OPTIONS EVALUATION REPORT (OER)

Constraints in Endeavour Energy's 132 and 66 kV Network between Macarthur and Nepean

OER 000000001438 revision 1.2

Ellipse project description: P0008371 – Macarthur 330-66kV Second Tx
TRIM file: [TRIM No]

Project reason: Reliability - To meet connection point reliability requirements
Project category: Prescribed - Augmentation

Approvals

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Change history

Revision	Date	Amendment
0	28/10/2016	Initial issue
1		Updated risk costs and options evaluation.

1. Need/opportunity

The population in Sydney's south-west sector is expected to grow steadily over the next decade to 2026. An average 3.9% p.a. increase in the maximum summer demand at Macarthur BSP is forecast over the same period.[a]

As a result, Endeavour Energy has carried out a comprehensive planning study on its Macarthur-Nepean network which identifies the nature and likely timing of emerging constraints as follows:[b]

(1) A forced outage of the Macarthur 330/66 kV transformer at times of peak demand would cause:

   (a) Endeavour Energy's Nepean 132/66 kV transformers to exceed their contingency rating of 127 MVA from 2016;

   (b) Endeavour Energy's 132 kV 9L1 line to Nepean to exceed its thermal contingency rating of 358 MVA from 2016; and

   (c) TransGrid's Macarthur 330/132 kV transformer to exceed its contingency rating of 412.5 MVA from 2018.[c]

   Transfer of Ambarvale and Kentlyn loads to Ingleburn would provide some relief to this constraint until 2020; however the capacity of the Ingleburn 66 kV network is forecast to be reached around 2022.[d]

(2) A forced outage of the Macarthur 330/132 kV transformer at times of peak demand would cause:

   (a) TransGrid's Macarthur 330/66 kV transformer to exceed its short-time step rating by 2018.[e]

   As above, transfer of Ambarvale and Kentlyn loads to Ingleburn would provide some relief to this constraint until 2020; however the capacity of the Ingleburn 66 kV network is forecast to be reached around 2022.

(3) There are also problems associated with maintenance outages of the Endeavour Energy Nepean No.4 132 kV bus section that result in the entire 66 kV network load being supplied radially by the Macarthur 330/66 kV transformer and Endeavour Energy's tail-ended 85L 66 kV line to Nepean.

Refer to NOS-1438 for further details.

2. Related needs/opportunities

The following Needs at Macarthur BSP have similar Need dates and consideration should be given to packaging all emerging works into a single project, if possible:

> Need 1437 – Macarthur 66 kV Line Switchbay (Menangle Park ZS) – Need Date 2019/20

  This switchbay will be needed to supply the proposed Menangle Park ZS, which has been identified as a distribution supply point for the NSW Government's Greater Macarthur Land Release.

> Need 1440 – Macarthur 66 kV Line Switchbay (Mt Gilead ZS) – Need Date 2021

  This switchbay will be needed to supply the proposed Mt Gilead ZS, which has been identified as another distribution supply point for the NSW Government's Greater Macarthur Land Release.

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[a] Based on the demand forecast for Macarthur 132 and 66 kV published in TransGrid's Transmission Annual Planning Report (TAPR) 2016, p.76. Note that AEMO acknowledges that in its assessment of transmission network adequacy, it does not consider "local transmission augmentations driven by local demand growth" (AEMO 2015, *National Transmission Network Development Plan*, November 2015, p.20), which may be higher at a given BSP than the overall demand growth across the NEM.

[b] Endeavour Energy, *Macarthur BSP Transformer Outage Study*, August 2016, Endeavour Energy Letter attachment 9.

[c] For TransGrid, the transformer contingency rating is defined as 110% of its nameplate rating (in this case 110% of 375 MVA).

[d] See footnote b.

[e] *Operating Manual (OM) 320 – Transformer Ratings* explains that short-time ratings are "the calculated maximum values up to which the 3-phase transformer may be safely operated" based on the ambient temperature and the transformer's initial (pre-contingent) loading. See *OM 322 – Transformer Ratings in Central Region* for specific transformer data.

3. Options

Base case

The Base Case involves continuing to operate the network 'as is', which means not addressing the Need. As outlined in NOS-1438[f], this option is not deemed credible as it would a risk cost comprising the following components:

- exposing customer load of 88 MW to risk of being lost on outage of the 330/66 kV transformer.
- exposing customer load of 124.5 MW to risk of being lost on outage of the 330/132 kV transformer.
- damage to TransGrid's reputation (poor media coverage).
- litigation by customers/consumer groups.

The total cost of these risks has been calculated in TransGrid's Investment Risk Tool thus:

<u>VCR Risk Cost (Unserved Energy)</u>

$$VCR\ risk\ cost = \{peak\ load\ at\ risk \ * probability\ of\ outage\ of\ Macarthur\ 330/132\ kV\ Tx\ at\ time\ of\ peak\ load \\ + peak\ load\ at\ risk * probability\ of\ outage\ of\ Macarthur\ 330/66\ kV\ Tx\ at\ time\ of\ peak\ load\} * VCR\,[g]$$

$$\therefore VCR\ risk\ cost = \{124.5\ MW * \frac{[Tx1\ yearly\ failure\ rate\,[h] * Tx\ failure\ duration\,[i]]}{[Total\ hours\ of\ peak\ load]\,[j]} + 88\ MW * \frac{[Tx2\ yearly\ failure\ rate\,[k] * Tx\ failure\ duration\,[l]]}{[Total\ hours\ of\ peak\ load]\,[m]}\} * VCR$$

$$\therefore VCR\ risk\ cost = 212.5\ MW * \frac{[0.17 * 24hrs]}{[8hrs]} * \$38{,}350/MWh$$

$$\therefore VCR\ risk\ cost = 212.5\ MW * 0.51 * \$38{,}350/MWh$$

$$\boldsymbol{\therefore VCR\ risk\ cost = \$4.16\ million\ per\ annum}$$

<u>Reliability Risk Cost</u>

$$Reliability\ risk\ cost = VCR\ risk\ cost + litigation\ costs$$

$$\boldsymbol{\therefore Reliability\ risk\ cost = \$4.16m + \$0.02m\,[n] = 4.18\ million\ per\ annum}$$

<u>Financial Risk Cost</u>

$$Financial\ risk\ cost\ = internal\ investigation\ costs = \$10{,}000\,[o]$$

<u>Reputational Risk Cost</u>

$$Reputational\ risk\ cost\ = external\ consultations\ \&\ communications\ costs = \$14{,}500\,[p]$$

<u>Total Risk Cost</u>

$$Total\ risk\ cost = Reliability\ risk\ cost + Financial\ risk\ cost + Reputational\ risk\ cost$$

$$\boldsymbol{\therefore Total\ risk\ cost = \$4.20\ million\ per\ annum}$$

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[f] See footnote a.

[g] TransGrid's Investment Risk Tool bases the Value of Customer Reliability (VCR) on figures published by AEMO in its *Value of Customer Reliability Review - Final Report*, September 2014. In this case we use the mixed residential/industrial figure of $38,350/MWh.

[h] IPART 2016, *Electricity transmission reliability standards Energy — Supplementary Draft Report September 2015* (sic), Table C.10, p.50.

[i] ibid, Table C.1, p.40.

[j] By definition, peak load occurs only once a year. For our calculations, we assume that the peak load occurs for 8 hours on the hottest day of the year.

[k] See footnote i.

[l] See footnote j.

[m] See footnote k.

[n] This component is an assumed litigation risk cost.

[o] This component is an assumed financial risk cost.

[p] This component is an assumed reputational risk cost.

Non-network Solutions

Endeavour Energy has investigated the following non-network options:

1. Permanent demand reduction.
2. Temporary demand reduction.
3. Network support agreement.
4. Distributed generation.

Details of each potential demand management (DM) solution may be found in Endeavour's report sent to TransGrid on 19 August 2016.[q] An extract is provided below:

> *"Previous successful DM programs implemented by Endeavour Energy offered incentives of between $100 and $120 per KVA. DM programs with incentives less than this amount struggled to meet their targets. The conclusion is that a demand management program is not feasible for this project based on the level of demand reduction in the area and the (insufficient) financial incentive available."* (Endeavour Energy report, p.17).

Option A — Installation of a Second 330/66 kV Transformer at Macarthur Substation <OFR-1438A, OFS-1438A>

This option will require the following works to be carried out by TransGrid:

> Provision of a 250 MVA 330/66 kV transformer, including compound, switchgear, oil containment and all other necessary HV gear.
> Establishment of a 330 kV busbar to allow cut in of the second 330/66 kV transformer into the existing 330 kV mesh.
> Installation of a 330 kV No.1 Transformer switchbay.
> Appropriate secondary systems for transformer control and protection are to be installed for the new transformer and switchbay.
> Integration of Automatic Voltage Regulation (AVR) for the new transformer with the existing 330/66 kV transformer control system.
> Installation of 110 V DC battery banks and chargers to meet new capacity.

Figure 1 below shows a single line diagram of the network arrangement under this option. The new transformer is shown in red as "M TX 4".

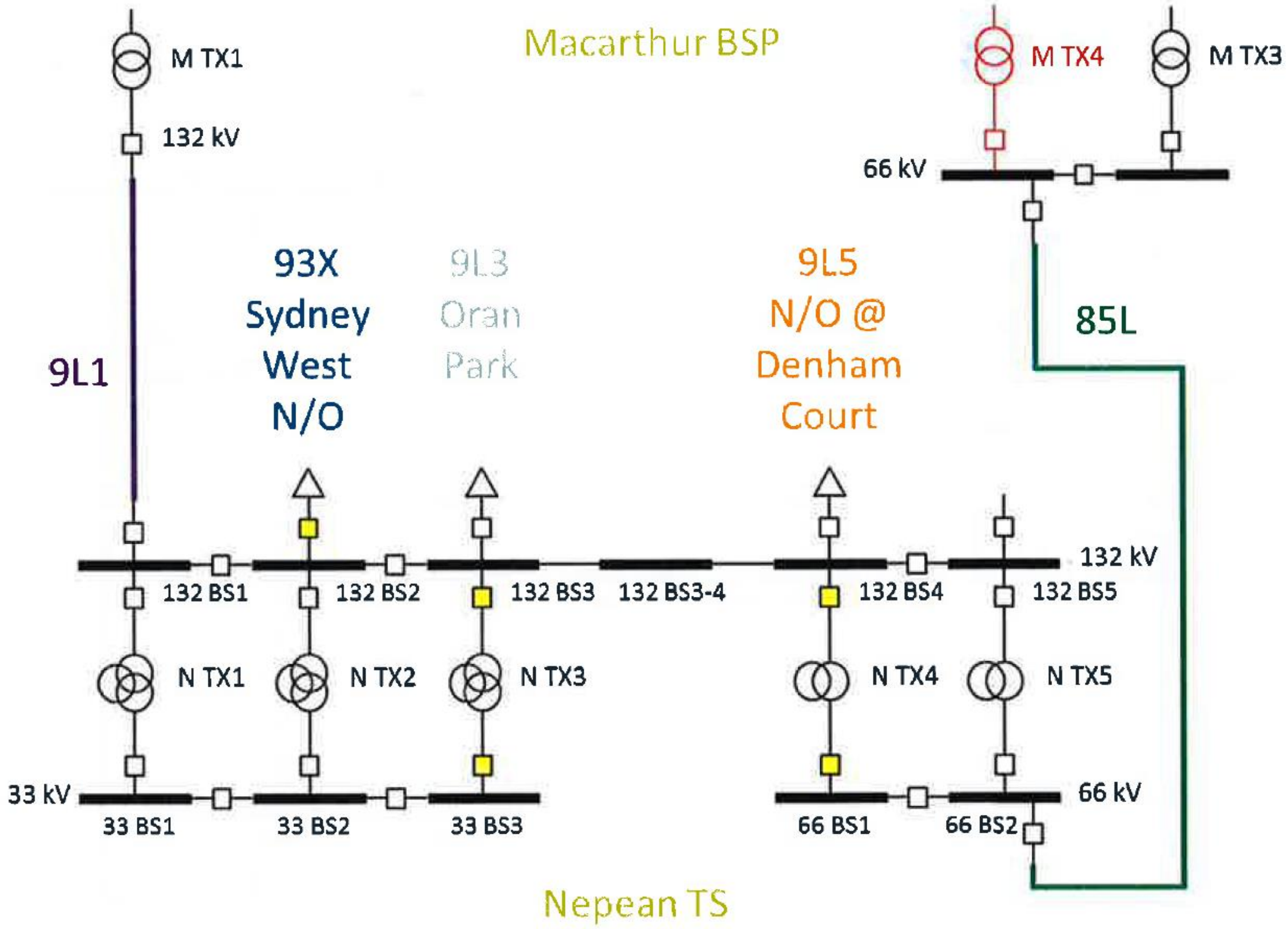
This option has been assessed for feasibility in OFS-1438A. The estimated un-escalated capital cost of the option is $8.6 million ± 25% in 2016-17 AUD.

The post-project risk cost of Option A is assessed to be zero.

The key driver of this risk cost is that should one of the existing transformers at Macarthur BSP trip, no load would be at risk, and therefore there would be no unserved energy.

[q] See footnote b.

Figure 1: Single Line Diagram of Option A – Second 330/66 kV Transformer at Macarthur BSP[r]



Option B — Increased Transfer Capacity from Macarthur BSP to Ingleburn BSP (Endeavour Energy Option)

This option would involve the transfer of the Kentlyn, Ambarvale and Campbelltown loads and augmentation of Endeavour Energy 66 kV feeders 862, 863, 861 and 85T. This increases the Ingleburn to Macarthur transfer capability; however, this option poses a supply security risk to Kentlyn, Ambarvale and Campbelltown.

This option poses a risk of unserved energy of 293,000 kWh per annum for loss of supply to Campbelltown ZS and 119,000 kWh for loss of Ambarvale ZS and Kentlyn ZS. The load transfers would also need to be implemented on a pre-emptive basis, which is unacceptable to Endeavour Energy.[s]

The total cost of this option is estimated by Endeavour Energy in its planning report to be $4.5 million and the risk cost of expected unserved energy has been assessed to be $11.2 million per annum.[t]

As this risk cost is deemed unacceptable to Endeavour Energy, this option has been deemed not feasible.

Option C — Installation of a Third 132/66 kV Transformer at Nepean TS (Endeavour Energy Option)

This option would be carried out entirely by Endeavour Energy at its Nepean Substation. See Figure 2 below for the single line diagram of this option. The new transformer is shown in red as “N TX 3*”.

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[r] Extracted from Endeavour Energy’s report (see footnote b), p.21.

[s] See footnote b.

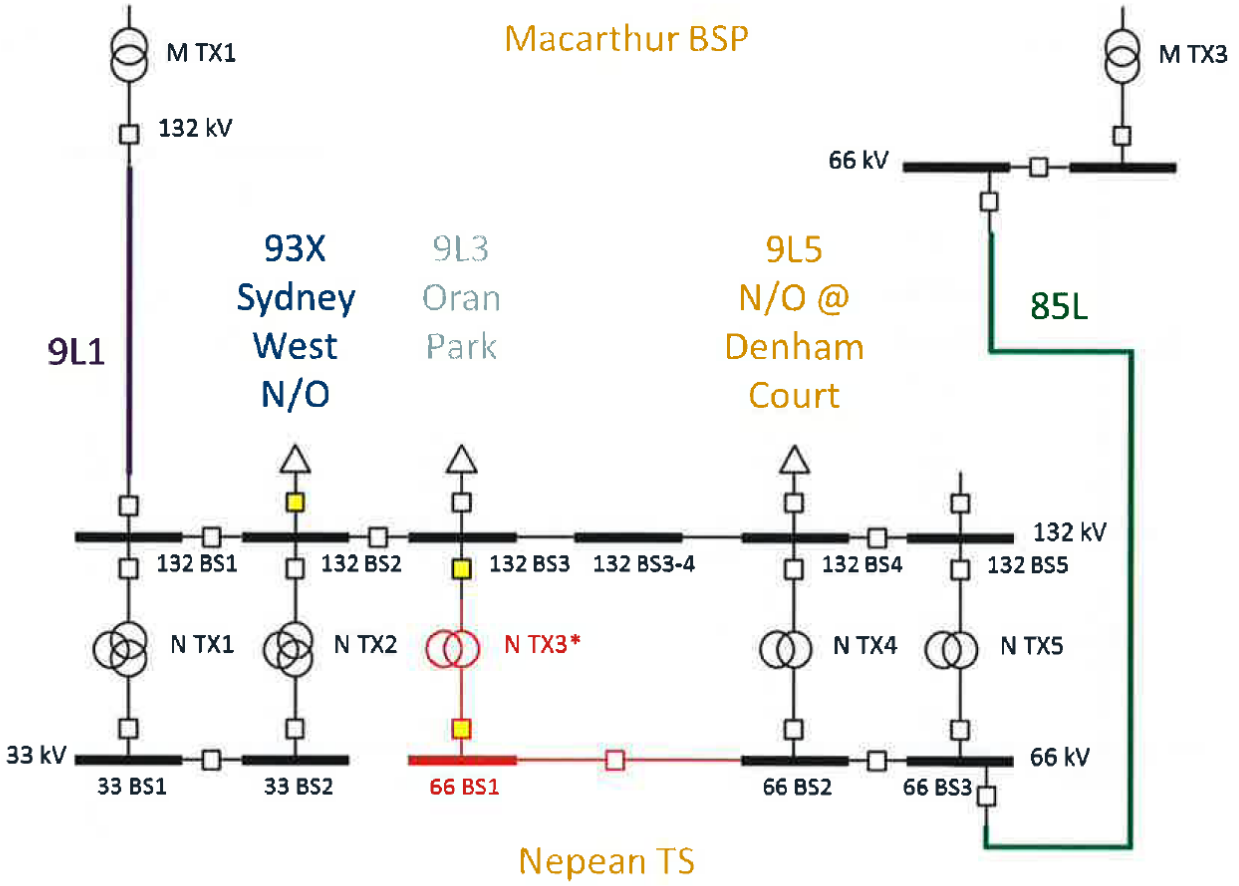
[t] See footnote b.

As outlined in Endeavour Energy's report[u], this option would involve replacing the existing spare 33 kV bus section and spare 132/33 kV transformer with a new 66 kV bus section and 132/66 kV transformer. This option has been estimated by Endeavour to cost $4.3 million.

Furthermore, Endeavour Energy's report states that:

> *"The 66 kV fault level at Nepean [Substation] will exceed the breaking capacity of some 66 kV circuit breakers at Nepean [Substation] if all four of the 66 kV transformers (Macarthur BSP and the three Nepean [Substation]) are paralleled. The preferred normal network configuration is to parallel the 330/66 kV transformer at Macarthur…BSP with two 132/66 kV transformers at Nepean…"*
>
> Endeavour Energy's 132 kV 9L1 Macarthur to Nepean feeder *"…and Macarthur 330/132 kV transformer will still be overloaded in the pre-switching stage with this option. As pre-switching is not acceptable to Endeavour the overload of feeder 9L1 cannot be easily resolved. The manual switching of [Endeavour Energy's] 132 kV feeder[s] 93X [Sydney West to Nepean] or 9L5 [Nepean to Smeaton Grange tee Denham Court] and or (sic) the transfer of Kentlyn and Ambarvale [loads to Ingleburn] to offload 9L1 are time consuming and result in an exposure to high risk."* (Endeavour Energy report, p.20).

Figure 2: Single Line Diagram of Option C – New Nepean 132/66 kV Transformer[v]



It is assumed for the purpose of the Net Present Value (NPV) comparisons in this OER, the risk cost of this option is the same as Option B, i.e. $11.4 million.

As this risk cost is deemed unacceptable to Endeavour Energy, this option has been deemed not feasible.

[u] See footnote b.

[v] Extracted from Endeavour Energy's report (see footnote b), p.20.

4. Evaluation

The commercial evaluation of the credible options is summarised in Table 1.

Table 1: Commercial Evaluation of the Credible Options

Option	Description	Total Capex ($m)	Yearly Opex ($m)	Yearly Post Project Risk Cost ($m)	Economic NPV ($m)	Financial NPV ($m)	Rank
Base case	'Do nothing' (Do not address the emerging constraint).	-	-	4.20	-	-	2
A	Installation of a Second 330/66 kV Transformer at Macarthur Substation	8.6	0.172	0.00	23.18	(8.58)	1

The commercial evaluation is based on:

- a 10% discount rate
- a life of the investment of 15 years and a corresponding residual/terminal value
- Discount rate sensitivities based on TransGrid's current AER-determined pre-tax real regulatory WACC of 6.75 percent and 13% appear in Table 3 for the preferred option, A:

Table 3: Discount rate sensitivities ($ million)

Option	Description	Economic NPV @ 13%	Economic NPV @ 6.75%
A	Installation of a Second 330/66 kV Transformer at Macarthur Substation	16.14	35.45

ALARP Evaluation

An ALARP assessment is triggered by the following hazard and the disproportionate factor:

- Unplanned outage of HV equipment → 3 times the safety risk reduction and taking 10% of the reliability risk reduction as being applicable to safety.

However, as this will only produce 30% of the benefit derived in the economic evaluation, a full ALARP evaluation will not produce an alternative preferred solution.

Capital and operating expenditure

The yearly incremental operating expenditure of Option A is estimated to be 2% of the upfront capital cost of the option, which equates to $0.172 million, escalated at a rate of 2.9% per annum.[w]

Regulatory Investment Test – Transmission

Option A will be subject to the RIT-T process as it has an estimated cost greater than the mandated $6 million threshold.

[w] TransGrid Success Database as at May 2016.

5. Recommendation

Based on the economic evaluation above, Option A is the preferred option to address the Need as it:

> enables TransGrid to meet its supply obligations under the National Electricity Rules.

> significantly reduces TransGrid's risk exposure and reduces the annual risk cost from $4.20m to zero.

It is recommended that:

> Asset Management/Portfolio Management issue a DG1 paper and RPS for Option A, in consultation with PSA and other relevant stakeholders.

Appendix A - Financial and Economic Evaluation Reports

Project_Option Name	Need 1438 - Option A - Second 330/66 kV transformer at Mac

1. Financial Evaluation (excludes VCR benefits)

NPV @ standard discount rate	10.00%	-$8.58m	*NPV / Capital (Ratio)*	*-1.00*
NPV @ upper bound rate	13.00%	-$8.00m	*Pay Back Period (Yrs)*	*Not measurable*
NPV @ lower bound rate (WACC)	6.75%	-$9.36m	*IRR%*	*-10.39%*

2. Economic Evaluation (includes VCR benefits but excludes tax benefits from non-cash transactions, ENS penalty and overall tax cost)

NPV @ standard discount rate	10.00%	$23.18m	*NPV / Capital (Ratio)*	*2.70*
NPV @ upper bound rate	13.00%	$16.14m	*Pay Back Period (Yrs)*	*2.14 Yrs*
NPV @ lower bound rate (WACC)	6.75%	$35.45m	*IRR%*	*40.02%*

Benefits

Risk cost	As Is	To Be	Benefit
Systems (reliability)	*$4.18m*	*$0.00m*	*$4.18m*
Financial	*$0.01m*	*$0.00m*	*$0.01m*
Operational/compliance	*$0.00m*	*$0.00m*	*$0.00m*
People (safety)	*$0.00m*	*$0.00m*	*$0.00m*
Environment	*$0.00m*	*$0.00m*	*$0.00m*
Reputation	*$0.01m*	*$0.00m*	*$0.01m*
Total Risk benefits	$4.20m	$0.00m	$4.20m
Cost savings and other benefits			$0.00m
Total Benefits			$4.20m

VCR Benefit	*$4.16m*
ENS Penalty	*$0.00m*
All other risk benefits	*$0.04m*
Total Risk benefits	$4.20m
Benefits in the financial NPV* **excludes VCR benefits*	$0.04m
Benefits in the economic NPV** ***excludes ENS penalty*	$4.20m

Other Financial Drivers

Incremental opex cost pa (no depreciation)	-$0.17m	Write-off cost	$0.00m
Capital - initial $m	-$8.60m	Major Asset Life (Yrs)	40.00 Yrs
Residual Value - initial investment	$2.80m	Re-investment capital	$0.00m
Capitalisation period	3.00 Yrs	Start of the re-investment period	0.00 Yrs