Supporting Document 12.1.15c
Major Project Detailed Options Report
ESS_4016 Morrow St ZS 66kV Indoor Busbar

April 2018

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1. Executive Summary

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Unacceptable protection / reliability issues that could lead to significant loss of supply, catastrophic failure of power transformer and possible engulfing fire.</td></tr>
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2. Overview

This Major Project report investigates options to alleviate risks associated with loss of supply, including injury/fatality and decreased reliability posed by the Wagga 66kV network configuration, in particular the double tee connection on the 66kV feeder to Ashmont 66/11kV zone substation (ZS) as highlighted (red oval) in Figure 1 below.

The double tee on the Ashmont 66kV feeder causes protection, reliability, fault location and routine switching issues.

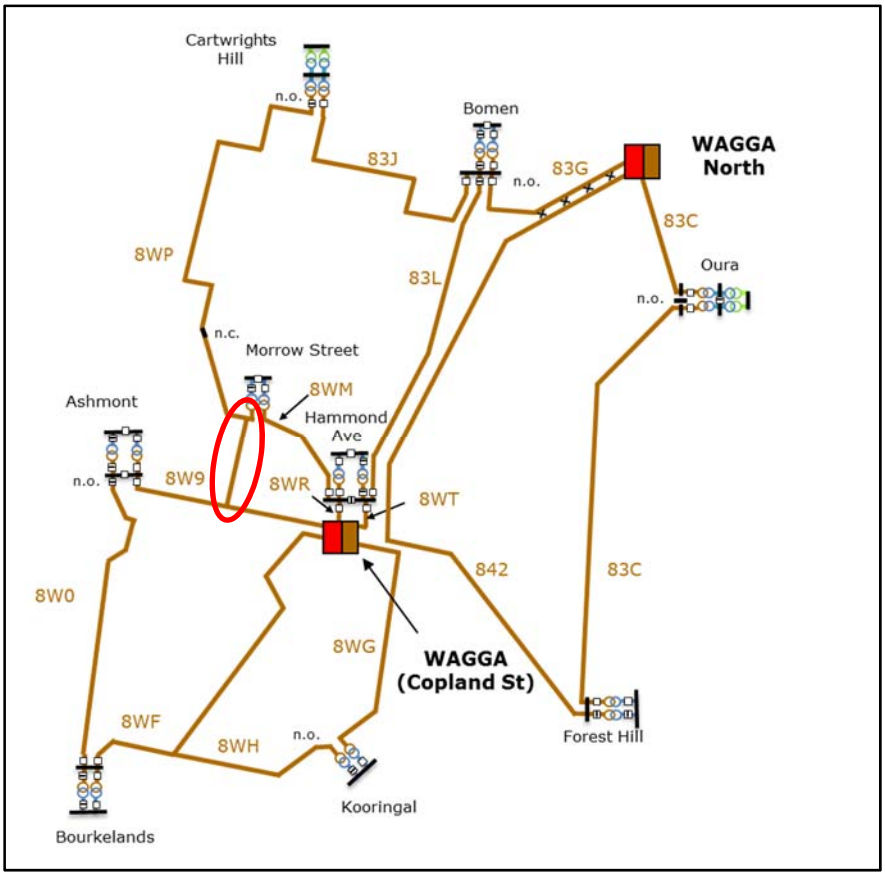

Figure 1 Wagga Subtransmission Network

The protection issue at Morrow St ZS is of most concern, with clearance of a power transformer fault reliant on a fault thrower to trip the supply from TransGrid. This creates an unacceptable delay in clearing the fault and does not meet the industry standard or Essential Energy's policy (CEOP 8002) of high speed tripping for large transformers.

To alleviate these issues an indoor 66kV busbar (three 66kV circuit breakers) will be installed at Morrow St ZS. The estimated expenditure for this project ($4.2M) will occur over the 2018/19 and 2019/20 financial years, with an $2M expected in 2019/20.

3. Network

The Wagga 66kV network was originally configured as indicated below in Figure 2. It comprised a number of radial 66kV feeders emanating from the TransGrid Copland St 132/66kV bulk supply point (BSP) substation, each having a number of hard "tee" connections to Essential Energy's 66/11kV zone substations (ZS).

Each ZS had two transformers with either a sectioned or cross connected 11kV switchboard with some of the ZS's having 66kV transformer CB's and limited 66kV bus facilities. This arrangement has been designated a "ladder" configuration with the radial 66kV feeders forming the "ladder rails" and the teed cross connections the "ladder rungs" as shown below in Figure 2.

66kV feeder protection and control was provided from the TransGrid Copland St BSP circuit breakers and there was no provision for sectioning or cross connection and limited transformer switching facilities.

The “ladder” 66kV network configuration presented significant protection, reliability, fault location, restoration and routine switching issues for the Wagga area supply.

Whilst 11kV changeover switching could be used to reduce supply interruption times it did not address the network protection and operating issues which were inherent in the “ladder” configuration.

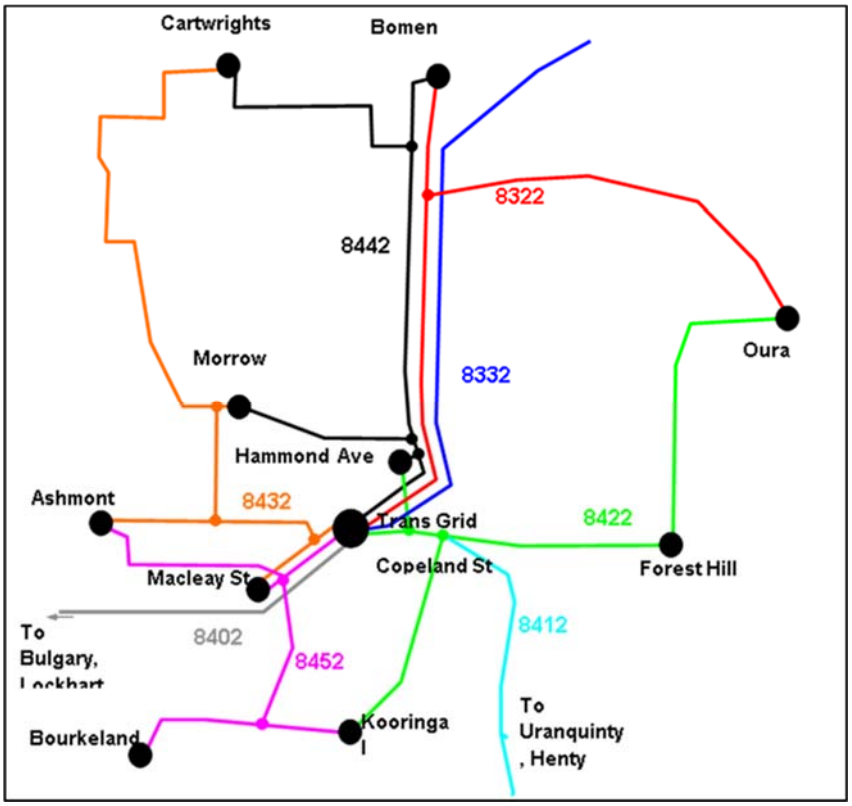

Figure 2 Original Wagga Subtransmission Network

The solution adopted to address these constraints and other needs relating to ageing assets and evolving supply capacity issues, was to undertake a series of substation augmentations and feeder reconnection project works to change the network to “ring” configurations with some “tail-ended” transformer connections. These 66kV augmentations were also accompanied with TransGrid’s establishing a new Wagga North 132/66kV BSP which provided a second 66kV source and additional 66kV reconfiguration solutions.

The 66kV network reconfigurations began over ten years ago. The reconfigured network will ensure that all 66/11kV transformers are provided with circuit breaker protection, ZS’s are provided with 66kV busbars where required and 66kV feeder faults will affect either no ZS’s (where ring connected) or only one ZS (where tail end connected) with supply then to be maintained by a changeover scheme.

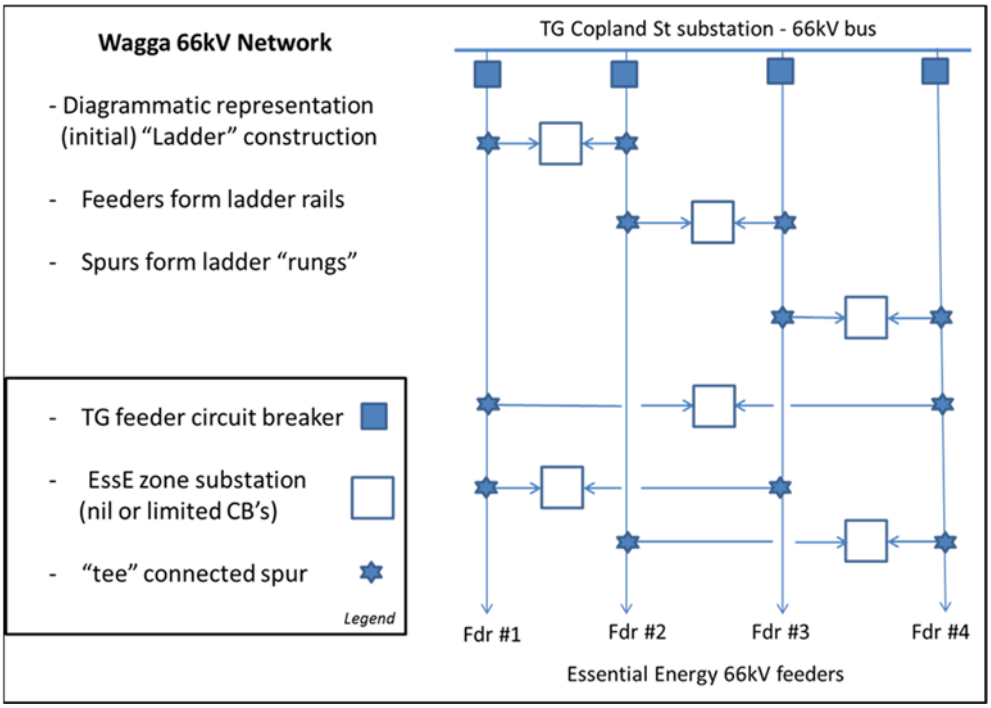

Figure 3 Original Wagga 'Ladder" Network

The majority of these 66kV reconfigurations are now complete with the 66kV network presently configured as shown above in Figure 1. The construction of a 'second' 66kV feeder from the TransGrid Copland St BSP to the Bourkelands/Kooringal tee to remove the tee (8WF/8WH) and establishment of a 66kV busbar at Morrow St ZS are the last projects to complete the reconfiguration. Construction of a 'second' 66kV feeder to the Bourkelands/Kooringal tee will be completed in the current regulatory period.

4. Constraint

Present configuration of Morrow St ZS and the Ashmont feeder double tee causes significant protection issues. The clearance of a power transformer fault is reliant on a fault thrower to trip the supply from TransGrid's Copland St BSP. This creates an unacceptable delay in clearing the fault and does not meet the industry standard or our Essential Energy policy of high speed tripping for large transformers. This is not acceptable, especially given the sensitive location of the substation in the Wagga CBD and housing of the transformer in a heritage listed building.

In the event the primary protection does not operate and backup protection is relied upon, the combination of the high fault level at the site (7kA) and unacceptably long clearing time (three seconds) would cause explosive failure of the transformer, likely engulfing the substation and surrounding houses with fire. This would have a severe impact on safety, as a fatality could be caused by the resulting fire, the network, as the Wagga CBD would suffer a major outage and the environment, as the heritage listed substation building would be lost.

There is also a protection constraint on the No.1 transformer at Cartwrights Hill. The transformer is protected by high speed primary protection, but the backup protection is slow (three seconds) and if the transformer failed it has the potential to damage other equipment in the Cartwrights Hill substation.

The Ashmont to Bourkelands ring network cannot be operated closed as intended due to a protection limitation associated with the long double tee connection to the Ashmont feeder. The value from the previous expenditure in reconfiguring the network will not be realised until the protection is addressed, and the ring can be operated closed. There is no isolation between the 66kV network and the Morrow St transformer connected to the Ashmont double tee. This is due to space constraints on the site, which complicates switching and planned maintenance activities.

The following options were investigated to address the constraints.

5. Network Options

5.1.1 Options

Option 1: Do Nothing

Doing nothing would retain the existing risk, that in the low probability but high consequence event the Morrow St 66/11kV transformer suffered explosive failure, it would cause a severe impact on safety, the network and the environment. The cost for doing nothing could be evaluated simply by estimating the Value of Unserved Energy (VUE) associated with a 1 in 100-year destruction of the Morrow St building.

It was assumed it would take six months to fully rebuild the zone substation. In that period up to half (7MW) of the peak demand (14MW) could be transferred to the adjacent Ashmont and Hammond Ave ZS's, but load beyond this level would be lost. The lost energy (MWH) can be evaluated to an annual VUE via Value of Customer Reliability (VCR[i])

The resulting VUE would equate to $515k p/a. This has not been included as a cost in the Net Present Value (NPV) analysis for the do nothing option but has been included as a saving in both Option 2 and 3.

Option 1 has estimated capital cost $0.0M and 40-year NPV of $0.0M

Option 2 - Bring forward the Wagga North ring

This option to bring forward the Wagga North ring would involve both construction of a second 66kV line from Wagga North BSP to the Cartwrights Hill ZS ($4.5M) and establishment of an outdoor 66kV bus bar at Cartwrights Hill ($2.9M) in the initial year. The Morrow St No.1 transformer would be supplied from the Cartwrights Hill ZS and the Ashmont tee would be removed. The second supply from Wagga North to Cartwrights Hill ZS would retain the existing amenity, following the removal of the alternate supply from the Ashmont double tee.

This is not the preferred option due to the lesser NPV benefit and the uncertainty around the future topology needed for the Wagga North ring network.

Option 2 has estimated capital cost $7.40M and 40-year NPV of $3.73M

Option 3 - Install GIS Circuit Breakers at Morrow St

This option would remove the need to bring forward the Wagga North ring by installation of indoor compact 66kV Gas Insulated Switchgear (GIS) circuit breakers in the Morrow St substation building ($4.2M). The proposal is to install a three-circuit breaker GIS unit to provide protection on the incoming feeder from the Ashmont tee, outgoing feeder to Cartwrights Hill ZS and the Morrow St No.1 transformer. In the future (20 year) a 66kV bus bar will need to be established at Cartwrights Hill ZS ($2.9M) as the take off point for a second substation to supply the growth area to the north. By maintaining the alternate supply to Cartwrights Hill this option allows the Wagga North supply to be deferred beyond the 20-year supply strategy.

This is the preferred option as it has the higher NPV benefit, provides the fastest possible transformer clearing time at Morrow St ZS and allows planning time to evaluate where the load will develop to the north of Wagga before the final network configuration is committed. It also addressed the other network issues such as improving the backup protection clearing time at Cartwrights Hill ZS and allowing the Ashmont Bourkelands ring to be operated closed as intended. The total capital cost of this project includes both the Morrow St ($4.2M) and future Cartwrights Hill ($2.9M) expenditures.

Option 3 has estimated capital cost $7.08M and 40-year NPV of $5.48M
The resulting network configuration is shown in Figure 4.

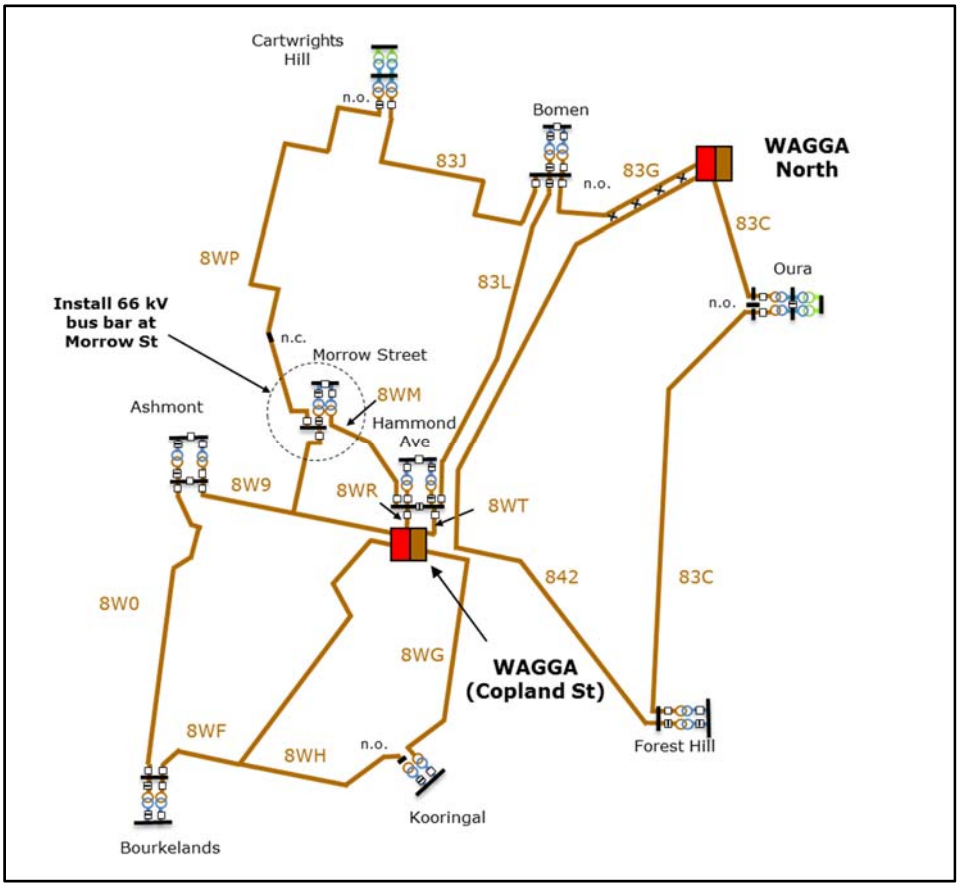

Figure 4 Wagga City 66kV Network - Install GIS at Morrow St

5.1.2 NPV Analysis

The results of the NPV is shown below in Table 1.

In analysing the NPV of each option, the key assumption beyond capital and operating costs is the annual VUE that is saved by undertaking the network option. VUE is based on the energy lost by not undertaking the network option and is included as a positive annual benefit.

A summary of the results of the NPV is shown below in Table 1 with Option 3 – Install GIS Circuit Breakers at Morrow St showing the greater NPV benefit in all sensitivities.

	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	$3.73	$8.23	$0.94	$1.88	$5.57	$6.50	$0.95
3	**$5.48**	**$9.26**	**$3.17**	**$4.07**	**$6.88**	**$8.33**	**$2.78**

Table 1 NPV Analysis Results

Further detail of the NPV analysis is shown in Attachment A.

6. Non-Network Options

With all network augmentation investigations Essential Energy examines the opportunities to alleviate network constraints with non-network solutions. Non-network options generally consist of either demand management or embedded generation.

Demand management requires the peak demand to be reduced to a level which removes or defers the network constraint. The reduction in demand can be achieved by a number of methods, mainly load curtailment or fuel substitution.

With load curtailment, customers agree to provide a significant reduction in their demand (switch off air-conditioning, hot water, manufacturing plant etc) when requested during high peak demand periods. It is generally cost effective with large individual commercial/industrial customers or substantial numbers of existing residential customers. With fuel substitution, customers are given incentives or are provided with appliances that use alternate energy sources to electricity; gas stove replace electric stove etc.

In the case of Morrow St ZS and Ashmont feeder double tee constraints demand management solutions were investigated and deemed unsuitable to remedy the constraints with protection, reliability and switching. Due to the nature of the constraints a demand management solution has been ruled out as the level of load is not the issue, rather the configuration of the network and possible catastrophic transformer failure.

7. Recommendation

The recommended option is Option 3 entailing installation of 66kV GIS circuit breakers at Morrow St. This option would alleviate the need to bring forward the construction of the Wagga North ring and resolves all network constraints related to Morrow St ZS and Ashmont feeder double tee. The recommended option has been approved through the Essential Energy Network Steering Committee and the project is underway with estimated expenditure in 2018/19 of $2.2M and 2019/20 $2.0M (Real FY17).

8. References

Doc No.	Document Name	Relevance
1	Morrow St Positive NPV V1.xlsx	Net Present Value Analysis

9. Key Terms and Definitions

Term	Definition
AER	Australian Energy Regulator
NER	National Electricity Rules
NPV	Net Present Value
VUE	Value of Unserved Energy
VCR	Value of Customer Reliability
GIS	Gas Insulated Switchgear

Appendix A – NPV Summary

Do Nothing option not shown

Project:	Morrow St GIS												
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: Bring Forward Wagga North Ring	(7,400,000)	(3,120,992)	(35,929)	2,161,724	3,727,227	3,727,227	3,727,227						
OPTION 3: Install GIS Circuit Breakers at Morrow St	(7,078,000)	130,187	1,713,507	3,910,478	5,475,497	5,522,515	5,556,008						
												Year 10	Year 20
Timeline (Year)		0	1	2	3	4	5	6	7	8	9	10	20
OPTION 2: Bring Forward Wagga North Ring	Depreciation Age												
Capital Expenditure:													
Cartwrights Hill 66kV Bus	40	(2,920,000)											
Second line from Transgrid	40	(4,480,000)	-	-	-		-	-	-			-	
Cash Outflows - Risk													
O&M		(74,000)	(74,000)	(74,000)	(74,000)	(74,000)	(74,000)	(74,000)	(74,000)	(74,000)	(74,000)	(74,000)	(74,000)
Operating Profit:		(74,000)	(74,000)	(74,000)	(74,000)	(74,000)	(74,000)	(74,000)	(74,000)	(74,000)	(74,000)	(74,000)	(74,000)
Depreciation Capital Investment 1			(73,000)	(73,000)	(73,000)	(73,000)	(73,000)	(73,000)	(73,000)	(73,000)	(73,000)	(73,000)	(73,000)
Depreciation Capital Investment 2			(112,000)	(112,000)	(112,000)	(112,000)	(112,000)	(112,000)	(112,000)	(112,000)	(112,000)	(112,000)	(112,000)
Depreciation Capital Investment 4			-	-	-	-	-	-	-	-	-	-	-
Net Profit Before Tax		(74,000)	(259,000)	(259,000)	(259,000)	(259,000)	(259,000)	(259,000)	(259,000)	(259,000)	(259,000)	(259,000)	(259,000)
Tax at Company Tax Rate of Operating Profit		22,200	77,700	77,700	77,700	77,700	77,700	77,700	77,700	77,700	77,700	77,700	77,700
Net Profit After tax		(51,800)	(181,300)	(181,300)	(181,300)	(181,300)	(181,300)	(181,300)	(181,300)	(181,300)	(181,300)	(181,300)	(181,300)
VUE Saving		-	515,731	515,731	515,731	515,731	515,731	515,731	515,731	515,731	515,731	515,731	515,731
		10 Yr NPV	20 Yr NPV	30 Yr NPV	40 Yr NPV	50 Yr NPV	60 Yr NPV						
NPV (Option 2):		(3,120,992)	(35,929)	2,161,724	3,727,227	3,727,227	3,727,227						
OPTION 3: Install GIS Circuit Breakers at Morrow St													
Capital Expenditure:													
Morrow St GIS	40	(4,158,000)											
Cartwrights Hill 66kV Bus	40												(2,920,000)
Cash Outflows - Risk													
O&M		(41,580)	(41,580)	(41,580)	(41,580)	(41,580)	(41,580)	(41,580)	(41,580)	(41,580)	(41,580)	(41,580)	(70,780)
Operating Profit:		(41,580)	(41,580)	(41,580)	(41,580)	(41,580)	(41,580)	(41,580)	(41,580)	(41,580)	(41,580)	(41,580)	(70,780)
Depreciation Capital Investment 1			(103,950)	(103,950)	(103,950)	(103,950)	(103,950)	(103,950)	(103,950)	(103,950)	(103,950)	(103,950)	(103,950)
Depreciation Capital Investment 2			-	-	-	-	-	-	-	-	-	-	-
Depreciation Capital Investment 4			-	-	-	-	-	-	-	-	-	-	-
Net Profit Before Tax		(41,580)	(145,530)	(145,530)	(145,530)	(145,530)	(145,530)	(145,530)	(145,530)	(145,530)	(145,530)	(145,530)	(174,730)
Tax at Company Tax Rate of Operating Profit		12,474	43,659	43,659	43,659	43,659	43,659	43,659	43,659	43,659	43,659	43,659	52,419
Net Profit After tax		(29,106)	(101,871)	(101,871)	(101,871)	(101,871)	(101,871)	(101,871)	(101,871)	(101,871)	(101,871)	(101,871)	(122,311)
VUE Saving		-	515,731	515,731	515,731	515,731	515,731	515,731	515,731	515,731	515,731	515,731	515,731
		10 Yr NPV	20 Yr NPV	30 Yr NPV	40 Yr NPV	50 Yr NPV	60 Yr NPV						
NPV(Option 3):		130,187	1,713,507	3,910,478	5,475,497	5,522,515	5,556,008						