Timber Poles Overview and Opportunities

Network Failure Investigation

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Contents

1 Purpose 5
2 Background 5
3 Timber Pole Population Overview 5
4 Pole Serviceability, Reinforcing and Condemning Criteria 9
4.1 Serviceability Criteria 9
4.2 Reinforcement Criteria 9
4.3 Inspection Process 12
5 Conditional and Functional Failure Data 13
5.1 Failure Performance by Cause 13
5.2 Functional Failure Data (Financial Year 2013) 13
5.3 Comparison with Ausgrid & Endeavour 18
5.4 Pole Condition 19
6 Opportunities for Improvement 19
6.1 Inspection Interval 19
6.2 Serviceability Criteria 20
6.3 Inspection Effectiveness 20
6.4 Time to correct once defected 22
6.5 Pole Reinforcing 22
6.6 Data Quality Issues and WASP Modifications 23
6.7 Pole Failure Definition 23
6.8 Recommendations 24
7 Future Work 24

Figures

Figure 1: Timber Pole Age by Type[2] ... 7
Figure 2: Average Pole Age by Type ... 8
Figure 3: Reinforcing Criteria Comparison - Top Fixing Point ... 11
Figure 4: Reinforcing Criteria Comparison - Bottom Fixing Point ... 11
Figure 5: Functional Failures - Months since Condemned (condemned only) ... 17
Figure 6: Functional Failures - Years since Inspection (excluding condemned) ... 17

Tables

Table 1: Pole Material Count by Owner ... 5
Table 2: Essential Owned Poles ... 6
Table 3: Essential Owned Timber Pole Types ... 6
Table 4: Timber Poles - Rural/Urban ... 6
Table 5: Timber Poles - Distribution/Subtransmission Count ... 6
Table 6: Timber Pole Age by Type - Statistical Values ... 7
Table 7: Serviceability Criteria Comparison ... 9
Table 8: Reinforcement Criteria Comparison ... 10
Table 9: Inspection Process Comparison ... 12
Table 10: Failure Performance by Cause (2013 Financial Year) ... 13
Table 11: Functional Failures - Conclusion by Cause ... 15
Table 12: Functional Failures - Conclusion by Failure Location ... 15
Table 13: Functional Failures - Wall Thickness Comparison at Inspection and Failure ... 16
Table 14: Functional Failures - Average Age at Failure by Pole Type ... 18
Table 15: Pole Strategy Performance Comparison (Estimate) ... 18
Table 16: Timber Poles for Proactive Reinforcement ... 19
Table 17: Pole Inspection Costs ... 19
Table 18: Cost of Reinforcing vs Replacing ... 22

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		Tony Scroope	Manager Planning
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		Ken Stonestreet	Chief Engineer
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		Neil Chapman	Group Manager Maintenance and Refurbishment Strategy
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		Terry Holmes	Group Manager Asset Management Planning
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1 Purpose

This document has been prepared to provide an overview of the timber pole population, a summary of the current condition of the population as well as opportunities for improvement in asset management, inspection, data collection/storage and maintenance. It is intended that once this document has been reviewed and the opportunities for improvement have been discussed, the direction for management of our timber pole population will be clear and will set out the future strategy.

2 Background

The data has been filtered to include only timber poles owned by Essential Energy (Essential). Data is based on extracts from Works Assets Solutions People Database (WASP) and Electrical Network Incidents Database (ENI) extracted during August 2013 and has been cleansed to reduce data errors. Data has also been sourced through the FMECA/RCM sessions looking at Maintenance Requirements Analysis (MRA).

Reference data relating to Ausgrid and Endeavour Energy (Endeavour) practices and performance has been included in this report for comparison purposes; however this data needs to be validated for each distributor.

3 Timber Pole Population Overview

Timber poles account for roughly 87% of all Essential owned poles (Table 1 & Table 2). The timber pole type population breakdown (Table 3) shows that natural round poles represent 35% of the total population, with Copper Chrome Arsenic (CCA) treated poles representing 33%.

Table 1: Pole Material Count by Owner

Pole Material	Essential	Private Owner[1]	RTA	Shared Energex	Shared TransGrid	Telstra (AI)	Transgrid (AI)	Unknown	Total
Aluminium	408	168							**576**
Composite	40								**40**
Concrete	102,596	1,699	45		1	4		28	**104,373**
Steel Pole	20,364	4,840	192			4		12	**25,412**
Stobie	449								**449**
S/L Column	45,672	2,135	1,708					7	**49,522**
Timber	1,136,494	61,171	93	12	11	1,159	3	145	**1,199,088**
Tower	206	2							**208**
Unknown	558	55			1			15	**629**
Total	**1,306,787**	**70,070**	**2,038**	**12**	**13**	**1,167**	**3**	**207**	**1,380,297**

[1] Private owner includes poles that were previously privately owned (or recorded as such) but are in the process of being transferred to Essential ownership.

Table 2: Essential Owned Poles

Pole Material	Far West	North Coast	Northern	South Eastern	Southern	Total
Aluminium	1	47	218	88	54	**408**
Composite	7	6	9	13	5	**40**
Concrete	32,176	2,069	11,572	4,677	52,102	**102,596**
Steel Pole	2,930	816	10,092	1,661	4,865	**20,364**
Stobie	447	1			1	**449**
Street Light Column	661	16,531	7,039	11,600	9,841	**45,672**
Timber	61,914	257,515	336,386	233,960	246,719	**1,136,494**
Tower	18	31	50	99	8	**206**
Unknown	21	222	92	103	120	**558**
Total	**98,175**	**277,238**	**365,458**	**252,201**	**313,715**	**1,306,787**

Table 3: Essential Owned Timber Pole Types

Pole Type	Far West	North Coast	Northern	South Eastern	Southern	Total
Copper Chrome Arsenic(CCA)	7,236	158,781	59,106	92,613	63,291	**381,027**
Desapped Durable(DES)	22	9,520	10,762	4,094	2,634	**27,032**
Low Temperature Creosote	1,725	409	5,461	5,466	1,140	**14,201**
Natural Round	10,759	67,335	165,056	82,991	70,560	**396,701**
Pigment Emulsified Creosote	11,787	9,911	72,746	10,311	14,184	**118,939**
Pressure Impregnated(PI)	29,814	10,969	22,024	37,639	94,170	**194,616**
Unknown Timber	571	590	1,231	846	740	**3,978**
Total	**61,914**	**257,515**	**336,386**	**233,960**	**246,719**	**1,136,494**

From the timber pole population of 1,136,494 poles, 76% are classified as rural (Table 4), and 92% are used on the distribution network (Table 5).

Table 4: Timber Poles - Rural/Urban

Rural Urban	Far West	North Coast	Northern	South Eastern	Southern	Total
Rural	51,271	175,040	269,554	181,038	187,485	**864,388**
Urban	10,370	79,332	63,332	50,198	56,688	**259,920**
(Empty)	273	3,143	3,500	2,724	2,546	**12,186**
Total	**61,914**	**257,515**	**336,386**	**233,960**	**246,719**	**1,136,494**

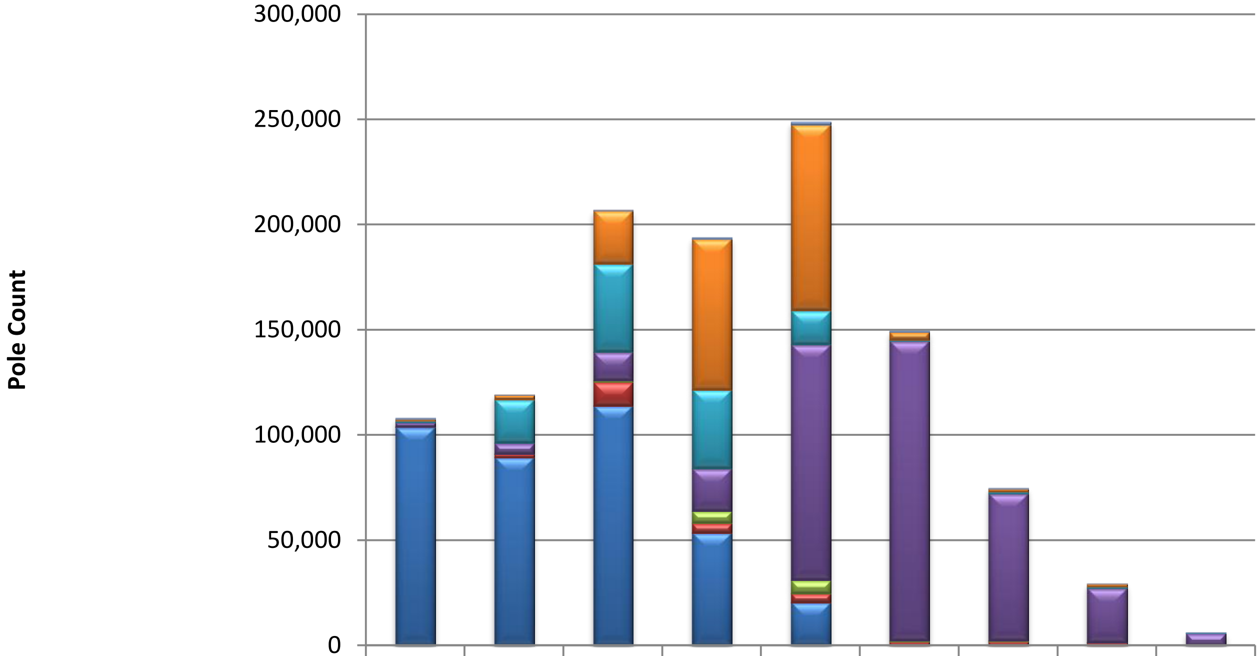
Table 5: Timber Poles - Distribution/Subtransmission Count

Distribution / Subtransmission	Far West	North Coast	Northern	South Eastern	Southern	Total
Bollard	424	7,128	4,841	3,321	3,115	**18,829**
Distribution	53,445	237,319	312,113	216,236	224,316	**1,043,429**
Distribution 33kV	2,654	720	4,664	1,839	4,481	**14,358**
Subtransmission	5,391	12,348	14,768	12,564	14,807	**59,878**
Total	**61,914**	**257,515**	**336,386**	**233,960**	**246,719**	**1,136,494**

Table 6: Timber Pole Age by Type - Statistical Values

Pole Type	Average Age[2]	Median	Std Deviation
Copper Chrome Arsenic(CCA)	19.77	19.67	12.05
Pigment Emulsified Creosote	29.78	28.99	10.86
Desapped Durable(DES)	36.71	30.65	17.03
Pressure Impregnated(PI)	38.81	39.65	9.21
Low Temperature Creosote	40.45	40.65	8.87
Unknown Timber	42.02	45.65	21.09
Natural Round	53.39	52.67	13.13
Grand total	**36.55**	**36.65**	**18.56**

Figure 1: Timber Pole Age by Type[2]

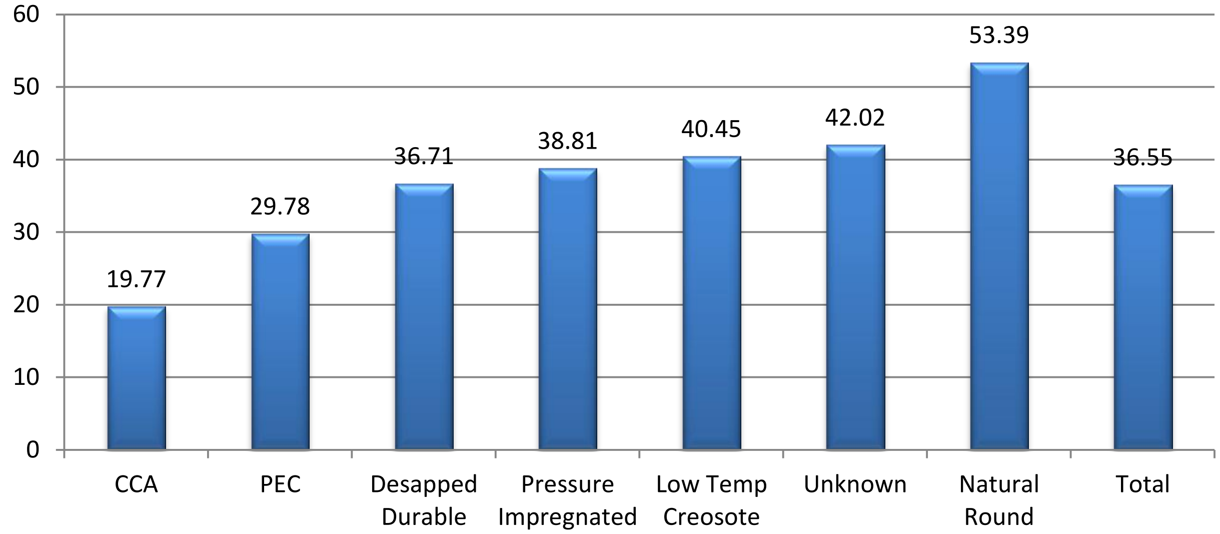


	0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90
Unknown Timber	459	224	360	507	1,182	528	419	298	1
Pressure Impregnated(PI)	680	2,067	25,250	71,777	88,535	3,854	1,288	1,165	
Pigment Emulsified Creosote	841	20,667	41,844	37,378	16,061	471	782	773	122
Natural Round	2,037	5,099	13,514	20,223	111,921	142,232	70,014	25,763	5,898
Low Temperature Creosote	68	116	821	5,789	6,361	581	407	58	
Desapped Durable(DES)	145	1,617	11,156	4,653	4,325	1,835	1,878	1,421	2
Copper Chrome Arsenic(CCA)	103,736	89,394	113,996	53,471	20,430				

Pole Age (Years)

[2] Timber pole installation date has been corrected for data errors as follows;
CCA poles with install date unknown or prior to 1965 have been dated 1965.
Poles older than 1924 or install date unknown have been split between install dates of 1935 & 1945.

Figure 2: Average Pole Age by Type



4 Pole Serviceability, Reinforcing and Condemning Criteria

The tables below are a summary only, due to the complex nature and varying inspection processes between the three utilities. Please refer to the relevant utility standard for a complete description of the process.

4.1 Serviceability Criteria

Table 7 below compares Essential's pole serviceability criteria (based on minimum wall thickness & replacement priority based on safety factor) with those of Ausgrid and Endeavour. Essential's wall thickness values override all other pole serviceability criteria used for poles.

Current pole serviceability criteria for Essential only provide a short warning time. This suggests that unless there is a corresponding short inspection interval that poles may fail due to the short warning time.

Table 7: Serviceability Criteria Comparison

Criteria/Process	Essential	Ausgrid	Endeavour
Serviceability Minimum Criteria	SF ≥ 2 and average wall thickness ≥ • 20mm (Fully Supported Dist) • 25mm (Unsupported Dist) • 30mm (Loaded Dist/Fully Supported Subtrans) • 50mm (Unsupported or Loaded Subtrans)	Residual strength ≥ 50% and average wall thickness ≥ 70mm,	SF ≥ 2 and; • 2 walls ≥ 30mm (normal & stay poles) • 2 walls ≥ 50mm (Street light, Sub pole, HV operational pole, UGOH pole, cross service pole at kerb line).
Rectification Priority	• SF 1 ≤ x < 2 - Unserviceable, condemned pole. Not to be climbed. Reinforce if suitable. Rectify within 6 months. • SF < 1 - Unserviceable, dangerous pole. Not to be climbed. Replace ASAP. Apply struts if required.	The replacement priority is determined by a second desktop assessment by Ausgrid staff after a pole exceeds the minimum serviceability criteria. Following this assessment, the following outcome was realised; • Reinforce 46% • Replace 51% • Return to Service 2.5% • Re-Inspect or awaiting assessement 0.5%	• SF < 0.8 or 2 walls < 20 mm - Replace immediately • SF < 2 or 2 walls < 50 mm (Street light, Sub pole, HV operational pole, UGOH pole, cross service pole at kerb line) - Replace within 6 months • Safety factor < 2 or 2 walls < 30 mm (Stay pole) - Replace within 6 months • Safety factor < 2 or 2 walls < 30 mm (Normal pole) - Nail pole if possible, else replace within 6 months

4.2 Reinforcement Criteria

Ausgrid reinforce their poles with a higher wall thickness at the bottom fixing point than both Endeavour and Essential, however interestingly both Endeavour and Ausgrid have similar criteria for wall thickness at the top of the reinforcement. Essential has a minimum wall thickness that is used for both reinforcement installation suitability assessment as well as reinforced pole serviceability.

Table 8: Reinforcement Criteria Comparison

Criteria/Process	Essential	Ausgrid	Endeavour
Reinforcement type used	Ausplint C-Splint	UAM bolted reinforcement nail	Single stake RFD nail
Trigger Point to Install Reinforcing	When serviceability minimum criteria is exceeded	When serviceability minimum criteria is exceeded	Only for normal poles (see rectification priority in Table 7)
Reinforcement Installation Criteria - Wall Thickness at Groundline	Average ≥15mm		≥30mm
Reinforcement Installation Criteria - Wall Thickness at bottom fixing point	No requirement (other than ground line measurement above)	30mm @ 200mm above ground line	≥30mm
Reinforcement Installation Wall Thickness Criteria at top fixing point	6% of pole diameter + 10mm @ 1m (28mm for 12.5m/6kN) (11% of pole diameter + 10mm @ 1.5m) (43mm for 12.5m/6kN)	60mm @ 0.8 above groundline & 60mm @1m above groundline	16% of pole diameter + 10 mm @ 1.2m above groundline (60mm for 12.5m/6kN)
Reinforced Pole Condemning Criteria – Wall Thickness at Groundline	Average <15mm		<10mm
Reinforced Pole Condemning Criteria – Wall Thickness at bottom fixing point	No requirement (other than ground line measurement above)	<30mm @ 200mm above ground line	<10mm
Reinforced Pole Condemning Criteria – Wall Thickness at top fixing point	6% of pole diameter + 10mm @ 1m (28mm for 12.5m/6kN) (11% of pole diameter + 10mm @ 1.5m) (43mm for 12.5m/6kN)	<50mm @ 0.8 above groundline & <50mm @1m above groundline	11% of pole diameter + 10 mm @ 1.2m above groundline (43mm for 12.5m/6kN)
Poles suitable for reinforcement	All timber poles except; • Poles not expected to last beyond the next inspection cycle • Have > 15 deg lean • Operational poles • Privately owned • Used as bollards • Have concrete or timber baulks or collars • Have lines crossing or are situated within a rail corridor • Are located in swampy, tidal, snowy or terrain that cannot be accessed by heavy vehicles	All timber poles except; • Poles associated with two pole substations • Poles with raiser brackets (excluding OHEW raiser), • Poles with below ground baulks • Poles in swampy/tidal areas	All timber poles except; • Street light poles • Cross-road service poles at kerb • Operational poles • Substation poles • UGOH poles • Stay poles

Figure 3: Reinforcing Criteria Comparison - Top Fixing Point

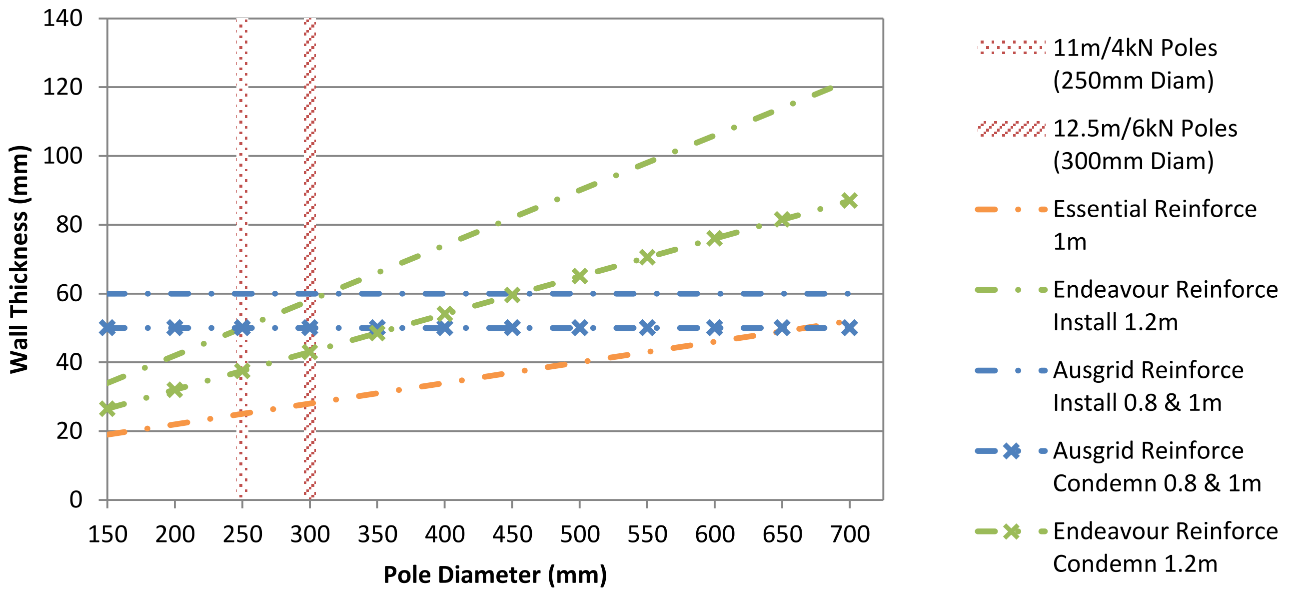
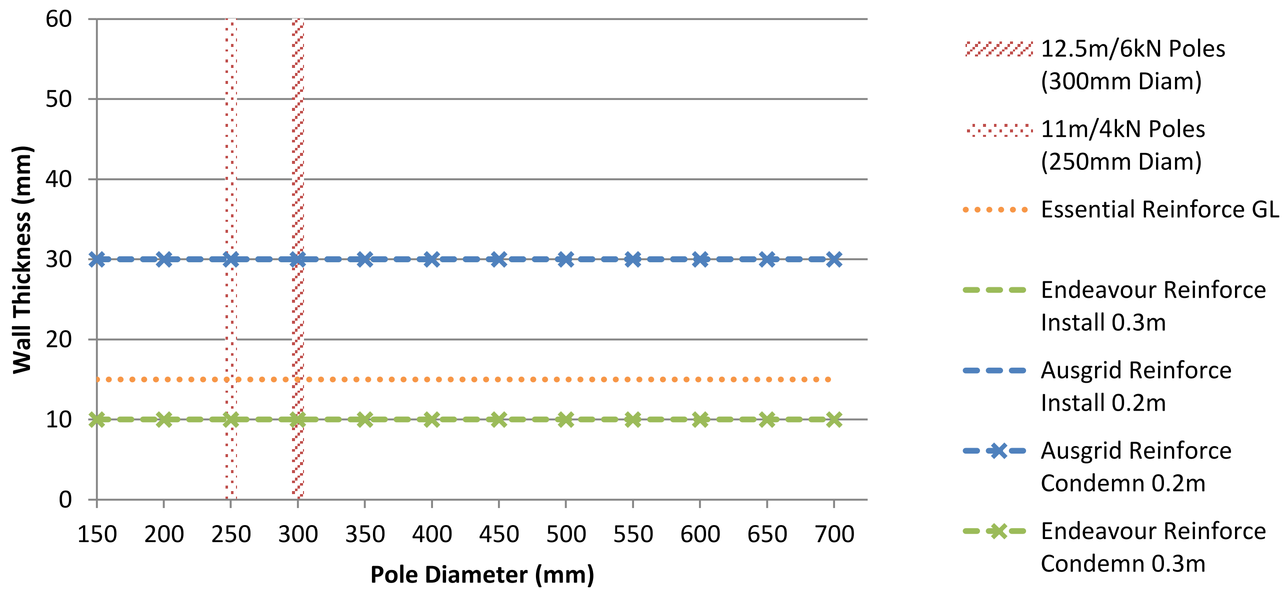


Figure 4: Reinforcing Criteria Comparison - Bottom Fixing Point



4.3 Inspection Process

The inspection process at Essential currently involves four levels of inspection. The level of the inspection is determined based on a number of factors including material type, preservative type, age and past inspection results. Comparison with Endeavour and Ausgrid (as shown in Table 9) reveal a few interesting characteristics;

- Essential perform below ground internal inspection using a 60° drill angle. Both Endeavour and Ausgrid use a 45° angle. The use of a 60° angle will give a slightly deeper hole (particularly for the far wall measurement) however it will likely have a reduction in the measurement accuracy (particularly for the far wall measurement).
- Essential generally excavate 1/3rd of the pole circumference (Level 3 inspection), meaning that portions of the exterior of the pole may never be inspected, and the areas that are inspected will (for Level 3 inspections) only be inspected at every second inspection. This means that soft rot or external termite deterioration may not be picked up, however it may also lead to a reduced incidence of external soft rot due to the soil around the pole not being disturbed as frequently.
- Essential only measure one wall thickness, and it is the wall thickness that is not in the critical axis. This means that there is a reasonable chance that a wall thickness that could lead to a failure will not be detected. Both Ausgrid and Endeavour measure both walls (front and back) in the neutral axis through the one hole.

Table 9: Inspection Process Comparison

Criteria/Process	Essential	Ausgrid	Endeavour
External below ground inspection	Level 3 – Pressure impregnated >24 years, All Natural Rounds and Desapped Durables, All C-Splint Reinforced Poles; • Excavate 1/3 of pole in non-critical zone to 350mm depth on opposite side to last inspection. Level 4 – Where issue discovered at Level 3 • Full excavation to 350mm (decay) or 400mm (termites)	Fully excavate to 350mm (when no termites are present and following an internal inspection at 100mm below ground line to confirm safe to fully excavate), except CCA pressure impregnated timber poles less than 15 years old, excluding Blackbutt species.	Excavate to 350mm depth (starting in a quadrant on the neutral axis), extend to 450mm depth if significant degradation.
Internal below ground inspection	Level 2 – Pressure impregnated poles 12-24 years old; • Drill 1 x 16mm abaxial hole starting at 150mm above ground at 60° to horizontal Level 3 – Pressure impregnated >24 years, All Natural Rounds and Desapped Durables, All C-Splint Reinforced Poles; • Drill inspection hole starting at 100mm below ground at 60° to horizontal Level 4 - Where wall thickness at Level 3 < 25% pole diam • Second inspection hole on other side starting at 100mm below ground, or same side starting at 350mm below ground.	Drill a 14mm, 45° hole at the location where the defect is suspected to be (NS145 S3.3.2), or at 100mm below ground line. Measure both walls.	Drill a 45° hole starting at ground line on the neutral axis (subsequent holes to start below previous holes). If a pocket is found that extends beyond the centre of the pole a second hole is required at 90° to the first hole and starting at 200mm below groundline. Both walls (or where a second hole is drilled, all four walls) are to be measured. Methylated spirits (not pole saver rods) is used to sterilize inspection holes. Polymeric date tape is installed at the bottom of the excavation to indicate the year of inspection and the depth of inspection.
Reinforced pole below ground inspection	Excavate to a depth of 100mm and inspect for external defects.	Excavate to a depth of 100 mm, extended to 600 mm if rust is present.	Excavate to a depth of 350 mm, extended to 450 mm if rust is present.
Reinforced pole above ground inspection	Drill inspection holes at 1m & 1.5m in neutral zone	Drill angled upwards at 5° to horizontal	

5 Conditional and Functional Failure Data

5.1 Failure Performance by Cause

The major failure modes for timber poles are fungal decay (rot) and termites. The performance of timber poles for these failure modes has been analysed by region, as shown in Table 10 below.

Table 10: Failure Performance by Cause (2013 Financial Year)

Fungal Decay	Far West	North Coast	Northern	South East	Southern	Total
Conditional Failures[3]	207	1249	1775	734	1220	**5185**
Functional Failures[4]	2	11	10	5	11	**39**
Timber Pole Population	61,914	257,515	336,386	233,960	246,719	**1,136,494**
MTBF	296	204	188	317	200	**218**
Cond/Funct Ratio	104	114	178	147	111	**130**
1 failure in n poles	**30,957**	**23,410**	**33,639**	**46,792**	**22,429**	**29,141**

Termites	Far West	North Coast	Northern	South East	Southern	Total
Conditional Failures[4]	297	231	1095	164	711	**2498**
Functional Failures[4]	3	2	14	0	10	**29**
Timber Pole Population	61,914	257,515	336,386	233,960	246,719	**1,136,494**
MTBF	206	1,105	303	1,427	342	**450**
Cond/Funct Ratio	99	116	78	-	71	**86**
1 failure in n poles	**20,638**	**128,758**	**24,028**	**-**	**24,672**	**39,189**

Insufficient Detail (Wind)	Far West	North Coast	Northern	South East	Southern	Total
Functional Failures[4]	3	1	19	5	23	**51**
Timber Pole Population	61,914	257,515	336,386	233,960	246,719	**1,136,494**
1 failure in n poles	**20,638**	**257,515**	**17,705**	**46,792**	**10,727**	**22,284**

Overall Performance	Far West	North Coast	Northern	South East	Southern	Total/Average
Conditional Failures[4]	504	1480	2870	898	1931	**7683**
Functional Failures	8.0	14.0	43.0	10.0	44.0	**119**[5]
Timber Pole Population	61,914	257,515	336,386	233,960	246,719	**1,136,494**
MTBF	121	172	115	258	125	**145.7**
1 failure in n poles	**7,739**	**18,394**	**7,823**	**23,396**	**5,607**	**9,550**

5.1.1 Unassisted Failures based on ENA Pole Failure Definition

The functional failures shown in Table 10 as having a cause of fungal decay and termites represent the unassisted failures where an autopsy is available or the cause is known. There were 51 failures that were attributed to causes of high wind or storm. As these failures didn't have an autopsy performed, there is insufficient detail known about these failures to categorise them by their primary cause.

5.2 Functional Failure Data (Financial Year 2013)

There were 68 functional failures of timber poles this financial year where pole failure data is available. Table 11 below shows a count by failure cause and conclusion, and Table 12 shows a count by failure cause and failure location.

- 15 of the poles (22%) failed outside the inspection zone (see Table 12). Avoiding these failures in future will be difficult and would require substantial changes to current inspection processes.

[3] Reported with causes of decay, internal pipe, or termites
[4] Reported as primary cause of wind or storm, with insufficient data to determine the wind loading
[5] Originally reported to ELG in July 2013 as 92 unassisted failures. Revised to 119 (timber only, 128 total) unassisted failures based on ENA pole failure definition and detailed review of 2013 financial year failures.

  - 8 of these were above ground and are typically white rot (although some brown rot) well above the inspection zone. These failures would not be reduced by any change to the ground line inspection process.
  - The other 7 were below the inspection zone. There is a potential that some of these could be avoided with modified inspection or condemning criteria. Looking at safety factor and pole loading may assist in this area.
- 9 of the poles that failed (13%) were condemned at the time of failure (see Table 13 and Figure 5). These failures could have possibly been prevented, either by improved prioritisation or by strutting when they were condemned. An additional pole (pole CE171623) had a previous replace work task that had been closed in WASP in recent years, but appears not to have actually been replaced. The 9 condemned failures are explained below;
  - Pole 9603868 failed 200mm below ground line due to termites. The pole had been condemned 5 months earlier, but was still within the defect rectification period. High winds were recorded as being a factor at failure. The autopsy showed a wall thickness of 20mm and a safety factor of 2.96.
  - Pole 97090039 failed at ground line due to fungal decay. The pole had been inspected 3 weeks earlier and had a safety factor at inspection of 2.07 with a wall thickness of 20.
  - Pole CE205277 failed at ground line due to external decay on the opposite side to which it was inspected.
  - Pole 97001179 failed above ground line due to termites and fungal decay. The pole was condemned 6.5 months earlier so was just outside the defect rectification period.
  - Pole 830148 failed at ground line. The pole had been condemned 7.5 months prior, so was outside the defect rectification period.
  - Pole 97152157 failed at ground line due to termites. High winds were recorded at the time of failure. The pole had been condemned 6.1 months earlier, so was just outside the defect rectification period.
  - Pole 18601A failed at ground line due to termites. It had been condemned 1.5 months earlier. The pole had a significant reduction in diameter at ground level giving a safety factor of approx. 0.72. This pole should have had struts applied when it was condemned, and the severity should have been raised to an urgent risk.
  - Pole 973 704 failed due to termites, during a storm. According to WASP the pole was overdue for inspection, however the pole measurements were updated (and the defect created) 10 weeks before failure.
  - Pole 9609500 failed due to termites and fungal decay. The pole had been condemned 3.5 months earlier, with a wall thickness of 20mm and a safety factor of 1.85. The pole was within the defect rectification period.
- 6 of the pole failures were concluded to be due to inadequate inspection or condemning criteria. Examples of this are inspection on one side of the pole when the defect was on the other side. It may be possible to avoid some of these type of failures if inspection processes were changed, however there could be a significant cost implication in doing so.
- The remaining 37 failures occurred without the defect being detected. Some of these may be due to inspection effectiveness (experience of the Asset Inspector and how closely they followed the process), and some will be due to the defect not being present at the time of inspection. The latter is the most likely conclusion for the 15 that were caused by termites. This suggests that either
  - damage due to termites is not being detected, or
  - the severity is not being detected at inspection, or
  - deterioration due to termites is quicker than our inspection process allows for.

Table 11: Functional Failures - Conclusion by Cause

Failure Conclusion	Fungal Decay - Brown Rot	Fungal Decay - Other	Fungal Decay - White Rot	Termites - Other	Unknown (Wind)	Total
Condemned at Time of Failure		4		5		**9**
Defect not detected or not present at inspection	7	13	1	15		**36**
Inspection or condemning criteria inadequate		3		3		**6**
Outside inspection criteria - above ground		3	5			**8**
Outside inspection criteria - below ground	1	2		5		**8**
Previous pole defect (not rectified)				1		**1**
Unknown (Insufficient Detail)					51	**51**
Total	**8**	**25**	**6**	**29**	**51**	**119**

Table 12: Functional Failures - Conclusion by Failure Location

Failure Conclusion	Groundline	Above Groundline	At Head	Below Insp Zone	Unknown (Wind)	Total
Condemned at Time of Failure	8	1				**9**
Defect not detected or not present at inspection	33	3				**36**
Inspection or condemning criteria inadequate	6					**6**
Outside inspection criteria - above ground		3	5			**8**
Outside inspection criteria - below ground				8		**8**
Previous pole defect (not rectified)	1					**1**
Unknown (Insufficient Detail)					51	**51**
Total	**48**	**7**	**5**	**8**	**51**	**119**

The following table (Table 13) shows a summary of the failure conclusion, with the inclusion of the wall thickness measurements at inspection (on the horizontal axis) and at failure (on the vertical axis). This data suggests;

- a more proactive pole reinforcement process could potentially save 7 of the 68 pole failures with failure data (12 poles if scaled to 119 failures). These failures are highlighted in yellow in Table 13.
- increased strutting of condemned poles could potentially save 5 failures (9 poles if scaled to 119 failures). These are highlighted in red in Table 13.
- of the 36 poles that failed without the defect being discovered, 21 were due to fungal decay. It is likely that some of these weren't discovered due to the current inspection process, due to;
    - the defect not being located on the side of the inspection (external defects)
    - the defect not being symmetrical (for internal defects)

Table 13: Functional Failures - Wall Thickness Comparison at Inspection and Failure

	Wall Thickness at Inspection					
Wall Thickness at Failure (Inspection Hole)	**0-25**	**26-50**	**51-69**	**≥ 70**	**Unknown**	**Total**
Condemned at Time of Failure	**5**	**3**		**1**		**9**
Above Ground line						
51-69		1				1
At Ground line						
0-25	1					1
Unknown	4	2		1		7
Defect not detected or not present at inspection	**1**	**5**	**1**	**27**	**2**	**36**
Above Ground line						
≥ 70				1		1
Unknown				2		2
At Ground line						
0-25	1			7	1	9
26-50		1		5	1	7
≥ 70				2		2
Unknown		4	1	10		15
Inspection or condemning criteria inadequate		**1**	**1**	**4**		**6**
At Ground line						
0-25				1		1
51-69			1			1
≥ 70				2		2
Unknown		1		1		2
Outside inspection criteria - above ground				**8**		**8**
Above Ground line						
≥ 70				1		1
Unknown				2		2
At Head						
≥ 70				2		2
Unknown				3		3
Outside inspection criteria - below ground			**1**	**7**		**8**
Below Inspection Zone						
≥ 70				3		3
Unknown			1	4		5
Previous pole defect (not rectified)				**1**		**1**
At Ground line						
Unknown				1		1
Unknown (Insufficient Detail)					**51**	**51**
Unknown						
Unknown					51	51
Total	**6**	**9**	**3**	**48**	**53**	**119**

Pole failures that could potentially be saved with a proactive reinforcing process

Pole failures that could potentially be saved with increased strutting of condemned poles

The count of poles vs the number of months since the pole was condemned is shown in Figure 5.

Figure 5: Functional Failures - Months since Condemned (condemned only)

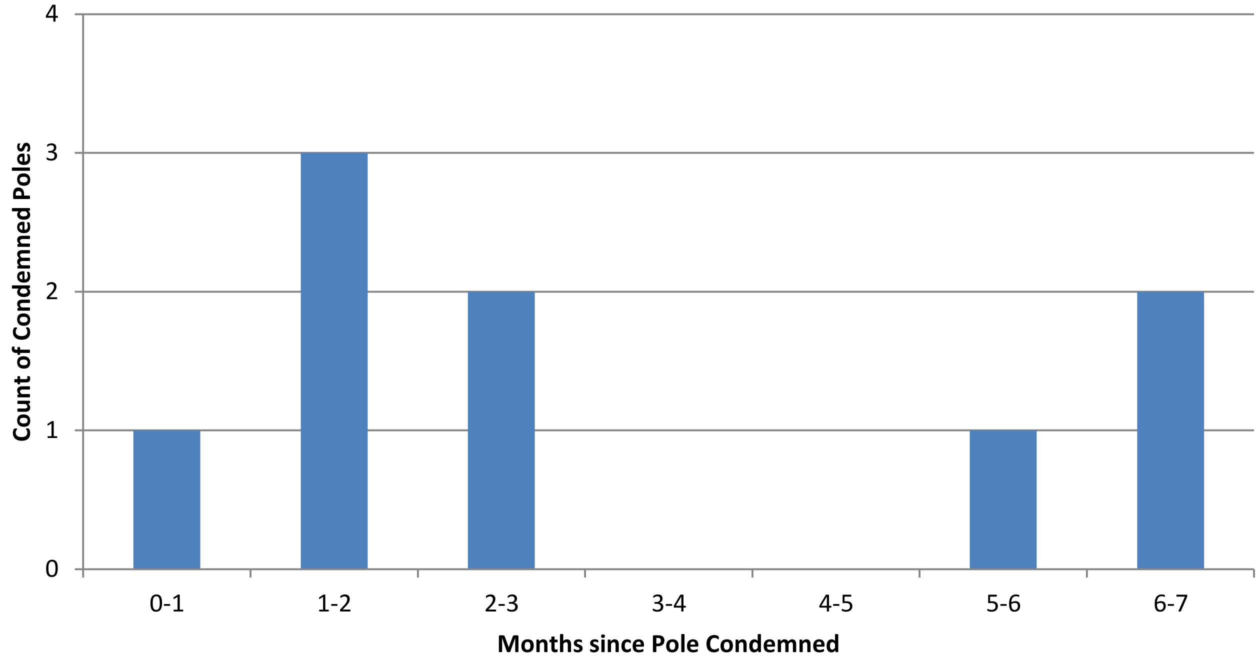
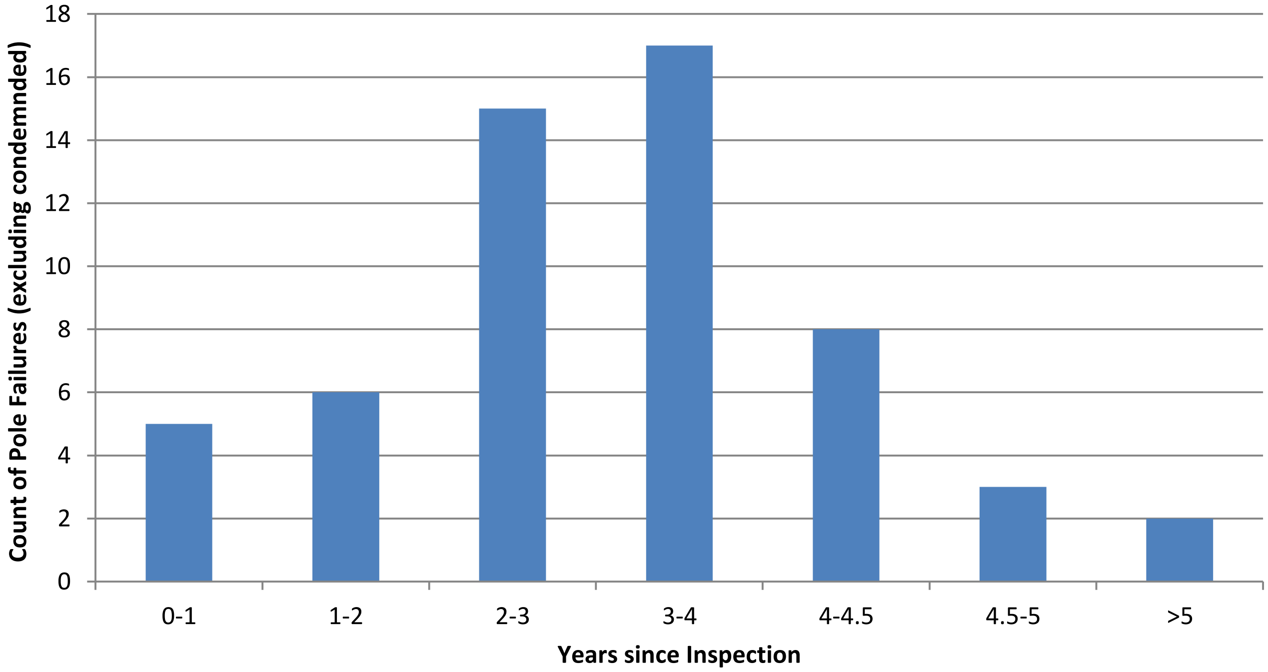


Figure 6: Functional Failures - Years since Inspection (excluding condemned)



NOTE: Figure 6 shows the number of failures vs the time since inspection. The failures that occurred greater than 4 years from inspection are from a smaller population (as the inspection frequency is 4 years with 6 months latitude), hence the significance of these failures is greater due to the smaller population.

Table 14 shows the average age at failure by pole type and failure mode. This table is included as a reference for future comparison, as the number of failures for all but natural round poles is too small to make any statistical conclusions. What is evident here is that natural round poles are the most common pole type when looking at unassisted failures (which is not surprising considering the older age profile and significant population), and they typically fail around 47 years old regardless of the failure mode (however this average

age at failure needs to be considered along with the failure cause conclusion). External decay on treated poles is rare, leaving the strongest, outer sapwood section of the pole intact, with a corresponding lower failure rate.

Table 14: Functional Failures - Average Age at Failure by Pole Type

Average Age at Failure (Years)	Fungal Decay						Termites		Average / Total	
	Brown Rot		Other		White Rot					
Pole Type	**Age**	**Count**	**Age**	**Count**	**Age**	**Count**	**Age**	**Count**	**Age**	**Count**
Copper Chrome Arsenic (CCA)	24	1	40	1			34	2	**33**	**4**
Desapped Durable(DES)							38	2	**38**	**2**
Pressure Impregnated(PI)	47	1	44	1	26	1	46	4	**42**	**7**
Low Temperature Creosote			45	1					**45**	**1**
Natural Round	46	3	47	20	51	5	47	20	**47**	**48**
Pigment Emulsified Creosote							48	1	**48**	**1**
Unknown	51	3	Unknown	2					**51**	**5**
Average / Total	**44**	**8**	**46**	**25**	**46**	**6**	**45**	**29**	**46**	**68**

5.3 Comparison with Ausgrid & Endeavour

Table 15 below shows a comparison of failure performance and respective strategy cost between the three distributors. Some data used to generate this table has been estimated (in particular the Endeavour reinforcement % and cost of reinforcement for Ausgrid and Endeavour) so is indicative only. What is apparent from this table is that lower failure rates equate to higher strategy cost. **This table does not accurately represent the actual strategy cost for any organisation.**

Table 15: Pole Strategy Performance Comparison (Estimate)

Overall Performance (Estimate)	Essential	Essential (Scaled to Ausgrid CF)	Ausgrid (Scaled to EE Population)	Endeavour (Scaled to EE Population)	Ausgrid	Endeavour
Conditional Failures	7683[6]	23867	23867	11616	9108	3463
Functional Failures	119[6]	20.1	20.1	10.1	7.7	3.0
Timber Pole Population	1,136,494	1,136,494	1,136,494	1,136,494	433,706	338,841
1 failure in n poles	**9,550**	**56,497**	**56,497**	**112,947**	**56,497**	**112,947**
Pole Inspection Cycle	4	5	5	4.5	5	4.5
Poles Inspected per year	284,124	227,299	227,299	252,554	86,741	75,298
Ground Line Inspection cost	$54[7]	$93[9]	$93[9]	$54[8]	$93[9]	$54[8]
OH Pole Inspection cost		$56[9]	$56[9]		$56[9]	
Annual Inspection cost	**$15,439,271**	**$33,867,521**	**$33,867,521**	**$13,723,796**	**$12,924,439**	**$4,091,693**
Reinforcement % (Estimate)	8.5%	47.4%	47.4%	15.0%	47.4%	15.0%
Annual Reinforcements	656	11,309	11,309	1,742	4,316	273
Reinforcement cost	$1287	$1287	$830[9]	$1287[8]	$830[9]	$1287[8]
Annual Reinforcement cost	**$844,272**	**$14,554,709**	**$9,386,487**	**$2,242,558**	**$3,582,048**	**$351,351**
Replacement % (Estimate)	91.5%	52.6%	52.6%	85.0%	52.6%	85.0%
Annual Replacements	7,146	12,578	12,578	9,884	4,800	2,947
Replacement cost (Estimate)	$8,517	$8,517	$10,700[9]	$8,000[10]	$10,700[9]	$8,000[10]
Annual Replacement cost	**$60,863,054**	**$107,127,200**	**$134,583,806**	**$79,072,433**	**$51,359,536**	**$23,575,120**
Annual Strategy Cost	**$77,146,597**	**$155,549,430**	**$177,837,814**	**$95,038,788**	**$67,866,022**	**$28,018,164**

[6] Reported during 2013 financial year, with causes of decay, internal pipe, termites, or unknown (wind).
[7] Essential inspection, reinforcement and replacement costs include on-costs and overheads (based on 12/13 FY actuals)
[8] Endeavour inspection & reinforcement costs unknown so Essential costs have been used.
[9] Ausgrid inspection, reinforcement and replacement costs obtained from 2013 report ACAPS4001 'Poles'. It has been assumed that these costs include overheads.
[10] Endeavour replacement cost estimate

The 'Essential (Scaled to Ausgrid CF)' column above shows an ongoing annual strategy cost applicable only after a significant initial investment to increase the conditional failure rate and reduce the unassisted failure rate, by significantly improving the available capacity of the average pole. No attempt has been made to cost this improvement.

5.4 Pole Condition

Table 16 below shows a subset of the in service pole population. This data includes all poles that

- are not marked as reinforced
- had an inspection of level 2 or higher at the last inspection
- are at least 10 years old
- have a wall thickness between 20 and 50mm as at last inspection
- are not condemned

These poles represent potential poles for proactive reinforcement.

Table 16: Timber Poles for Proactive Reinforcement

Wall Thickness	20 - 25	25 - 30	30 - 40	40 - 50	Grand total
Bollard	3	41	105	184	**333**
Distribution	245	1,666	5,654	10,064	**17,629**
Distribution 33kV		15	74	106	**195**
Subtransmission[11]			37	98	**135**
Grand total	**252**	**1,725**	**5,870**	**10,452**	**18,299**

6 Opportunities for Improvement

6.1 Inspection Interval

The current conditional and functional failure performance suggests that the optimum inspection interval should be reduced (based on Failure Mode Effects and Criticality Analysis currently underway using software tool MIMIR 3.1). Reducing the inspection interval would have a positive impact on pole failure performance, however to do so would come at a considerable cost (Table 17). The transition from maintenance area to feeder based inspection may have led to a temporary increase in the inspection period with resulting impacts on pole performance. Bringing the inspection period back to the 4 year cycle will likely show an improvement in the number of failures compared to the past few years performance. There are a number of alternatives (see remaining topics in this section) to improve performance that should be considered before a decision is made to adjust the inspection interval.

Table 17: Pole Inspection Costs

Inspection Cycle (Years)	3	3.5	4	4.5	5
Pole Population (Timber only)			1,136,494		
Inspections / yr	378,831	324,713	284,124	252,554	227,299
Cost / inspection			$53		
Cost / yr	$20,153,827	$17,274,709	$15,115,370	$13,435,885	$12,092,296
Cost Differential	-$5,038,457	-$2,159,339	$0	$1,679,486	$3,023,074

[11] The minimum wall thickness for most subtransmission poles is 50mm, hence it is expected that most of the subtransmission poles listed here are due to data errors.

6.2 Serviceability Criteria

Distribution poles represent 93% of the timber poles on the network. They also have a significantly lower condemning point, allowing wall thickness from 20-30mm depending on the loading on the pole. The thinner the wall thickness, the shorter the pole failure warning time will be. A simple way to increase the warning time is to increase the wall thickness, however this would obviously have a negative impact on the strategy cost.

6.3 Inspection Effectiveness

6.3.1 Pole Inspection Process

The pole inspection process is detailed in CEOM7005 Asset Inspection Manual. There are a number of aspects of the pole inspection process that require clarification or review. These are listed below;

- Revise pole serviceability criteria to remove inconsistent information
- Expand the list of terms used throughout the manual. There are a number of terms that are not adequately defined.

Term	**Proposed Definition**
Fully Supported	A pole that has stays (or conductors) to relieve the horizontal load (i.e. has no resultant horizontal load)
Loaded (Stressed)	A pole that has a constant horizontal load.
Unsupported	A pole that has negligible horizontal load (e.g. pin pole with minimal angle deviation). *Note: short, slack span LV services can be considered to not add sufficient load to a pole to classify it as loaded.*
Critical Zone	For a normal pole without reinforcing; Is the area extending from 350mm above to 350mm below ground. For a reinforced/reinstated or rebutted pole; Is the area extending from 350mm above to 350mm below the top of the reinforcing splint or new butt. *NOTE: Critical zone is currently used in two different contexts in the Asset Inspection Manual and WASP. Neutral axis should be used to refer to the side of the pole that is least affected by pole loading.*
Above Ground Diameter	The diameter measured above ground that represents the original diameter of the pole. This measurement is used to determine the amount of decay or deterioration that has occurred below ground, as well as the wind load.
Below Ground Diameter	The diameter of the pole measured below ground at the point of minimum diameter (within the inspection zone) after removal of fungal decay affected timber.
Inspection Zone	The area of the pole extending from 1800mm above ground to 450mm below ground
Neutral Axis	The axis of the pole that is least affected by pole loading (conductor and wind loading), and hence the safest location for condition assessment such as drilling. For an in-line unsupported pole, this would be the axis parallel to the conductors.
Loaded (Critical) Axis	The axis of the pole that is most affected by pole loading (perpendicular to the neutral axis). For an in-line unsupported pole, this would be the axis perpendicular to the conductors.

- Accurately record the location of the last inspection (such as using a tag/no tag, or compass bearings). This should be possible as the map of the pole is available in WASP and DAIS. This will improve the ability to accurately determine the side that was inspected at the previous inspection, and hence reduce the likelihood of a slot excavation being repeated on the same side.

- Review the criteria for when, where and to what extent poles are excavated during inspection. Partial excavation may not find external decay, whereas there is a suggestion that full excavation can increase the likelihood and degree of external decay. Focus on natural round poles.
- Review the criteria for each level of inspection and more clearly describe the requirements. Provide flow charts for each inspection process with references to the section of the asset inspection manual that provides the detail.
- Emphasise the need to strut poles that are condemned and may not last 6 months until the pole is reinforced/replaced.
- Whilst not related to timber poles, there is a need to reconsider the criteria for triggering a Level 2 inspection on steel poles and columns. At present the criteria specify that a Level 2 inspection (the first inspection where the pole is excavated to check for corrosion) is only required in areas with acid sulphate soils or salt contamination, or where there is evidence of cracking or spalling at ground line. Suggest that the criteria for Level 2 inspections of steel poles be for all steel poles greater than 5 (or maybe 10) years old.
- Review the criteria for measuring wall thickness. A number of autopsies have returned suspect wall thickness measurements that may not have taken into account damage due to termites and rot.
- Increase (and clearly define) the trigger point for when a condemned pole is strutted. Suggested trigger point wall thickness of 20mm or less should be strutted.

6.3.2 Pole Inspection Audit Process

Currently Asset Inspectors are audited a minimum of twice per year, with each audit involving assessment of the Asset Inspector's performance over 20 poles. The poles are randomly selected with a rating out of 5 given for each of the following areas; Worksite, Data Accuracy, Inspection, Measurements, Treatments and Defects. The audit process allows for a rating of 100% to be given for any of the 20 poles that cannot be inspected. To improve the audit process, the following changes should be considered;

- Review the process of giving an audit result of 100% for poles that cannot be inspected, as this will skew results.
- Consider a reactive audit process for areas/inspectors with recent poor failure performance or inconsistent data collection
- Consider augmenting the auditors role to also include regular training sessions
- Consider increasing the number of auditors (say to one per inspection area/one per Asset Operations Coordinator). This would help to provide senior skilled staff to oversee pole failure autopsies, as well as increasing the auditing of day to day inspections.
- Introduce desktop audits to greatly increase the number of pole inspections that have some degree of audit. This will also assist with data accuracy, as well as providing a mechanism for feedback to the asset inspector.

6.3.3 Pole Failure Autopsy Process

The pole failure autopsy process is critical in the effective management of our pole assets. The autopsy process needs to clearly determine the cause of each failure and highlight any important factors in the failure. In order to achieve this, the following changes are proposed.

- Pole autopsies should be an independent process. This could be achieved by having the Asset Operations Coordinator (AOC) or Auditor oversee each failure autopsy, with the Asset Inspector present.
- Record pole failure autopsy results in WASP. This will require a new tab in the asset details screen, and a number of new attributes created to capture the data.
- Create a dedicated autopsy procedure, with sections for both routine autopsies and failure autopsies. Include the following requirements for failure autopsies;
  - Minimum wall thickness at failure point
  - Diameter at failure point
  - All fields are to be completed
  - Pole failure report to be completed for all failures (first page only for vehicle/aircraft impact, non asset related fire, lightning causes).
  - Require 3 photos for all failures regardless of the cause.
    - 1 photo showing the pole and the cause of failure if possible (i.e. photo of pole with tree fallen on lines)

        - 2 photos of the pole taken at the failure point, (1 photo of the top of the failure point, and 1 of the bottom)
    - Revise pole failure work flow so that pole failure reports are completed promptly and with the required level of detail.
    - Pole failure reports to be initiated by field staff, and forwarded to AOC (by Primary Systems staff) if autopsy required, or otherwise to Primary Systems staff for review.
- Revise the current failure autopsy form to be a pole failure report
    - Add process check boxes for assistance in completing the report
    - Add ability to attach photos to the form, with prompts for the photos required
    - Modify form so that only necessary information is required to be entered when an autopsy is not required (i.e. only need to complete section 1)
    - Add sign off/approval box
- Remove the section on autopsies from the asset inspection manual and refer to the new autopsy procedure.

6.4 Time to correct once defected

There were 9 timber poles that failed in 2012-2013 financial year that were already condemned. This suggests that a review of the prioritisation of defect rectification could improve failure performance. A mandatory urgent risk defect for all poles with a wall thickness of say 20mm or less (in line with the strutting suggestion in 6.3.1) could help to improve these failures, with minimal cost impact.

6.5 Pole Reinforcing

6.5.1 Reinforcing Criteria

The current reinforcing criteria consist of a single wall thickness measurement (at ground line) which is used for both installing reinforcement and condemning a reinforced pole. This needs to be reviewed to determine the appropriate minimum wall thicknesses (and corresponding heights above ground) to ensure that we achieve the optimum balance of reduced pole failures, CAPEX saving from reduced pole replacements, as well as optimising the useful life of the reinforcing splint.

Essential has engaged the services of an industry timber pole expert to analyse our current reinforcing criteria and associated processes and provide recommendations for improvement.

6.5.2 Ratio of Reinforcing to Replacing

The average no of pole reinforcements (reinstatements) over the 2010-2012 financial years represented only 6.6% of the total condemned pole defects completed. WASP data suggests that a large percentage of the pole replace work tasks could have been reinforce (reinstate) work tasks, with a proportional saving.

The table below (Table 18) shows the average number of completed ‘Pole – Reinstate’ and ‘Pole Condemned – Replace’ over the 2010-2012 financial years as well as an estimate of the cost. It also shows scenarios with increasing percentages of reinforcement and the corresponding reduction in total cost. These scenarios represent potential outcomes dependent on increased trigger criteria for pole reinforcement. It should be noted that pole replacements have been assumed to cost an average of $6000, however subtransmission pole replacements cost considerably more than this, so the figures should be conservative.

Table 18: Cost of Reinforcing vs Replacing

Scenario	Reinforce %	Reinforce	Replace	Reinforce $ (@ $900 ea)	Replace $ (@ $6000ea)	Total	Annual Saving
2013 Financial Year	***8.5%***	***656***	***7,027***	***$590,400***	***$42,162,000***	***$42,752,400***	
10% Reinforcements	10%	768	6,915	$691,470	$41,488,200	$42,179,670	**$572,730**
15% Reinforcements	15%	1,152	6,531	$1,037,205	$39,183,300	$40,220,505	**$2,531,895**
20% Reinforcements	20%	1,537	6,146	$1,382,940	$36,878,400	$38,261,340	**$4,491,060**
25% Reinforcements	25%	1,921	5,762	$1,728,675	$34,573,500	$36,302,175	**$6,450,225**
30% Reinforcements	30%	2,305	5,378	$2,074,410	$32,268,600	$34,343,010	**$8,409,390**
35% Reinforcements	35%	2,689	4,994	$2,420,145	$29,963,700	$32,383,845	**$10,368,555**
40% Reinforcements	40%	3,073	4,610	$2,765,880	$27,658,800	$30,424,680	**$12,327,720**

There is a significant potential for Essential to increase the number of poles that are reinforced by creating a trigger wall thickness above the current serviceability limit. Analysis of the pole population (see Table 16) shows that there are approximately 18,299 poles with a wall thickness between 20mm and 50mm that are potential candidates for proactive reinforcement if the criteria for reinforcing was moved out to 50mm wall thickness. It is proposed that initially the wall thickness criteria for reinforcement be increased to 40mm giving around 9000 poles backlog that could be reinforced over the coming 4 year inspection cycle. This would mean an increase in annual reinforcements from 656 to approximately 2906, plus there would be additional reinforcements picked up during inspection due to the increased reinforcement wall thickness criteria. Following the initial 'catch up', the reinforcement rate is likely to be 30% or greater. This increase in reinforcements would have a positive impact on pole failures, but obviously only for those failures that occur due to ground line deterioration. There would be an initial cost penalty in increasing reinforcements, however this would be offset with the savings from reduced replacements. The remainder of the savings from reduced replacements will initially be used to fund additional reinforcements, hence this strategy would cause the current strategy cost to remain the same. The savings shown in Table 18 will therefore not be realised until the next inspection cycle, however it should be remembered that reinforcing only postpones the need for replacement, so the annual saving will not be sustainable (it is expected that there will be an on-going saving due to increasing the reinforcement rate, but further work is required to determine the actual saving). Consideration will also need to be given to how quickly we could increase reinforcements due to availability of sufficient skilled tradesmen and equipment.

6.6 Data Quality Issues and WASP Modifications

In order to gain the maximum benefit from pole performance analysis, there is a need to improve data quality. Some examples where there is an opportunity for improvement include;

- Alignment of failure causes between ENI, WASP and the Networks NSW RCM/FMECA Project
- Modifying the way poles are stored in WASP by creating a pole 'Site' with pole 'Children'. This would enable easy identification of the pole attributes, condition and maintenance work completed for any failed poles. At present this data is incredibly difficult to calculate.
- Removal of WASP failure cause 'Internal Pipe'. Internal pipes are caused by either rot or termites, but by attaching a cause of "Internal Pipe" it is impossible to determine which.
- Running a script in WASP to update 'Loading' field (a large percentage of the poles do not have this field populated, which makes determining what the minimum wall thickness should be, quite difficult).
- Creation of a pole failure autopsy form in WASP that can be printed as well as being able to be electronically populated.
- Creation of a work task and causes to capture poles replaced due to reasons other than deterioration (for e.g. strength upgrade etc)
- Integration of ENI & WASP, rather than separate databases. This needs to include the following;
  - Inclusion of secondary cause field in the work tasks table
  - Ability to be able to extract work tasks limited by asset type and sub component for reporting purposes
- Add attributes to WASP for poles at 1000mm and 1500mm to accommodate inspection of reinforced poles. Also need to modify DAIS to accept these values on inspection
- Add an additional SF calculation for nailed poles (the current guidance on when the nail should be removed revolves around the assumption that the pole is fully loaded which it almost never is).

6.7 Pole Failure Definition

The pole failure definition used by Essential is the Energy Networks Association (ENA) definition, as shown in 6.7.1 below.

6.7.1 ENA Pole Failure Definition

Any functional failure of the pole itself, or where only conductors or stays are supporting the pole, will be classified as an 'unassisted' failure unless it can be shown that the pole was:

1. *Subject to sufficient force to exceed the design strength requirements set out by the relevant Utility's standards at the time of construction;*
2. *Burned by a fire ignited by any source;*
3. *Compromised by vandalism;*
4. *Struck by lightning; or*

5. *Otherwise subjected to a failure mechanism demonstrated by evidence to be outside the control of the Utility*

6.8 Recommendations

- Review the current serviceability criteria to determine suitability with regard to the organisations acceptable balance of cost and risk.
- Create an asset strategy policy to outline the required serviceability criteria (as a separate document to the asset inspection manual, which would include the 'how to').
- Revise the asset inspection manual (with reference to pole inspections specifically)
- Review the process that determines if a pole is reinstated/replaced? Possibly require additional detail for why it is replaced. Consider implementing a trigger point above the condemning point, initially targeting poles with wall thickness values less than 40mm, and following up with those less than 50mm
- Independent audits of defected poles, to ensure that the (revised) reinforcement policy is being applied correctly
- Revise the asset inspection manual to clarify when a pole is to be reinstated. Communicate the change of focus from replacement to reinstatement.
- Review the excavation requirement and consider increasing so that the whole circumference of the pole is excavated.
- Revise the current pole failure section in the Asset Inspection Manual and create a dedicated pole failure procedure that clearly specifies the requirements following a failure. This will significantly improve the data on failures and greatly enhance the ability to make informed decisions to improve the pole strategy effectiveness.
- Review the defect prioritisation for condemned poles

7 Future Work

The following is a summary of future work that should be completed to finalise some of the questions raised in this paper. It is understood that some or all of this may be completed by the Networks NSW Pole Strategy Working Group.

Pole inspection effectiveness comparison

Comparing effectiveness between the three utilities is not straight forward. There are different inspection regimes, different serviceability criteria, and markedly different geographical conditions. Further work could give an indication of inspection effectiveness, but it relies on having an accurate understanding of the time from conditional to functional failure. This data will become more readily available over the next few years due to enhancements in data capture and upcoming changes to the structure of pole data in WASP.

Failure rate for poles outside inspection period

Further work is required to determine the failure rate where poles are overdue for inspection, and comparison of this with the failure rate for those inspected within the inspection period.

Age of poles at replacement

An interesting metric would be the average age by species of poles at replacement, however due to IT limitations and data structure this analysis has not yet been completed. Further work is required to provide this.

Cost Implications

Further analysis needs to be done to estimate the cost of moving condemning criteria, increasing reinforcement rates and the associated impact on pole strategy costs.

Reinforcement Installation and Condemning Criteria

A study is required to review our current criteria for installing (and ultimately condemning) pole reinforcement. The asset inspection manual does not currently have sufficient detail on the process. An industry expert has been commissioned to provide this analysis.

Pole Condemning Criteria based on Consequential Risk

Look into whether there is a case for different condemning criteria based on the risk level of the consequences due to failure. For e.g., should there be more stringent condemning criteria for urban poles than for rural poles.