nd 132/11kV transformer at the Googong Town Zone Substation
Drivers for Investment	The Googong Town Zone Substation relies upon a single 132/11kV power transformer with limited backup from the distribution network. The Googong development is rapidly growing and the Value of Unserved Energy for the loss of the single transformer will soon become more than the annualised cost of installing a second power transformer
Investment Options	The investment options include installing a second 132/11kV power transformer, increasing the distribution alternate supply capacity and installing smart switches to reduce the time to utilise the distribution supply. Given the minimal time that the distribution options would defer the need for the transformer the recommended option is the installation of a second 132/11kV transformer at the Googong Town Zone Substation.
Estimated Expenditure $million (Real $FY19)	

2019/20	2020/21	2021/22	2022/23	2023/24
$0	$1.05	$0	$0	$0

2. Network

The Googong Town 132/11kV Zone Substation (ZS) is part of the Queanbeyan Subtransmission network shown in Figure 1. Normal supply is provided via the 132kV line 975 from the TransGrid Queanbeyan 132/66kV substation with an alternate supply available from the 97Y line emanating from the TransGrid Williamsdale 330/132kV substation.

Googong is a recently established satellite township south east of Canberra with a development plan of 6,200 residential lots. Along with schools and commercial businesses, it has an estimated ultimate peak demand in excess of 25MVA. Googong Town 132/11kV zone substation (ZS) was established early 2016 to cater for the Googong development and alleviate constraints in the distribution network.

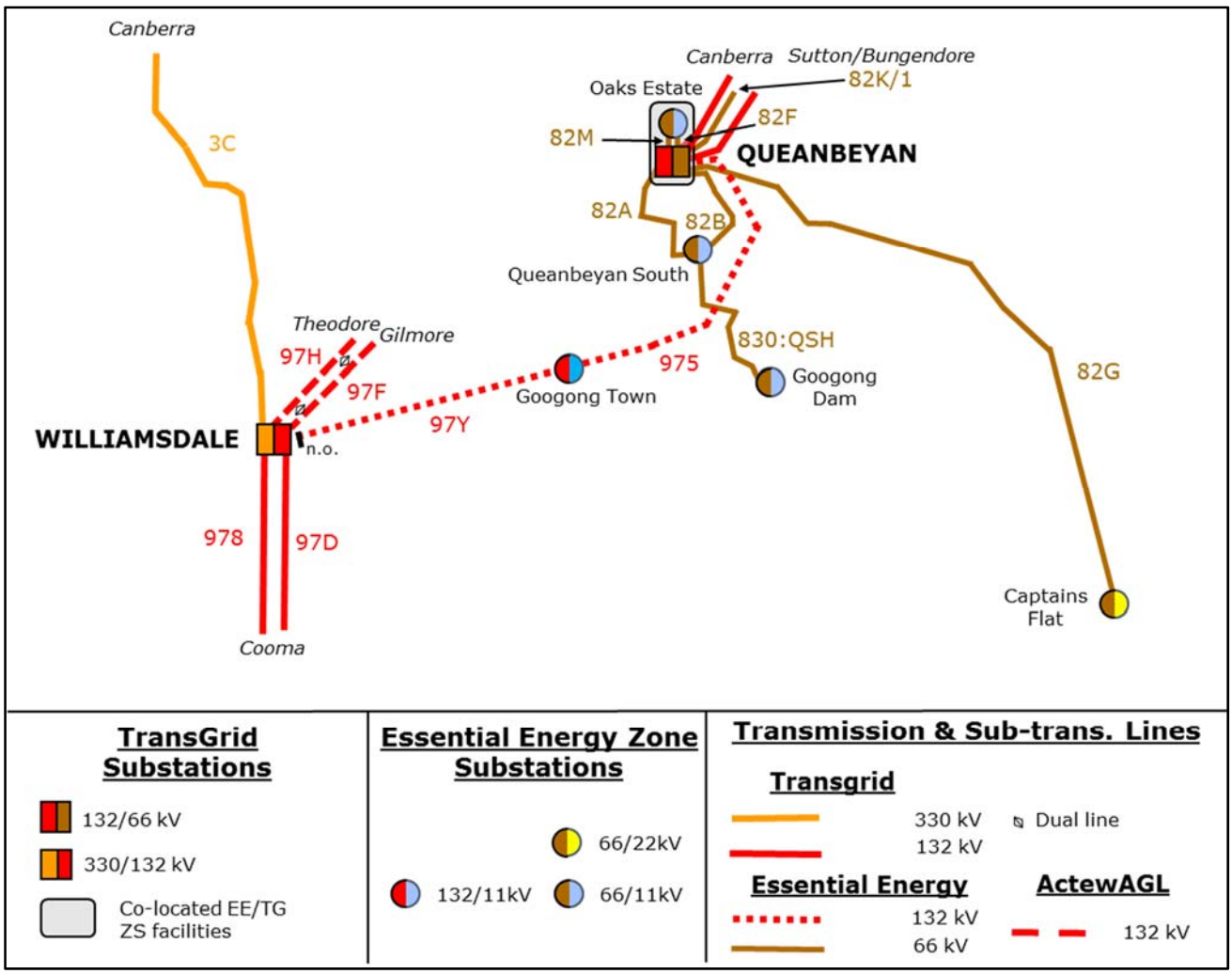

Figure 1 – Queanbeyan Subtransmission Network

There is a single 132/11kV transformer at the Googong Town ZS which has limited alternate supply available over the 11kV distribution network. There are two alternate supplies including a 4MVA capacity supply from the Queanbeyan South ZS and a 5.2MVA capacity supply from the Googong Dam ZS as shown in Figure 2.

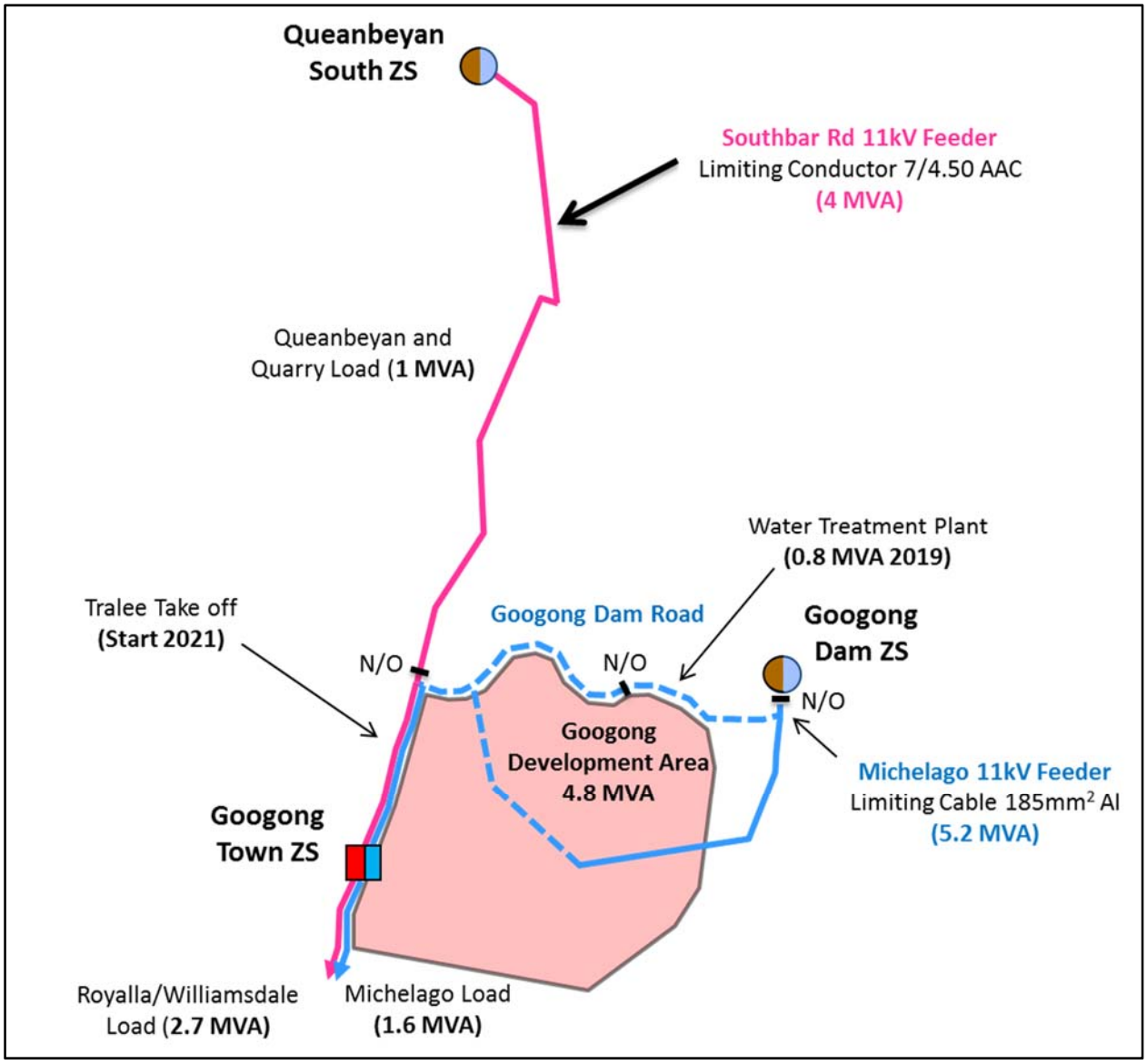

Figure 2 Googong Town ZS Distribution Network Alternate Supplies (2019 Forecast Shown)

For a failure of the single 132/11kV transformer, the Royalla load can be supplied via the Southbar Road feeder from the Queanbeyan South ZS and the Googong and Michelago load supplied from the Michelago feeder out of the Googong Dam ZS. There is one manually switched open point between each of the two alternate supplies. It is estimated it would take 90 minutes to restore all supply after failure of the single 132/11kV transformer.

3. Load Forecast

The Googong residential development is experiencing a high take up rate due to strong housing growth in the ACT region, with a forecast growth rate of 900kVA per annum. The Tralee development is another residential development to the south of Queanbeyan which is expected to begin construction in the period between September 2018 and September 2019, with the first load expected from 2021 onward. Initial supply will be provided from an 11kV extension from the Jerrabomberra network which has a capacity of 2MVA. Once the capacity of this supply is exceeded it's expected that the full demand will be supplied by an extension of the Googong Town 11kV network.

Tralee is expected to grow at 150 dwellings per annum with 30Ha of industrial starting development in 2023 at a rate of 2 Ha per annum. The Tralee growth rate is expected to be 500kVA/annum from 2021 to 2023 and 700kVA from

2023 onward. The Googong Dam ZS supplies the Googong Water Recycling plant which is forecast to increase capacity from 800kVA in 2019 to a maximum of 1.4MVA in 2022. The load factor of the residential load is expected to be 0.5, similar to the load supplied by the Queanbeyan South Zone Substation. The peak (winter) MVA load forecasts are shown below in Table 1.

	2019	2020	2021	2022	2023	2024
Googong Development	4.8	5.8	6.7	7.6	8.5	9.5
Royalla Feeder	2.7	2.8	2.9	3.0	3.1	3.1
Michelago Feeder	1.6	1.7	1.7	1.8	1.8	1.8
Tralee (Googong Supply)	0.0	0.0	0.0	0.0	0.0	2.5
Googong Town ZS Total	**9.2**	**10.2**	**11.2**	**12.3**	**13.4**	**16.8**
Googong Dam ZS	0.8	1.0	1.2	1.4	1.4	1.4

Table 1 Googong Load Forecast (MVA)

4. Constraint

There is only one 132/11kV transformer at the Googong Town ZS, so a transformer disruption would in the first instance will cause loss of supply to all customers connected to the Googong Town ZS. There is a full capacity alternate supply available to the Royalla feeder from Queanbeyan South and partial supply available to the Googong Town and Michelago feeders from Googong Dam.

The supply from Googong Dam is limited to 5.2MVA due to the thermal rating of the 185mm Aluminium (Al) exit cable from the substation. The Googong and Michelago load is forecast to exceed the rating of this cable in the winter of 2019, after which time load above 5.2MVA will be lost.

4.1.1 Failure Modes and Causes

The causes of transformers disruptions can be split into minor and major failures.

Minor Issues

- Relay failures
- Protection mal-grade
- Animal/bird strike
- Minor problems with tap changer

Major Issues

- Bushing failure
- Tap Changer Failure
- Insulation breakdown
- Tank Failure

Minor issues occur more frequently but have a much quicker restoration time, in this report minor issues are expected once every 25 years and would have 6-hour duration. Major issues will require a spare transformer to be relocated to Googong with an estimated 2 day turn around for the spare transformer to be delivered and installed. These type of faults are unlikely and only estimated to occur once every 250 years.

5. Risk Analysis

5.1.1 Safety

There is potential for a major transformer failure to injure personnel within the substation yard at the time of failure. The likelihood of injury is rare due to the combination of unlikely major failure and limited time personnel spend within the yard. The consequence could be severe, with one or more fatalities possible. The options investigated for this project will not reduce the risk of a transformer failure so this is not included in the cost analysis

5.1.2 Network (Reliability)

The loss of the Googong Town 132/11kV transformer. Supply can be restored by the closing of two switches so an outage duration of 90 minutes has been assumed from fault to restoration. Minor transformer interruptions are expected to have a duration of 8 hours and major transformer interruptions 96 hours.

5.1.3 Environmental

The environmental impact of a major transformer failure would be limited to localised oil contamination which would be of insignificant environmental consequence. This would be a rare event so the risk to the Environment is low. The options considered for this option would not change the environmental impact.

5.1.4 Financial

The damage resulting from a transformer failure would be localised to the zone substation site and be less than $250k so classified as insignificant. The chance of a transformer failure is rare so the risk rating is low. The options will not mitigate this risk.

5.1.5 Compliance

Compliance risk is assessed for issues that may arise as a result of not complying to relevant standards, acts or guidelines. There exist no specific areas of compliance which govern the redundancy of power transformers therefore the risks associated with compliance have not been considered further in this instance.

5.1.6 Reputation

Reputational risks are categorised as those risks associated with the tarnishing of the company's reputation as the result of an overhead conductor failure, not including that incurred by the resultant outage. It is anticipated that the risk to corporate reputation as a result of transformer outage at Googong is minor under the corporate risk matrix. That is, the outage may result in attention from media and or heightened concern from local community / external stakeholders, or, criticism from multiple sources for one or two days.

6. Options and NPV Analysis

Net Present Value (NPV) analysis is used to show the benefit of each option. NPV analysis is over a base 40-year period and includes the estimated capital cost and Value of Unserved Energy (VUE) of each option. Beyond capital cost, a key consideration in NPV analysis is VUE, which is applied annually as a benefit and represents the value of improved customer reliability within each option. The VUE benefit for each option has been calculated considering key assumptions and Value of Customer Reliability (VCR[1]). VUE benefit takes into account the energy that can be provided by the backup or alternate supply and the time taken to restore the alternate supply.

The following is a summary of key NPV assumptions.

Distribution backup (manual switching): 90 min restoration
Distribution backup (smart switching): 15 min restoration
Minor transformer failure: probability - 1 in 25 year, restoration time - 6 hours
Major catastrophic transformer failure: probability - 1 in 250 year, restoration time - 48 hours
VCR - $41,210/MWh

[1] AEMO Value of Customer Reliability – Application Guide Dec14 , pg 5 NSW General Rate escalated by CPI

The estimated capital costs for each option in the NPV analysis is summarised in Table 2.

Option	2019/20	2020/21	2021/22	2022/23	2023/24
Option 1 - Do Nothing	$0.00	$0.00	$0.00	$0.00	$0.00
Option 2 - Cable Upgrade	$0.04	$0.00	$1.00	$0.00	$0.00
Option 3 - Auto Switching	$0.07	$1.00	$0.00	$0.00	$0.00
Option 4 - Cable and Auto Switching	$0.11	$0.00	$0.00	$1.00	$0.00
Option 5 - Transformer Upgrade	$0.00	$1.00	$0.00	$0.00	$0.00

Table 2 CAPEX cost per Option ($M)

The annual VUE for each option is summarised in Table 3.

Option	2019/20	2020/21	2021/22	2022/23	2023/24
Option 1 - Do Nothing	$0	$0	$0	$0	$0
Option 2 - Cable Upgrade	$13,439	$18,665	$46,618	$57,251	$66,415
Option 3 - Auto Switching	$12,386	$36,009	$46,618	$57,251	$66,415
Option 4 - Cable and Auto Switching	$25,825	$32,379	$33,772	$57,251	$66,415
Option 5 - Transformer Upgrade	$0	$36,009	$46,618	$57,251	$66,415

Table 3 VUE for each Option

With limited backup from the distribution network, transformer failure can only be fully alleviated by installation of a second transformer. Improvement to the distribution backup capability can be achieved by upgrading the exit cable at Googong Dam and installing automated 11kV switching but as load growth continues, the demand will exceed the backup capability and these options can only defer the installation of a second transformer, not alleviate the constraint.

Sensitivity on timing of second transformer installation for options 2,3,4 and 5 were undertaken to determine to greater NPV benefit for each individual option. In each case this occurred when the saving in unserved energy was greater than the annualised cost of the transformer.

6.1.1 Options

Option 1. Do Nothing

Continuing with the present supply arrangement would have an increasing adverse impact on customer reliability due to possible transformer loss and the increasing load. The manually switched limited alternate supply from the distribution network does not provide full backup capability. There is no capital cost and no improvement in customer reliability with this option thus there is no VUE benefit.

Option 1 has a 40-year NPV benefit of $0.00M

Option 2. Upgrade Distribution Network

The most cost-effective distribution network upgrade would be replacing the 185mm Al exit cable at Googong Dam with 240mm Cu XLPE to increase the rating of the alternate supply from Googong Dam to 7.7MVA. Upgrading the distribution network from Queanbeyan South ZS is not cost effective.

The Googong pumping station has a maximum demand of 2.2MVA so this alternate supply would utilise the capacity available at the Googong Dam ZS. This option would require replacement of 100m cable at an estimated cost of $40k.

The extra capability would give a VUE benefit of $13.4k in the first year and $18.7k in the second year as the load increases. In the third year it gives more VUE benefit ($46.6k) and greater overall NPV benefit to install the second transformer as the increased backup capability is exceeded and the value of the lost load is more than the annualised cost of the transformer.

Option 2 has a 40-year NPV benefit of $2.80M

Option 3. Replace Manual Switches with Smart Switches

Replacing the two manually operated open points with smart switches would enable a 15min restoration of limited supply following a transformer outage. The open point between the South Queanbeyan and Googong Town ZS could be replaced with a smart sectionaliser and the padmount substation separating Googong Dam and Googong Town could be retrofitted with communications to enable remote switching.

This option is estimated to cost $35k per site or $70k in total. This gives an VUE benefit of $12.4k in the first year. In the second year it gives more VUE benefit ($36k) and greater overall NPV benefit to install the second transformer as the backup capability is exceeded and the value of the lost load is more than the annualised cost of the transformer.

Option 3 has a 40-year NPV benefit of $2.76M

Option 4. Both Upgrade Distribution Network and Install Smart Switches

This option would include the replacement of the Googong Dam exit cable as outline in Option 2 and the automation of the remote switches as outlined in Option 3. This gives the combined VUE benefit of $25.8k in the first year. The VUE benefit increases as the load increases until the increased backup capability is significantly exceeded, and the reduced restoration time does not give an improved VUE compared to installing the second transformer in the fourth year.

Option 4 has a 40-year NPV benefit of $2.77M

Option 5. Install 2nd 132/11kv transformer

This option would involve the purchase and installation of a second 30/40MVA 132/11kV transformer. The transformer bund, 132kV and 11kV transformer circuit breakers have already been installed at the Googong Town ZS. This project has an estimated cost of $1M. Sensitivity testing indicates the second transformer has most benefit if installed in the second year 2020/21. In the initial year there is no VUE benefit applied, into the second and future years full VUE benefit is applied as the second transformer alleviates all constraints.

Option 5 has a 40-year NPV benefit of $2.81M

The NPV results of base case and NPV sensitivities is shown below in Table 4. Further summarised detail of the NPV analysis is shown in Appendix A.

	Base Dis. Rate	Discount Rate Sensitivity		Capital Sensitivity		VUE Sensitivity	
Option	**3.45%**	**1.45%**	**5.45%**	**+25%**	**-25%**	**+25%**	**-25%**
1	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
2	$2.80	$4.49	**$1.76**	$2.59	$3.00	$3.70	$1.90
3	$2.76	$4.47	$1.70	$2.54	$2.98	$3.67	$1.85
4	$2.77	$4.45	$1.75	$2.56	$2.99	$7.84	$1.87
5	**$2.81**	**$4.51**	$1.75	**$2.60**	**$3.01**	**$3.71**	**$1.90**

Table 4 NPV Benefit for each Option ($M)

7. Recommended Option

Option 2 to 5 have a significant benefit over Option 1 and are all similar cost. Given that Option 5 has the greater NPV benefit it is recommended that a second 132/11kV transformer be installed at Googong Town ZS in the financial year 2020/21.

8. References

Doc No.	Document Name	Relevance
1	Googong 2nd Transformer NPV V1.xlsx	Net Present Value Analysis calculations

9. Key Terms and Definitions

Term	Definition
FY	Financial Year
k	$ Thousand
M	$ Million
NPV	Net Present Value
VCR	Value of Customer Reliability
VUE	Value of Unserved Energy

Appendix A – Net Present Value Analysis (Base)

(Do Nothing not shown)

Project:	Googong 2nd Transformer
Company Tax Rate	30%
Discount Rate after Tax:	3.45%

NPV Summary	Total Capital Costs	10 Yr NPV	20 Yr NPV	30 Yr NPV	40 Yr NPV	50 Yr NPV	60 Yr NPV
OPTION 1: Do Nothing	-	-	-	-	-	-	-
OPTION 2: Cable 2019, Transformer 2021	(1,040,000)	(55,248)	1,365,116	2,230,043	**2,795,544**	2,795,544	2,795,544
OPTION 3: Auto 2019, Transformer 2020	(1,070,000)	(92,887)	1,328,812	2,194,692	**2,760,870**	2,760,870	2,760,870
OPTION 4: Auto and Cable 2019, Transformer 2026	(1,110,000)	(82,843)	1,340,638	2,207,787	**2,774,870**	2,774,870	2,774,870
OPTION 5: Transformer 2020	(1,000,000)	(39,651)	1,378,930	2,242,589	2,807,185	2,807,185	2,807,185

		FY20	FY21	FY22	FY23	FY24	FY25	FY26	FY27	FY28	FY29	FY30
Timeline (Year)	Book Life Yrs	0	1	2	3	4	5	6	7	8	9	10
OPTION 2: Cable 2019, Transformer 2021												
Capital Expenditure:												
Cable	40	(40,000)										
Transformer	40	-	-	(1,000,000)	-		-	-	-			-
Cash Outflows - Risk												
Cash Inflows - Benefits												
VUE Saving		13,439	18,665	46,618	57,251	66,415	97,416	130,536	144,516	158,523	172,558	186,623
		10 Yr NPV	20 Yr NPV	30 Yr NPV	40 Yr NPV	50 Yr NPV	60 Yr NPV					
NPV (Option 2):		(55,248)	1,365,116	2,230,043	2,795,544	2,795,544	2,795,544					
OPTION 3: Auto 2019, Transformer 2020												
Capital Expenditure:												
Auto	40	(70,000)										
Transformer	40		(1,000,000)									
Cash Outflows - Risk												
Cash Inflows - Benefits												
VUE Saving		12,386	36,009	46,618	57,251	66,415	97,416	130,536	144,516	158,523	172,558	186,623
		10 Yr NPV	20 Yr NPV	30 Yr NPV	40 Yr NPV	50 Yr NPV	60 Yr NPV					
NPV(Option 3):		(92,887)	1,328,812	2,194,692	2,760,870	2,760,870	2,760,870					
OPTION 4: Auto and Cable 2019, Transformer 2026												
Capital Expenditure:												
Auto and Cable	40	(110,000)					-					
Transformer	40				(1,000,000)			-				
Cash Outflows - Risk												
Cash Inflows - Benefits												
VUE Saving		25,825	32,379	33,772	57,251	66,415	97,416	130,536	144,516	158,523	172,558	186,623
		10 Yr NPV	20 Yr NPV	30 Yr NPV	40 Yr NPV	50 Yr NPV	60 Yr NPV					
NPV(Option 4):		(82,843)	1,340,638	2,207,787	2,774,870	2,774,870	2,774,870					
OPTION 5: Transformer 2020												
Capital Expenditure		0	1	2	3	4	5	6	7	8	9	10
Transformer	40	-	(1,000,000)	-								
Capital Investment 2	40											
Cash Outflows - Risk												
Cash Inflows - Benefits												
VUE Saving		-	36,009	46,618	57,251	66,415	97,416	130,536	144,516	158,523	172,558	186,623
		10 Yr NPV	20 Yr NPV	30 Yr NPV	40 Yr NPV	50 Yr NPV	60 Yr NPV					
NPV(Option 5):		(39,651)	1,378,930	2,242,589	2,807,185	2,807,185	2,807,185					