**Document 9**
**Asset Category – Distribution Transformers**
**EPN**

Asset Stewardship Report
2014

Zoe Cornish

**Approved by Richard Wakelen / Barry Hatton**

**Approved Date 01/03/2014**

## Document History

| Version | Date | Details | Originator | Revision Class | Section Update |
|---------|------|---------|------------|----------------|----------------|
| 1.0 | 19/02/2014 | Original Submission | N/A | N/A | N/A |
| 1.1 | 19/02/2014 | New Introduction addition & note in header | Zoe Cornish | Minor | Section 1.1 |
| | | Fault restoration costs updated to reflect 13th February S&R NAMP figures. | | Minor | Section 1.2, 1.4 & Appx 5 |
| | | Updated references to align to latest NAMP | | Minor | Throughout document |
| | | Addition of Appendices 8,9 & 10 | | Minor | Appx 8, 9 & 10 |
| | | Updated HI profiles to reflect latest RIGs tables | | Minor | Sec 1.4, 4.6, 7.7 & Appx 2 |
| 1.2 | 24/02/2014 | Updated references to reflect 19th February S&R NAMP | Zoe Cornish | Minor | Throughout document |
| | | Added preface and removed Introduction added in version 1.1 | | Minor | Pg 3 & 4 |
| | | Removed cost table from Appendix 8 | | Minor | Appendix 8 |
| 1.3 | 25/02/2014 | Removed HI/CI risk matrices | Zoe Cornish | Minor | Section 7.7 |
| 1.4 | 25/02/2014 | Changes to Appendix 8 & 10 Source references | Zoe Cornish | Minor | Appendix 8 & 10 |
| 1.5 | 27/02/2014 | Minor changes to preface & Appendix 9 & 10 | Zoe Cornish | Minor | Preface & App 9 & 10 |
| 1.6 | 27/02/2014 | Minor changes to App 10 | Zoe Cornish | Minor | Appendix 10 |
| 1.7 | 04/03/2014 | Minor changes to Exec Summary | Robert Lafferty | Minor | Section 1.3 |
| 2.0 | 01/03/2014 | Final Approved | Richard Wakelen / Barry Hatton | Minor | |

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# Preface

UK Power Networks uses Asset Stewardship Reports ('ASR') to describe the optimum asset management strategy and proposals for different groups of assets. This optimised asset management strategy and plan details the levels of investment required and the targeted interventions and outputs needed. Separate ASRs define the most efficient maintenance and inspection regimes needed and all documents detail the new forms of innovation which are required to maximise value, service and safety for all customers and staff throughout the ED1 regulatory period. Outline proposals for the ED2 period are also included.

Each DNO has a suite of approximately 20 ASR's. Although asset policy and strategy is similar for the same assets in each DNO the detailed plans and investment proposals are different for each DNO. There are also local issues which must be taken into account. Accordingly each DNO has its own complete set of ASR documents.

A complete list of titles of the ASR's, a summary of capex and opex investment is included in '**Document 20: Asset Stewardship Report: Capex/Opex Overview'**. This document also defines how costs and outputs in the various ASR's build up UK Power Networks 'NAMP' (Network Asset Management Plan) and how the NAMP aligns with Ofgem's ED1 RIGs tables and row numbers.

Where 'HI' or asset 'Health Index' information is included please note predicted ED1 profiles are before any benefits from 'Load driven investment.'

This ASR has also been updated to reflect the feedback from Ofgem on our July 2013 ED1 business plan submission. Accordingly to aid the reader three additional appendices have been added. They are;

1. **Appendix 8 - Output NAMP/ED1 Business Plan Data Table Reconciliation:** This section explains the 'line of sight' between the UKPN Network Asset Management Plan (NAMP) replacement volumes contained in the Ofgem RIGS tables. The NAMP is the UKPN ten year rolling asset management investment plan. It is used as the overarching plan to drive both direct and indirect Capex and Opex interventions volumes and costs. The volume and cost data used in this ASR to explain our investment plan is taken from the UK Power Networks NAMP. Appendix 8 explains how the NAMP outputs are translated into the Ofgem RIGS tables. The translation of costs from the NAMP to the ED1 RIGS tables is more complex and it is not possible to explain this in a simple table. This is because the costs of a project in the 'NAMP' are allocated to a wide variety of tables and rows in the RIGS. For example the costs of a typical switchgear replacement project will be allocated to a range of different Ofgem ED1 RIGs tables and rows such as CV3 (Replacement), CV5 (Refurbishment) CV6 (Civil works) and CV105 (Operational IT Technology and Telecoms). However guidance notes of the destination RIGs tables for NAMP expenditure are included in the table in the Section 1.1 of the Executive Summary of each ASR.

2. **Appendix 9 – Efficiency benchmarking with other DNO's:** This helps to inform readers how UK Power Networks is positioned from a benchmarking position with other DNO's. It aims to show why we believe our investment plans in terms of both

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volume and money is the right answer when compared to the industry, and why we believe our asset replacement and refurbishment investment proposals are efficient and effective and in the best interest for our customers.

3. **Appendix 10 – Material changes since the July 2013 ED1 submission:** This section shows the differences between the ASR submitted in July 2013 and the ASR submitted for the re-submission in March 2014. It aims to inform the reader the changes made to volumes and costs as a result of reviewing the plans submitted in July 2013. Generally the number of changes made is very small, as we believe the original plan submitted in July 2013 meets the requirements of a well justified plan. However there are areas where we have identified further efficiencies and improvements or recent events have driven us to amend our plans to protect customer safety and service.

We have sought to avoid duplication in other ED1 documents, such as 'Scheme Justification Papers', by referring the reader to key issues of asset policy and asset engineering which are included in the appropriate ASR documents.

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Version 2.0
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UK Power Networks

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## 1.0   Executive Summary EPN HV Transformers

### 1.1   Scope

This document details EPN's NLRE (non-load related expenditure) replacement proposals for ground-mounted HV Transformers for the RIIO-ED1 period. In total there are approximately 32,223 of these assets with an estimated MEAV of £397m. The proposed annual investment in ED1 is £2.5m and is 0.6% of the MEAV per annum.

Replacement costs for these assets are held in the following locations (Table 1) in Ofgem and UK Power Networks investment planning documents:

A full list of abbreviations is included in Section 6.0 of Document 20: Capex Opex Overview.

| INVESTMENT  TYPE | ED1 COSTS | NAMP LINE | RIGS REFERENCE (TABLE CV3) |
|---|---|---|---|
| Asset Replacement (GM) Distribution Transformers - 11kV | £11.3m | 1.19.01 | **Volumes - RIGS Table CV3:** Additions Row 48 - HV: 6.6/11kV Transformer (GM) Removals Row 176 – HV: 6.6/11kV Transformer (GM)<br><br>**Costs - RIGS Table CV3:** Row 48 – HV: 6.6/11kV Transformer (GM) |
| Asset Replacement - Capital replacement of damaged GM 11kV DTF | £1.9 | 2.50.03 | **Volumes - RIGS Table V4b:** Additions Row 48 – HV: 6.6/11kV Transformer (GM) Removals Row 48 – HV: 6.6/11kV Transformer (GM)<br><br>**Costs - RIGS Table CV15a:** Row 27 -  HV: All Other Plant and Equipment (inc GM transformers) - Asset Repair/Replacement Required |

*Table 1 – Investment Summary (Source: 21st February 2014 ED1 Business Plan Data Tables)*

*There are also £1.2m of civil costs associated with these assets but are included in the Civils ASR

### 1.2   Investment strategy

The long-term investment proposal for the replacement of ground-mounted distribution transformers has been set based on statistical model forecasts. The investment proposals have been validated by comparing the forecasts to historical fault rates and observed trends in condition data for the ageing distribution

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transformer population in EPN. Specific transformers identified for replacement each year will be based on:

- Overall condition of the transformer (determined from condition assessments and defects identified and reported from routine inspections and maintenance activities) and
- PCB levels greater than 500ppm and or in poor condition.

Investment levels have been set such that we maintain the level of risk on the network, i.e. the number of assets with a poor health index (HI 4 and HI 5) at the start and end of ED1.

## 1.3    ED1 Proposals

Figure 1 shows the HI profile at the start and end of ED1, with and without investment. The chart shows that there will be zero HI4 and HI5 assets at the start and end of the ED1, based on current condition data, if the proposed investment levels are carried out.
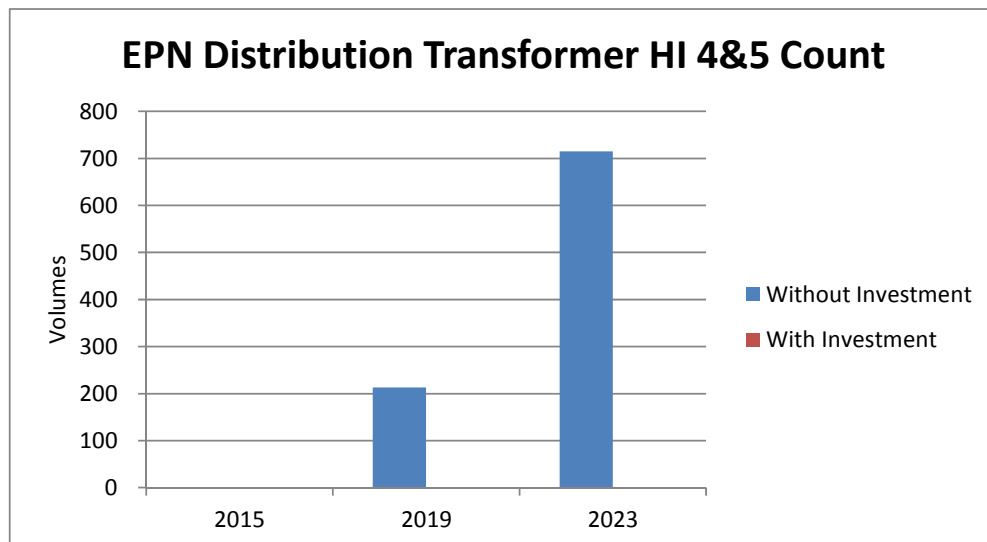


*Figure 1 - HI profile (with and without investment) for ED1 (Source: SARM V0.3 model)*

Appendix 9 benchmarks our ED1 proposals with reference to other DNOs July 2013 submissions. It shows that for Distribution Transformers we are proposing to replace **3%** of our assets while other DNOs were seeking funding to replace **6%** of these assets on average. This demonstrates the effectiveness of our asset risk management systems and the value for money of our proposals.

## 1.4    Innovation
A HV plug-in bushing ("Mekufa") bushing has been approved for use in the three licence areas (LPN, SPN and EPN). The new bushing will reduce oil handling requirements and make it easier to connect ring main units to the transformer. It will also reduce installation times (typically by a few hours).

## 1.5   Risks and Opportunities

Table 3 highlights the risks associated with the ED1 investment proposals for distribution transformers in EPN.

|  | Description of similarly likely opportunities or risks arising in ED1 period | Uncertainties |
|---|---|---|
| Risk | New EU regulation with regards to reducing losses will have an impact on prices for new transformers | Potentially + 20% of ED1 investment |

*Table 2 – Risks and opportunities*

# 2.0   Description of HV Transformer Population

## 2.1   HV Transformers

There are 32,223 ground-mounted HV transformers currently commissioned within the EPN region, with a primary winding voltage of 11/6.6kV and ratings ranging from 500 - 1000kVA.

The oldest 10% of distribution transformers in EPN have an average age of approximately 56 years.  This will rise to 67 years at the end of ED1 if there are no replacements.
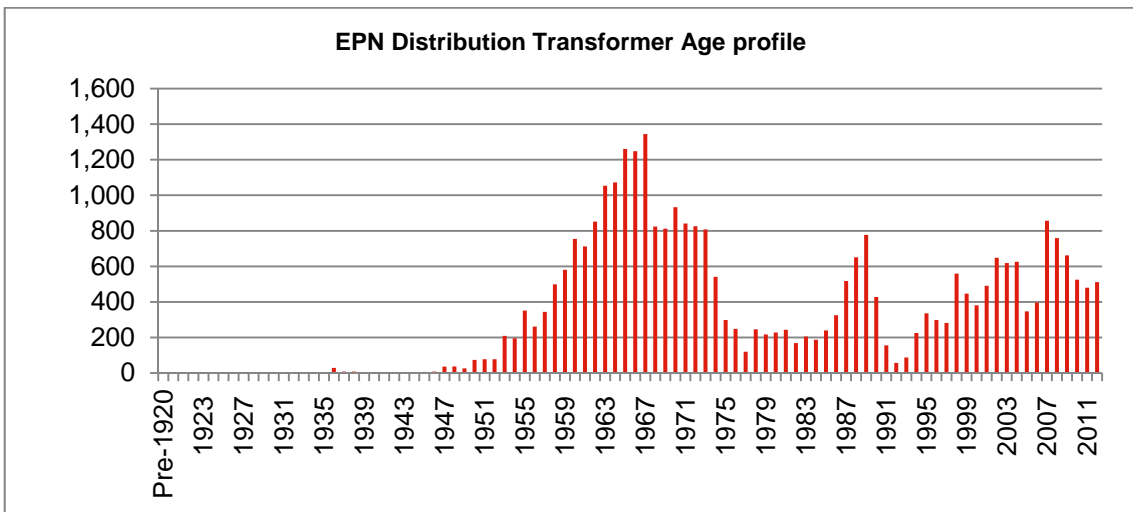


*Figure 2 - EPN Distribution Transformer Age Profile (Source – RIGS 2012 CV3 Table V5)*

All ground-mounted distribution transformer replacement provisions for ED1 are listed under NAMP Lines:

- 1.19.01 Asset Replacement - GM Distribution Transformers - 11kV
- 2.50.03 Asset Replacement - Capital replacement of damaged GM 11kV DTF

The corresponding RIGS lines are shown in Table 4.

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| RIGs Table | RIGs Row | Description | |
|---|---|---|---|
| CV3 | 48 | 6.6/11kV Transformer (GM) | Additions |
| CV3 | 162 | 6.6/11kV Transformer (GM) | Removals |

*Table 3 – RIGS categories*

## 3.0 Investment Drivers

### 3.1 Overview

The high level investment drivers for replacement of distribution transformers are detailed in EDP 00-0013 Asset Lifecycle Strategy Distribution Substations.

The long-term forecasts for distribution transformer replacements have been set based on statistical model forecasts. The investment proposals have been validated by comparing the forecasts to historical fault rates and observed trends in condition data for the ageing distribution transformer population. Statistical model forecasts are not asset-specific. Specific assets required for replacement each year are determined by key replacement drivers. The main investment drivers for replacing distribution transformers are:

- Overall condition and
- The amount of Polychlorinated Biphenyls (PCB) it contains.

*HSS 01 015 - Management of Oil Filled Equipment containing PCBs* outlines the procedure within UKPN to manage oil-filled equipment containing PCBs. Other drivers that influence the decisions involved in the management of ground-mounted distribution transformers are:

- Public and operator safety
- Asset and network performance
- Major defects in some asset types
- Non-availability of spares

These drivers are supported by:

- Asset condition reports.
- Asset and network performance records.
- ESQCR risk assessments.
- Historic, current and emerging equipment and diagnostic technologies.
- Statistical modelling
- Stakeholder options

Replacements will generally be co-ordinated with other planned works on the same site in line with the asset lifecycle strategy.

### 3.2 Condition and Defects

The overall condition of a transformer is determined based on a combination of condition ratings, for key *condition assessment measures* and *defect measures*. The defects and condition measures are shown below.
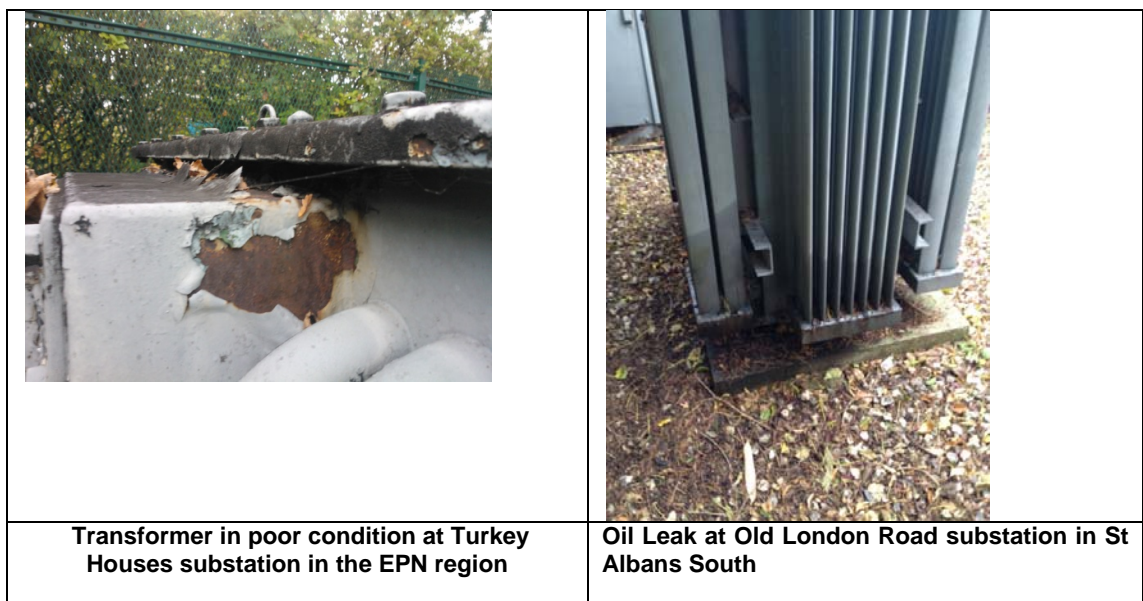
Principal condition assessment measures and defects:

- External condition of housing (including severe corrosion),
- Overall internal condition
- Oil containment (including defect oil level, Defect Transformer Oil Leak)
- Oil test results (e.g. Acidity levels)
- Amount of PCB in transformer oil

Other defects used to assess the condition of the transformer include:
- Defective MDI
- Plant Subsidence
- Defect Fluid Sight Glass
- Compound Leak
- Electrical Discharge Recorded
- Defective Cable Box
- Earthing defective
- Defective Gaskets
- Defect Protective Finish

Figure 3 shows two distribution transformers in poor condition with evidence of oil leaks and rust.

| Transformer in poor condition at Turkey Houses substation in the EPN region | Oil Leak at Old London Road substation in St Albans South |
|---|---|

*Figure 3 – Transformers in poor condition*

PCBs were historically used to improve the insulating properties of mineral oil in transformers. However, due to PCBs' environmental toxicity and classification as a persistent organic pollutant, PCB's were withdrawn from use in 1980 and it has been illegal to sell equipment that contains PCB's since 1985.

HSS 01 015 - Management of Oil Filled Equipment containing PCBs outlines the procedure within UKPN to manage oil-filled equipment containing PCBs:
- For all equipment with PCB results less than 50ppm a label indicating PCB Test Passed shall be attached
- All equipment found to contain between 50ppm to 500ppm PCBs may remain in service until removed. The equipment must have an approved label

indicating PCB contamination and registered with the Environment Agency within 28 days of the test.

- If the PCB level is identified as more than 500ppm, the Environment Agency shall be notified by the Environment Team immediately and arrangements made for the decontamination or disposal of the equipment by the Company's approved Scrap Contractor.

### 3.2.1 Correlation between Age and Defects

Figure 4 shows the comparison between:
- Current age profile of the population
- Number of defects reported historically (including the age of the transformer when the defect was reported)

Two observations can be made from the chart - Firstly, the number of defects increases with age and secondly that majority of defects generally occur between 40 and 55 years of age.
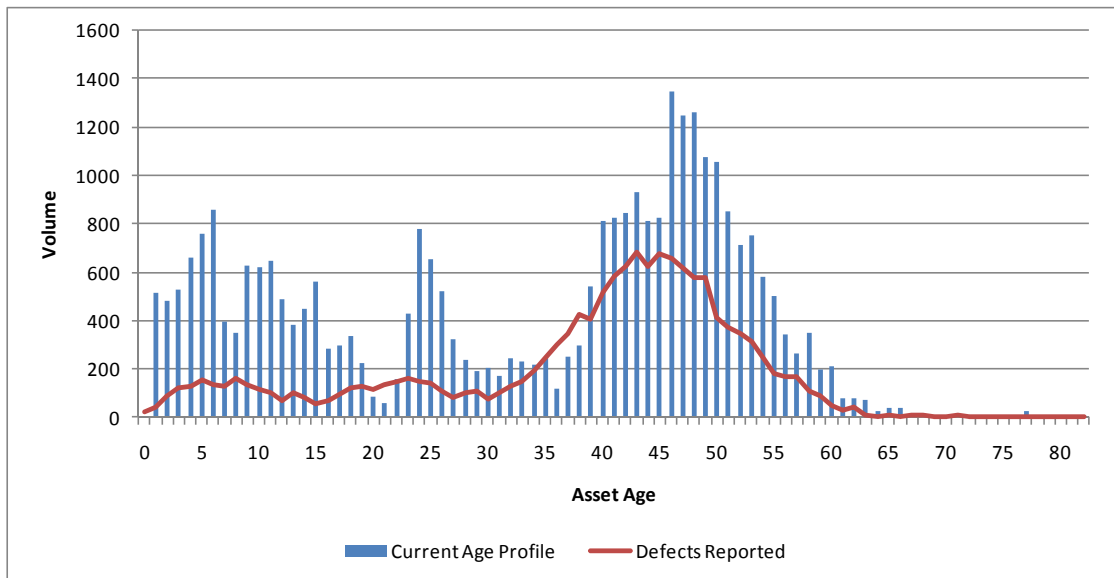


*Figure 4 – Correlation between Defects and Asset Age*

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### 3.2.2 Fault Rate

Review of historical fault rates show that there has been an overall decrease in fault rates over the last six years. There has also been a decrease in faults due to ageing and wear over the last six years. Figure 5 shows the fault rate trends. Replacement of distribution transformers, in poor condition, in ED1, will maintain the reducing fault rate trends due to ageing and wear. This will ensure that the number of CIs and CMLs associated with transformer failures or replacements are kept to a minimum.
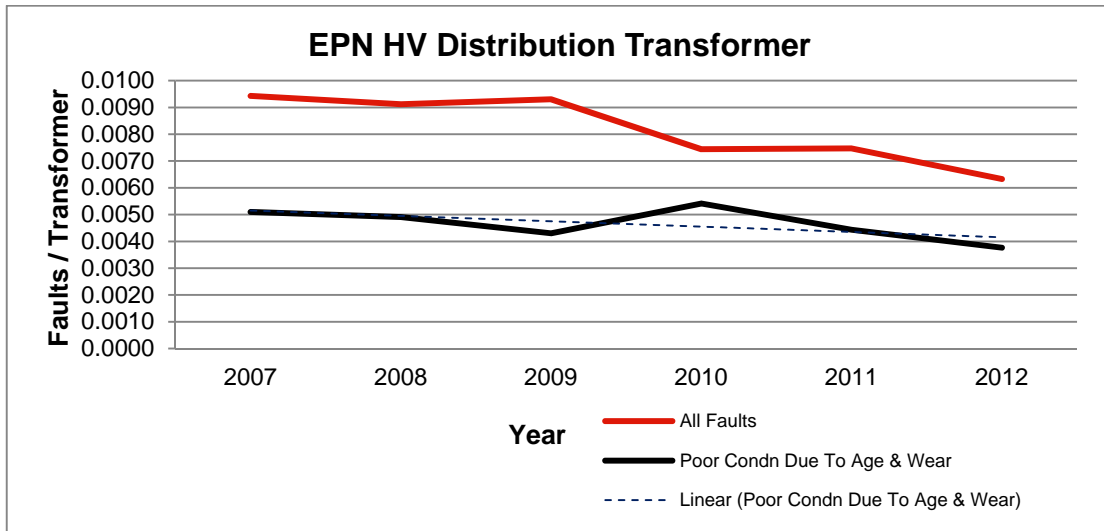
**EPN HV Distribution Transformer**

_Figure 5 - Fault rate - distribution transformers in EPN (Source - UKPN Fault Cube)_

## 3.3    Condition Measurements

### 3.3.1    Substation Inspection

The main source of condition data for our distribution transformers is from Substation Inspectors.  Inspections are carried out every three years in line with the inspection and maintenance policy (EMS 10-0002 Inspection and Maintenance Frequency Schedule). As part of the inspections process, inspectors complete scripts on hand held devices (HHD) or submit the relevant paper forms with key condition information. Figure 6 shows the handheld device and paper forms used by substation inspectors.



*Figure 6 - Handheld device (HHD) and paper form*

### 3.3.2    Maintenance

Maintenance fitters also use the same HHD technology to record their assessment of internal and external condition of the assets being maintained. This assessment is made twice, to provide condition data 'as found' and 'as left.'

Ellipse is used to schedule maintenance on assets and enables the efficient co-ordination of replacement, refurbishment and maintenance standards. Each asset recorded in Ellipse has a Maintenance Scheduled Task (MST), which drive maintenance activities. Maintenance tasks will be designed to ensure that the condition of mechanical components and systems is preserved and ensure that the integrity of insulation and condition of external surfaces are acceptable.

The replacement of distribution assets in poor condition will contribute to a reduction in operating costs by reducing the number of asset failures. Typically an asset failure will result in loss of supply to customers. This will result in operating costs for restoration of supplies through switching and or use of generation.

# 4.0   Asset Assessment

## 4.1    Asset Health (Statistical Asset Replacement Models)

A statistical asset replacement model (SARM) has been used to determine the long-term investment requirements for distribution transformers in RIIO-ED1. SARM uses the *age profile* of an asset and key inputs such as *average asset life* and *standard deviation* to determine projections.

The *average asset life* in the SARM model is the average life at which we expect most distribution transformers to be replaced. SARM assumes a normally distributed age and asset replacement profile for assets in the model. Further details on the SARM models can be found in the *'Modelling Overview document'*.
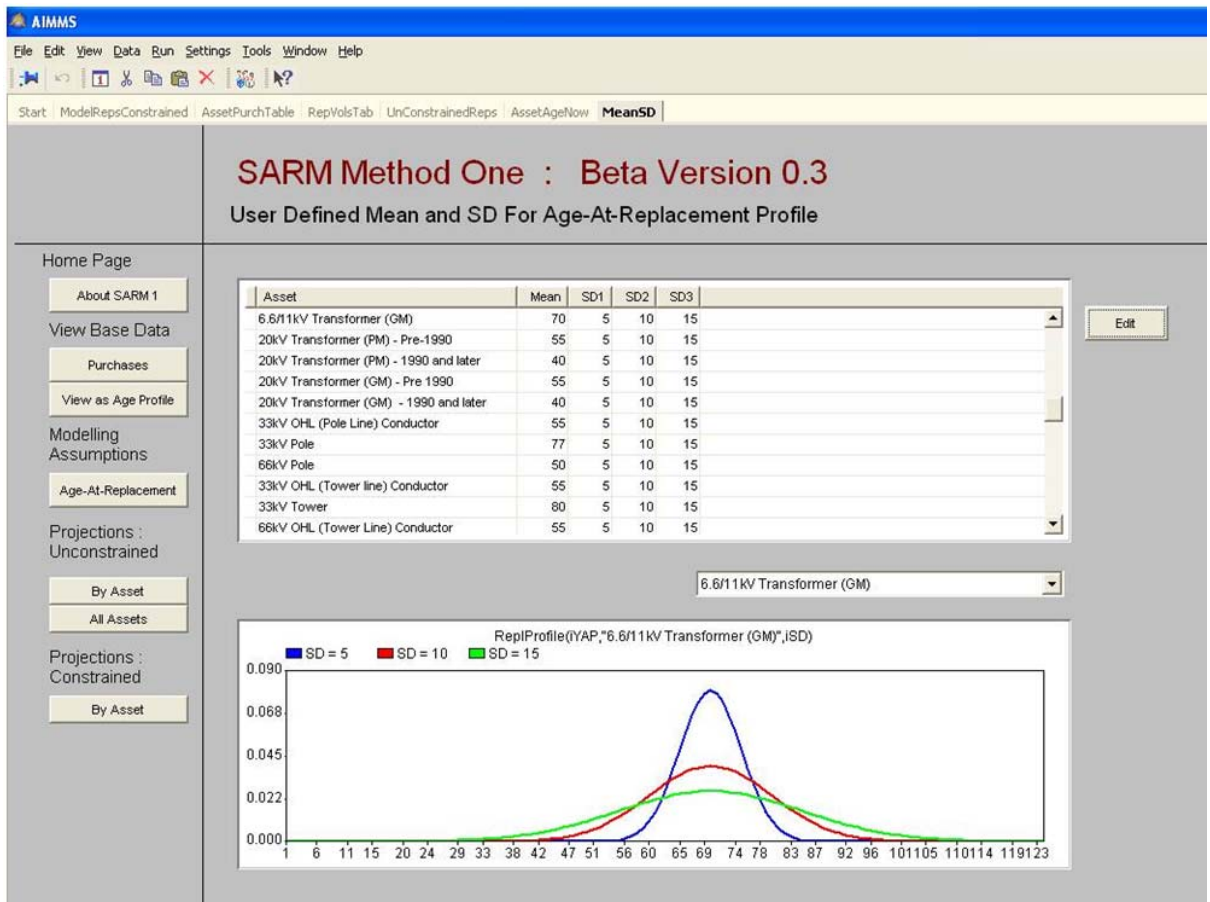


*Figure 7 – Screenshot of normally distributed profile for different standard deviation (SARM model)*

The SARM models are run for a range of inputs and the outputs are compared to historical replacement rates, fault rates and condition of the oldest 10% of the population to determine the right outputs to use for investment forecasts. Observed increases in historical condition-related fault trends usually imply that an increase in future rates of replacement is required and vice versa.

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ED1 asset replacement forecasts, in EPN, are based on an average *asset life* of 70 years and *standard deviation* of 5 years.

The average asset life used was determined by comparing the condition of the oldest 10% of the population with historical replacement rates. *An average asset life of 70 years and a standard deviation of 5 years implies that majority of transformers will be replaced when they are between 55 years and 85 years old.* Section 7.2 explains the process for constructing the ED1 Distribution transformer replacement plan.

## 4.2    Asset Criticality & Network Risk

The risk of an asset failing is a combination of the *probability of failure* (such as age and duty) and the *consequence of failure* (such as network performance). Asset criticality provides a measure of the consequence of failure and is evaluated in terms of the following four primary criticality categories:

- Network Performance
- Safety
- Financial Impact; OPEX (Licence area, spares/obsolescence) and CAPEX (Voltage and licence area); and
- Environmental Impact

In order to compare consequences of failures for different asset categories, a monetary value is assigned to each of the four primary criticality categories – network performance, safety, financial and environmental impact.

The criticality of an asset is determined from the sum of the consequences of failures (in monetary terms) for each of the four primary criticality categories. This is then converted to an OFGEM criticality index C1-C4.

A detailed methodology for calculating the criticality index can be found in 'Commentary Document 15: Model Overview'.

Criticality has not been used to set the long-term forecast for ED1 but will be used to prioritise planned replacements in ED1. Criticality index calculations are still under development as part of the OFGEM working group for HIs and criticality.

## 4.3    Data Validation

All data used in the statistical models is validated against a set of data requirements. The requirements ensure data is within specified limits, up-to-date and in the correct format for use in the model.  An exception report is issued on completion of the validation process. The exception report provides details of non-compliances. This forms a key part of the data quality improvement process.

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## 4.4    Data Verification

A sampling approach is routinely carried out following each data upload to the SARM model to ensure accurate transfer of data into the models.

## 4.5    Data Completeness

| Asset Type | Completeness | Accuracy | Timeliness |
|---|---|---|---|
| Distribution Transformers | 90% | * | * |

*Table 4 – CAT scores as of 8th February 2013*

Source: Decision Lab report "CAT Scoring" 8th February 2013
* Not available: quality standards are under review

Further information on CAT scores can be found in 'Commentary Document 15: Model Overview'

Inspector training courses and cyclic inspection schedules will improve data completeness and accuracy over the coming years.

## 4.6    HI Profiles With and Without Investment

Figure 8 shows the HI profiles, with and without intervention, at the start and end of ED1. The investment levels in ED1 have been set to ensure that the network risk at the start and end of ED1 remains the same. The HI profiles indicated are derived from condition related investment only and exclude the contribution from load related expenditure.
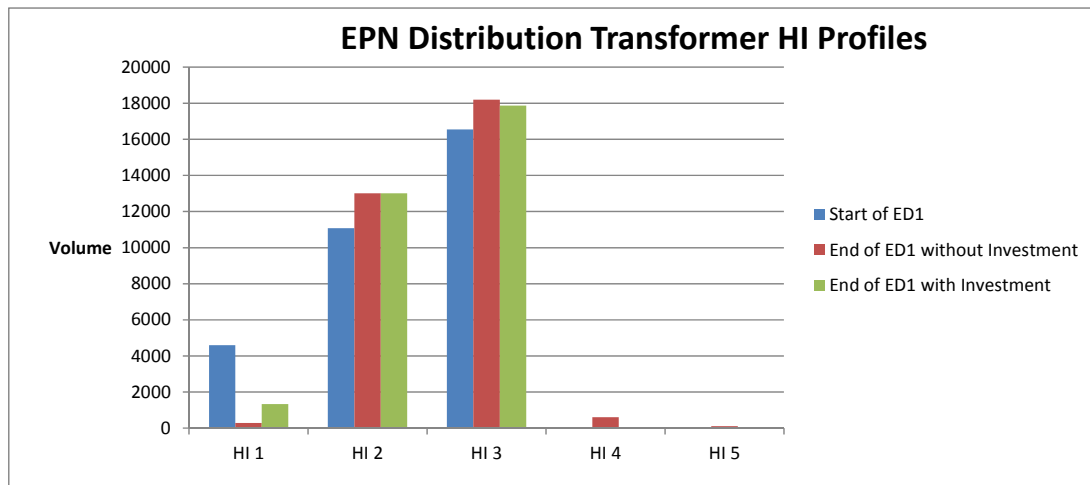


*Figure 8 - HI Profile (Start and end of ED1)*

## 5.0    Intervention policies

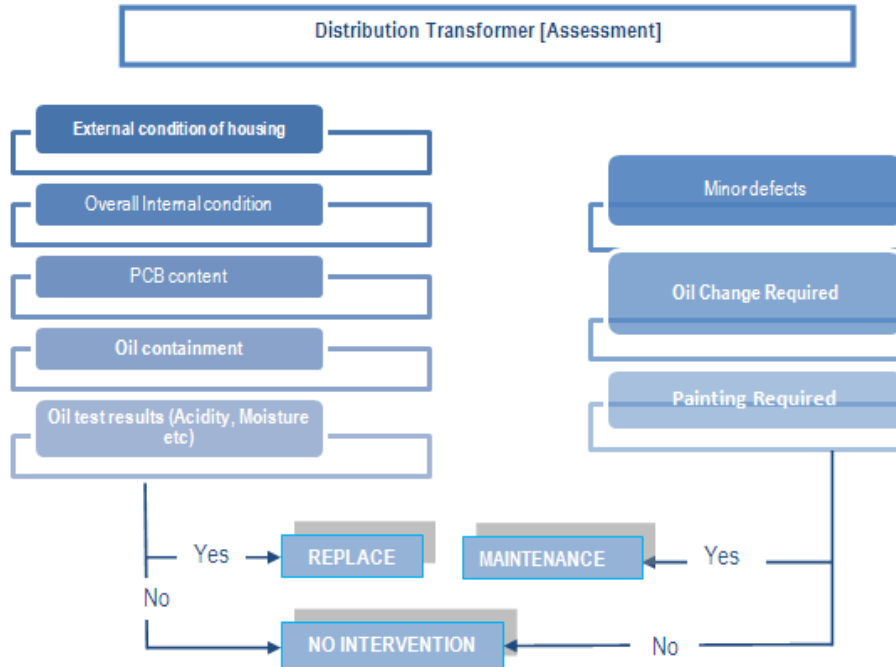### 5.1    Interventions: Description of Intervention Options



*Figure 9 - Decision tree for interventions*

Figure 9 shows the decision tree for interventions on distribution transformers. Interventions carried out on distribution transformers to improve condition include:

- Asset replacement and
- Maintenance

Asset replacement will be carried out when condition measurements from routine inspections show the overall health of a transformer is poor and or the transformer contains more than 500ppm of PCB. For less critical defects (such as damaged maximum demand indicators, defective cable boxes, taps etc.) repairs will be carried out as part of routine maintenance activities.

The refurbishment of distribution transformers has been discounted in ED1 because it is not cost effective. However maintenance activities such as oil change, painting etc. will be carried out in line with UK power networks maintenance policy, during ED1. Maintenance proposals for distribution transformers, in ED1, are held in *"Document 14 - I&M, Faults and Trees"*.

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## 6.0   Innovation

A bespoke plug-in 'Mekufa' bushing previously supplied only for LPN transformers will be supplied on all new transformers for use in EPN, SPN and LPN. The "Mekufa" bushing reduces the oil handling requirements traditionally associated with connecting a HV transformer to a Ring Main Unit.   By introducing the 'Mekufa' bushing, the oil handling and connecting of internal leads to the RMU associated with EPN and SPN transformers is removed from the plant assembly process. This significantly reduces the time to assemble a unit substation (typically by a few hours).



*Figure 10 – Mekufa bushing*

## 7.0   ED1 Expenditure Requirements for HV Transformers

### 7.1   Method
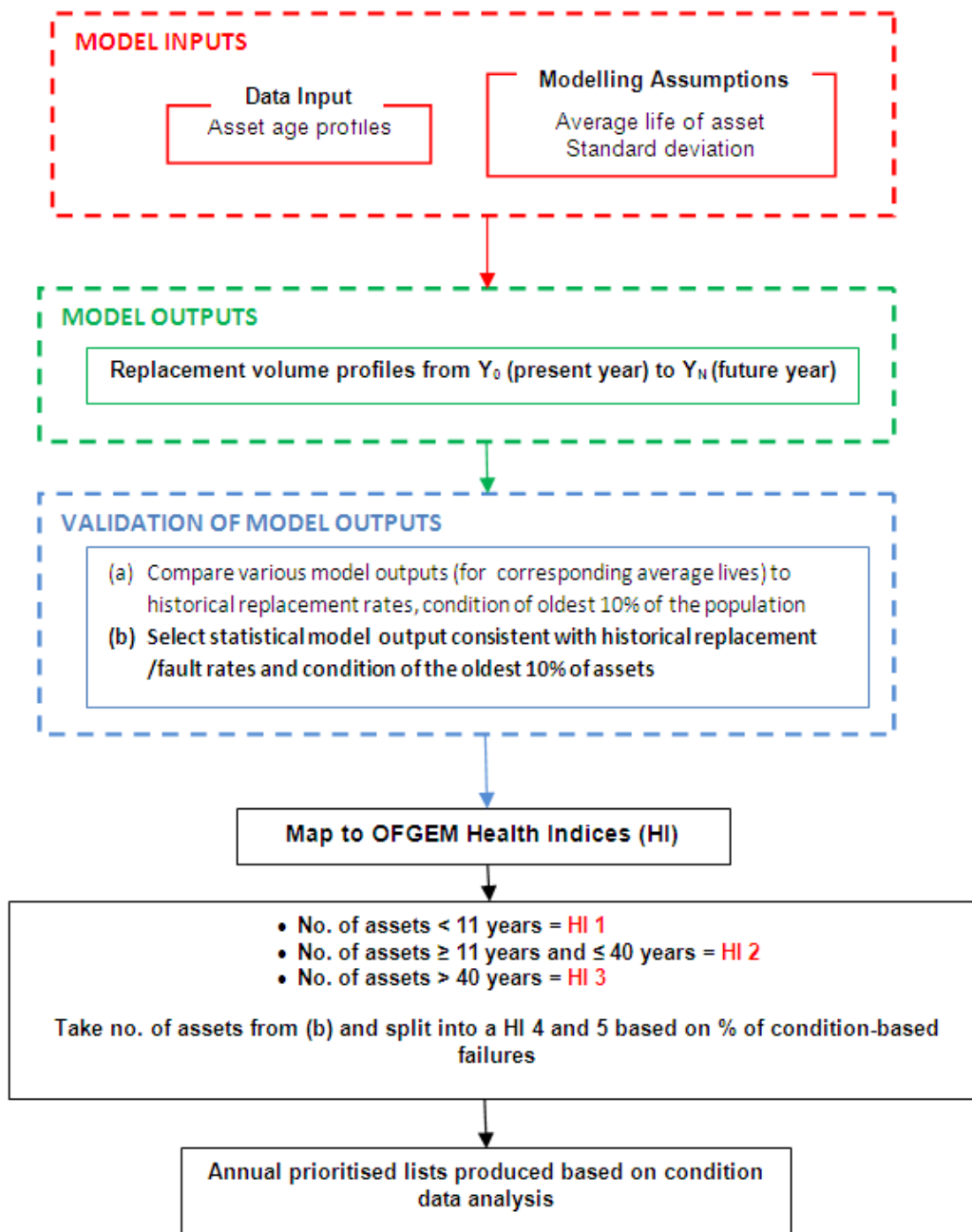


*Figure 11 – Decision flow diagram*

The statistical asset replacement model (SARM) is used to determine the overall number of poor condition transformers in the future. The model outputs are not asset-specific. Specific transformers that require replacement each year are determined from condition data analysis. The key condition measures used to qualify transformers for replacement each year are outlined in section 3.2.

Figure 11 shows the process for determining the volume requirements for distribution transformers. The key stages are as follows:

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- **Key inputs:**
  - Age profiles,
  - Average asset life (i.e. Point at which most distribution transformers are expected to be replaced before they fail) and
  - Standard deviation (used to specify the variation about the mean)

- **Model outputs:**
  - The outputs produced are the number of transformers that are likely to be in poor condition annually.
    - *Note - The SARM model is run to obtain several outputs for different average asset life inputs*

- **Validation of outputs:**
  - Validation of the output is done by comparing various model outputs (for corresponding average lives) to historical replacement rates and condition of the oldest 10% of the population.
  - The statistical model output consistent with historical replacement/fault rates and condition of the oldest 10% of assets is selected to set the ED1 NLRE forecast.

- **Producing HIs:**
  - The number of transformers forecast to be in poor condition annually (model output) is split between HI4 and HI5 based on historical condition-based failures as a fraction of all transformer failures.
  - HI1, HI2 and HI3 splits are determined using the age-related assumptions shown in figure 11.

Annual prioritised lists are determined by assessing the condition and criticality of the assets.

## 7.2    Constructing the Plan

The investment levels set in ED1 were determined based on the statistical asset replacement model (SARM). A range of *average asset lives* (from 60 to 75 years, all with a standard deviation of 5 years) were used as inputs to SARM.

The corresponding outputs were compared to historical replacement rates and the condition of the oldest 10% of distribution transformers in service. Table 6 shows the outputs from the statistical models for various *average asset lives* and *standard deviations*. The figures shown in Table 6 assume no investment is made between 2012 and 2023.

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| Inputs | | Outputs @ Year (N) | | |
|---|---|---|---|---|
| Average Asset Life | SD | 2012 | 2015 | 2023 |
| 60 | 5 | 272 | 1,346 | 6,692 |
| 65 | 5 | 91 | 465 | 3,252 |
| **70** | **5** | **30** | **142** | **1,222** |
| 75 | 5 | 12 | 52 | 377 |

*Table 5 – Statistical Model (SARM 1 output)*

An average life of 70 years and standard deviation of 5 years showed the closest correlation to historical replacement rates (107/year between 2007/2008 and 2011/2012). Table 7 shows the forecast replacement volumes in ED1.

| | 2015/ 2016 | 2016/ 2017 | 2017/ 2018 | 2018/ 2019 | 2019/ 2020 | 2020/ 2021 | 2021/ 2022 | 2022/ 2023 | Total |
|---|---|---|---|---|---|---|---|---|---|
| Distribution transformer replacements **(Planned )** | 115 | 115 | 115 | 115 | 115 | 115 | 115 | 115 | 920 |
| Distribution transformer replacements **(Capitalised faults)** | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 120 |

*Table 6 - ED1 forecast distribution transformer replacements (source; 19th February 2014 NAMP Table O)*

An average life of 70 years implies that most transformers will be replaced between 55 years and 85 years. This is consistent with the observed condition of the oldest 10% of distribution transformers. The oldest 10% of distribution transformers in EPN is 56 years (will rise to 67 years by 2023) and they are in relatively good condition.

## 7.3 Additional Considerations

Where justifiable distribution transformer replacements will be carried out simultaneously with distribution switchgear replacements on the same site as part of a refurbishment project.

Distribution transformers purchased for use on the network will be "low loss" units in compliance with the *Engineering Policy EI 08-0131 Guidance on the Management of Distribution Network Technical Losses.* The term 'low loss' relates primarily to the level of transformer iron losses. The use of low loss transformer units will reduce the technical losses on the network.

## 7.4 Asset Volumes & Expenditure

### 7.4.1 Volume Graphs (DPCR4 - ED1)

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All of the cost numbers displayed in this document are before the application of on-going efficiencies and real price effects
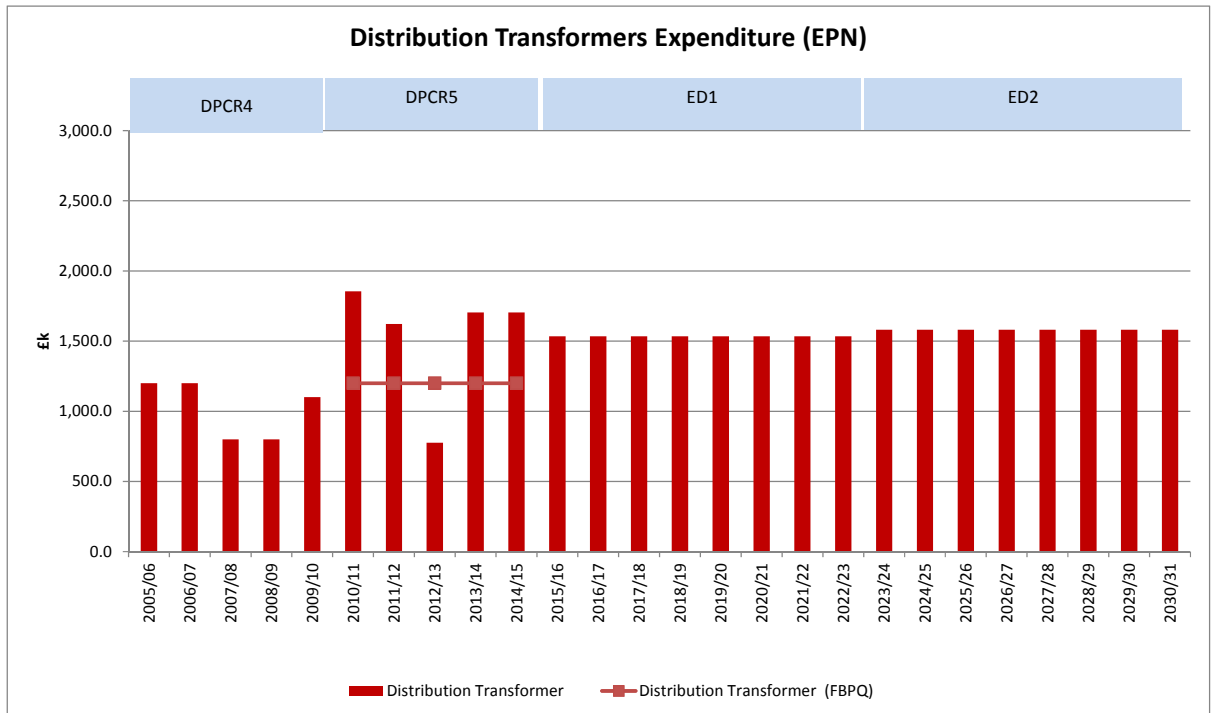
Figure 12 shows the number of distribution transformers installed and forecast to be installed from DPCR4 through to ED1. Figure 13 shows the corresponding expenditure forecasts.

The peak expenditure shown in the last three years of DPCR5 is due to a backlog of work from previous years. The backlog was due to non-availability of contractor resources (Senior Authorised Persons and fitters) which has now been resolved.

The ED2 figures shown in the chart have been derived from age-based modelling hence the increase in volumes and expenditure. Further work will be done in ED1 to explore additional intervention options that can be used to extend asset life.
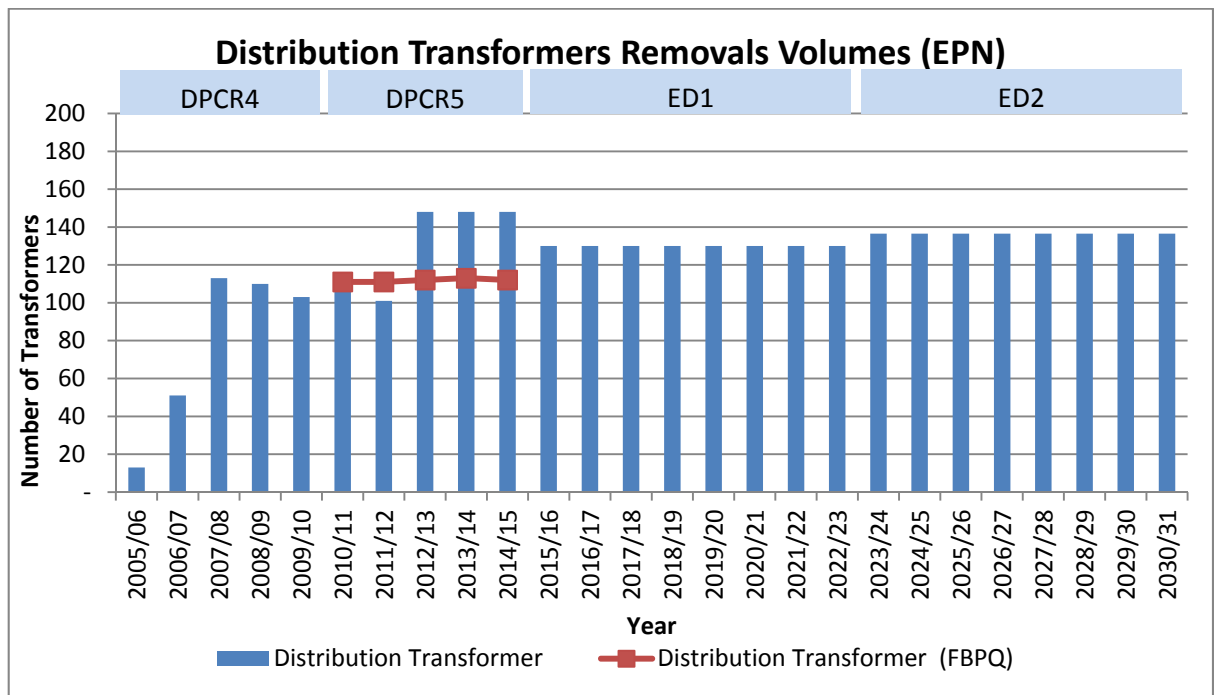


*Figure 12 - Distribution transformer volumes DPCR4– ED1*

Sources :
DPCR4  & DPCR5 FBPQ  - Table NL3 (DPCR5 FBPQ)
DPCR5 (First three years) - 2013/2014 RIGS CV3 table
DPCR5 (Last Two years) - 2013/2014 RIGS CV3 table
ED1 - 2013/2014 RIGS CV3 table
ED2 - From Age-Based Analysis

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### 7.4.2 Expenditure graphs (DPCR4 - ED1)



*Figure 13 - Distribution transformer costs DPCR4 – ED1*

Sources:
DPCR4 & DPCR5 FBPQ - Table NL1 (DPCR5 FBPQ)
DPCR5 (First three years) - 2013/2014 RIGS CV3 table
DPCR5 (Last Two years) – 14thJune NAMP (Table JLI)
ED1 – 19th February NAMP 2014 (Table J Less Indirect)
ED2 - From Age-Based Analysis * UCI

## 7.5   Commentary

The proposed level of investment for replacement of distribution transformers in EPN is £12.3m over the period 1st of April 2015 to 31st of March 2023. The investment levels have been set to maintain the same level of risk throughout ED1 (i.e. no HI4 or HI5 transformers).The number of replacements in the last three years of DPCR5 will be higher than in the first two years due to a backlog of work. The backlog was due to unavailability of key resources – Senior Authorised persons.

A statistical model has been used to develop the forecast and has been validated against historical asset replacement rates and condition of the oldest 10% of the population.

The ED2 figures shown in the chart have been derived from age-based modelling hence the increase in volumes and expenditure. Further work will be done in ED1 to explore additional intervention options that can be used to extend asset life.

## 7.6 Sensitivity Analysis and Plan Validation

A review of different outputs from the SARM model, for different average asset lives, shows that there is a high degree of sensitivity. Table 8 shows a summary of the sensitivity analysis.

| Inputs | | Outputs @ Year (N) | | | Sensitivity analysis | |
|---|---|---|---|---|---|---|
| Average Asset Life | SD | 2012 | 2015 | 2023 | Change to no of HI4/5 assets (If average asset lives other than 70 years is used) | % Change to HI4/5 assets (If average asset lives other than 70 years is used) |
| 60 | 5 | 272 | 1,346 | 6,692 | 5,470 | 448% |
| 65 | 5 | 91 | 465 | 3,252 | 2,030 | 166% |
| **70** | **5** | **30** | **142** | **1,222** | **0** | **0** |
| 75 | 5 | 12 | 52 | 377 | -845 | -69% |

*Table 7 - Sensitivity analysis*

Reducing the average asset life by 5 years or 10 years will increase the number of HI 4/5 assets in 2023 by 166% and 448% respectively.

The volumes of HI4/5 and assets that will result from a 60-year or 65-year average asset life will present a delivery challenge due to the number of skilled resources required and the negative impact on CIs and CMLs, due to outages that would be required.

## 7.7 Network Risk

An in-house criticality modelling technique for distribution transformers has the capability of producing a criticality index (C1-4) for each individual asset, although this is a new concept that is still being developed. The criticality index can be used with the health index to give an indication of the level of risk that can be seen on the network. Table 9 and 10 show the health and criticality matrix for 2015 and 2023 with investment.

| Asset categories | Criticality | Units | Estimated Asset Health and Criticality Profile 2015 | | | | | Asset Register |
|---|---|---|---|---|---|---|---|---|
| | | | Asset health index | | | | | 2015 |
| | | | HI 1 | HI 2 | HI 3 | HI 4 | HI 5 | |
| Distribution TX | Low | No. TX | 2,254 | 4,991 | 8,109 | 0 | 0 | 15,354 |
| | Average | No. TX | 1,472 | 4,148 | 5,296 | 0 | 0 | 10,916 |
| | High | No. TX | 644 | 1,426 | 2,317 | 0 | 0 | 4,387 |
| | Very High | No. TX | 230 | 509 | 827 | 0 | 0 | 1,566 |

*Table 8 - Estimated Asset Health and Criticality Profile 2015*

| Asset categories | Criticality | Units | Estimated Asset Health and Criticality Profile 2023 | | | | | Asset Register |
|---|---|---|---|---|---|---|---|---|
| | | | Asset health index | | | | | 2023 |
| | | | HI 1 | HI 2 | HI 3 | HI 4 | HI 5 | |
| Distribution TX | Low | No. TX | 581 | 6,088 | 8,685 | 0 | 0 | 15,354 |
| | Average | No. TX | 531 | 4,563 | 5,822 | 0 | 0 | 10,916 |
| | High | No. TX | 164 | 1,740 | 2,483 | 0 | 0 | 4,387 |
| | Very High | No. TX | 60 | 621 | 885 | 0 | 0 | 1,566 |

*Table 9 - Estimated Asset Health and Criticality Profile 2023*

## 7.8   Risks: EU Directive

There will be a change in transformers supplied after 2014, based on the Ecodesign Directive (also known as 'Energy-related Products', or 'ErP'). This is the EU's first 'life cycle' oriented directive addressing products. The draft Ecodesign regulation on transformers will improve the energy efficiency of power distribution transformers. Although transformers are already very efficient devices, their energy losses account for around 2.5% of the EU's final energy consumption. The proposed regulation, together with new European standards under development, will bring the EU in line with the strictest international transformer regulations. European manufacturers, electricity utilities and environmental NGOs are widely supportive of the proposed regulation, as it is likely to amplify existing market trends to design more efficient transformers. The impact on EPN is summarised below:

- Have to move from Aluminium to Copper
- Increases in weight up to 21%
- Increase in price of up to 10%

## 8.0   Deliverability

There are some challenges with regards to outages but we will endeavour to maintain supplies to customers via back-feeds (reconfiguration of the LV network) and/or generators, where possible, during planned replacement work.

The deliverability of the proposed replacement volumes in RIIO-ED1 have been reviewed and confirmed by the delivery teams. Contracts will be continually reviewed to ensure that we maintain the same level of contractor resource (Senior Authorised Persons and fitters) to deliver the work. Stakeholder consultations have been carried out with the delivery teams to ensure that the plans are deliverable.

The distribution transformer replacement work program will be prioritised based on the criticality indices for individual transformers. Prioritised replacement lists will be issued to the distribution planning teams for delivery.

## Appendices

## Appendix 1 - Age Profiles
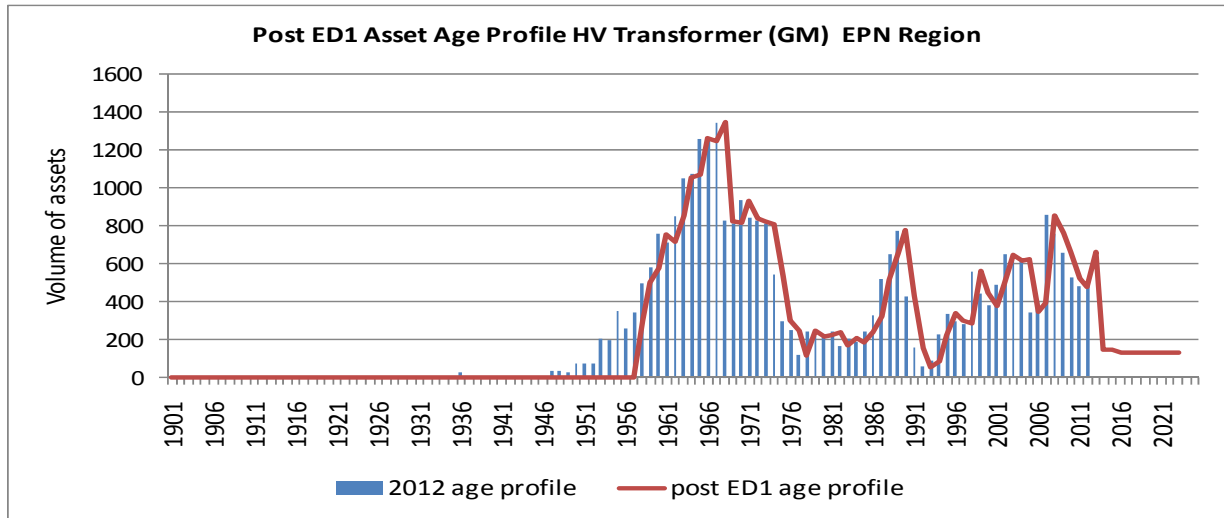


*Figure 14 – Correlation between Age and Defects*

## Appendix 2 – HI and Criticality Profiles
# Asset Health and Criticality

**Asset health and criticality- 2015**

| Asset categories | Criticality | Units | Estimated Asset Health and Criticality Profile 2015 | | | | | Asset Register |
|---|---|---|---|---|---|---|---|---|
| | | | Asset health index | | | | | 2015 |
| | | | HI 1 | HI 2 | HI 3 | HI 4 | HI 5 | |
| Distribution TX | Low | No. TX | 2,254 | 4,991 | 8,109 | 0 | 0 | 15,354 |
| | Average | No. TX | 1,472 | 4,148 | 5,296 | 0 | 0 | 10,916 |
| | High | No. TX | 644 | 1,426 | 2,317 | 0 | 0 | 4,387 |
| | Very High | No. TX | 230 | 509 | 827 | 0 | 0 | 1,566 |

*Table 11 - Criticality and HI Profiles for Distribution Transformers 2015*

All of the cost numbers displayed in this document are before the application of on-going efficiencies and real price effects

| Asset categories | Criticality | Units | Estimated Asset Health and Criticality Profile 2023 | | | | | Asset Register |
|---|---|---|---|---|---|---|---|---|
| | | | Asset health index | | | | | 2023 |
| | | | HI 1 | HI 2 | HI 3 | HI 4 | HI 5 | |
| Distribution TX | Low | No. TX | 581 | 6,088 | 8,685 | 0 | 0 | 15,354 |
| | Average | No. TX | 531 | 4,563 | 5,822 | 0 | 0 | 10,916 |
| | High | No. TX | 164 | 1,740 | 2,483 | 0 | 0 | 4,387 |
| | Very High | No. TX | 60 | 621 | 885 | 0 | 0 | 1,566 |

*Table 12 - Criticality and HI Profiles for Distribution Transformers 2023*

## Appendix 3 – Fault Data
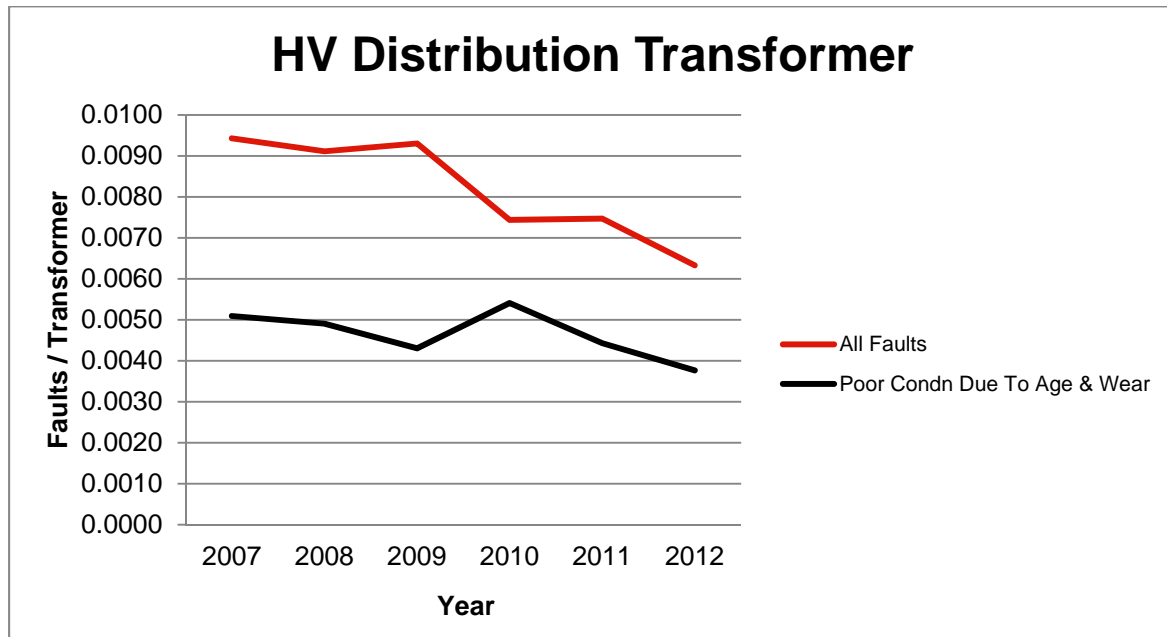


*Figure 15 - Fault Rate Distribution Transformers in EPN (Source - UKPN Fault Cube)*

## Appendix 4 – WLC Studies – Risk, Cost, Performance and Condition Profiles for Various Options

Not applicable for distribution assets

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## Appendix 5 NLRE Expenditure Plan

| NAMP lines | Description | 15/16 | 16/17 | 17/18 | 18/19 | 19/20 | 20/21 | 21/22 | 22/23 | ED1 Total (£k) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.19.01 | Replace GM Distribution Transformers - 11kV | 1460 | 1460 | 1460 | 1460 | 1460 | 1460 | 1460 | 1460 | 11,680 |
| 2.50.03 | Capital replacement of damaged GM 11kV DTF | 75.3 | 75.3 | 75.3 | 75.3 | 75.3 | 75.3 | 75.3 | 75.3 | 603 |
| Total | | 1,475.9 | 1,475.9 | 1,475.9 | 1,475.9 | 1,475.9 | 1,475.9 | 1,475.9 | 1,475.9 | 11,807.2 |

*Table 13 - Distribution transformer expenditure plan (Source – 19th February 2014 NAMP Table J Less Indirect)*

| ED1 Volumes (No. of transformers) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Description | 2015/2016 | 2016/2017 | 2017/2018 | 2018/2019 | 2019/2020 | 2020/2021 | 2021/2022 | 2022/2023 |
| Replace GM Distribution Transformers - 11kV | 115 | 115 | 115 | 115 | 115 | 115 | 115 | 115 |
| Capital replacement of damaged GM DTF | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| Total | 130 | 130 | 130 | 130 | 130 | 130 | 130 | 130 |

*Table 14 - Distribution transformer forecast replacement volumes (Source – 19th February 2014 NAMP Table O)*
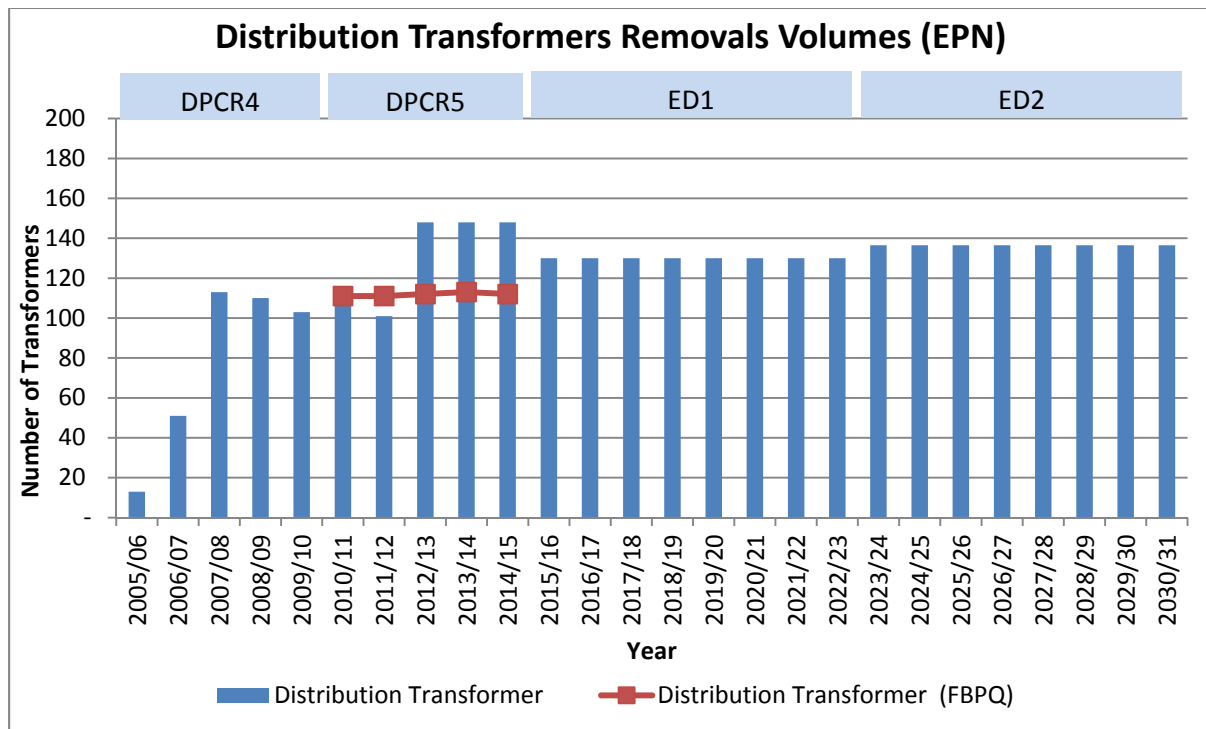


*Figure 16 - Distribution transformer volume charts*

Sources :
DPCR4 & DPCR5 FBPQ - Table NL3 (DPCR5 FBPQ)
DPCR5 (First three years) - 2013/2014 RIGS CV3 table

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All of the cost numbers displayed in this document are before the application of on-going efficiencies and real price effects
DPCR5 (Last Two years) - 2013/2014 RIGS CV3 table
ED1 - 2013/2014 RIGS CV3 table
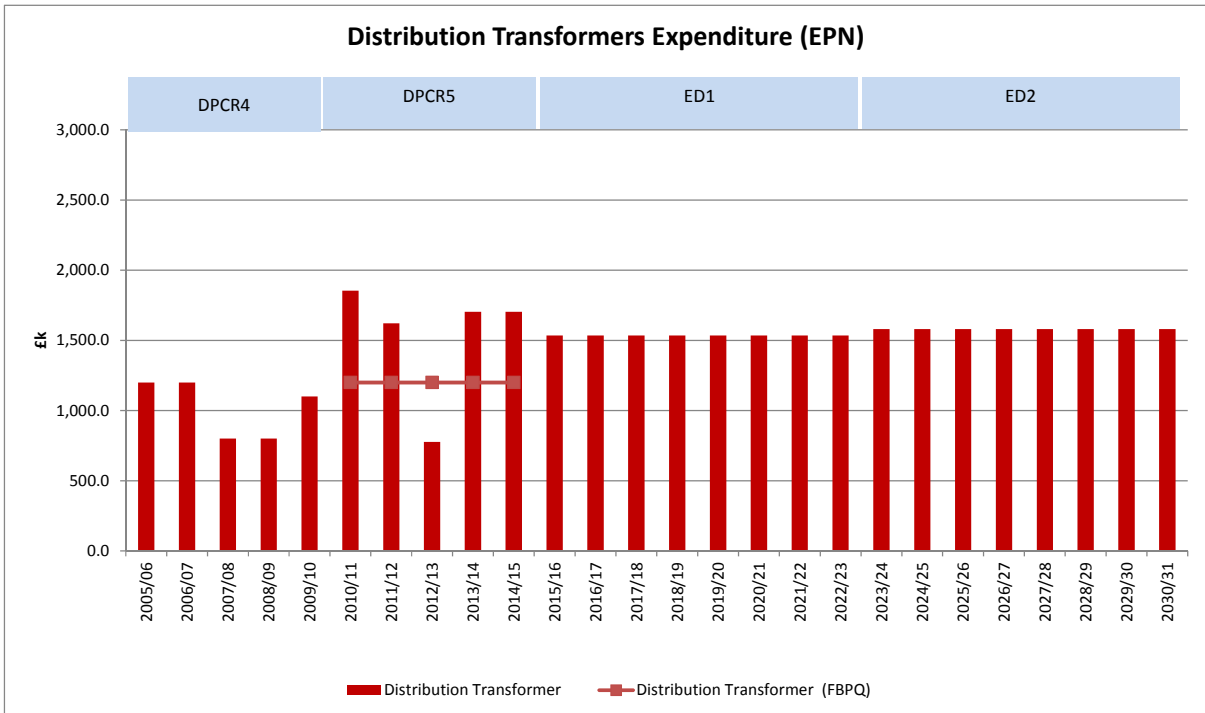ED2 - From Age-Based Analysis



*Figure 17 - Distribution transformer expenditure chart*

Sources :
DPCR4 & DPCR5 FBPQ  - Table NL1 (DPCR5 FBPQ)
DPCR5 (First three years) - 2013/2014 RIGS CV3 table
DPCR5 (Last Two years) - 14th June NAMP (Table JLI)
ED1 - 19th February NAMP 2014 (Table J Less Indirect)
ED2 - From Age-Based Analysis * UCI

## Appendix 6 Sensitivity Analysis and Plan Validation

See Section 7.6

## Appendix 7 Named Schemes

Not relevant for distribution assets – no named schemes

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## Appendix 8 Output NAMP/ED1 Business Plan Data Table Reconciliation

| Outputs | | VOLUMES | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Asset Stewardship Reports | | | | | | | | | Business Plan Data Table | | | | | | | | | |
| Investment Description | NAMP Line | 2015/16 | 2016/17 | 2017/18 | 2018/19 | 2019/20 | 2020/21 | 2021/22 | 2022/23 | Total | RIGs Table | RIGs Row | 2015/16 | 2016/17 | 2017/18 | 2018/19 | 2019/20 | 2020/21 | 2021/22 | 2022/23 | Total |
| 6.6/11kV Transformer (GM) | 1.19.01 | 115 | 115 | 115 | 115 | 115 | 115 | 115 | 115 | 920 | CV3 | 48 | 115 | 115 | 115 | 115 | 115 | 115 | 115 | 115 | 920 |
| 6.6/11kV Transformer (GM) (Capital) | 2.50.03 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 120 | V4B | 48 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 120 |
| Total | | 130 | 130 | 130 | 130 | 130 | 130 | 130 | 130 | 1,040 | | | 130 | 130 | 130 | 130 | 130 | 130 | 130 | 130 | 1,040 |

Table 15 – NAMP to ED1 Business Plan Data Table Reconciliation

[Source: 19<sup>th</sup> February 2014 Namp Table O / 21<sup>st</sup> February 2014 ED1 Business Plan Data Tables]
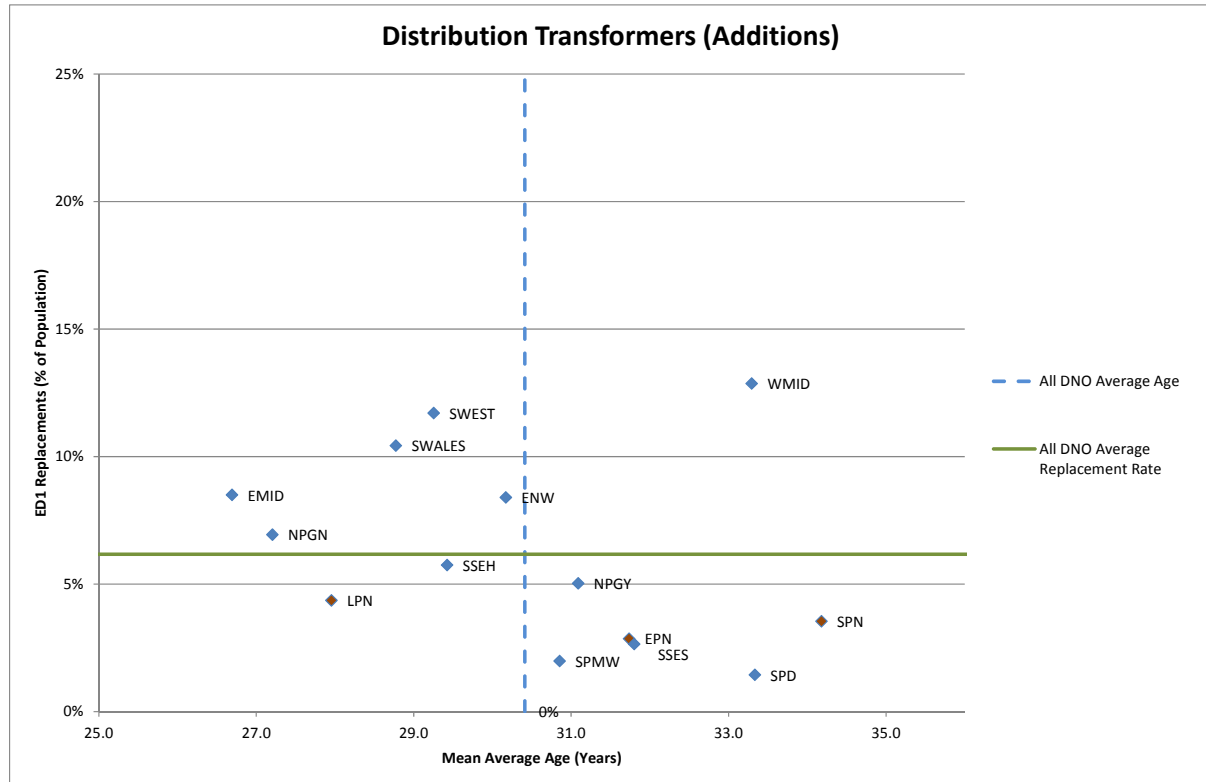
## Appendix 9 Efficiency Benchmarking with other DNOs



Figure 18 – Efficiency Benchmarking [Source: DNO Datashare_2013]

Figure shows that EPN has a lower replacement rate than the industry average per percentage of population and a higher average age. As discussed in Section 7.2, the average life of a distribution transformer in EPN is 70 years, implying that most transformers will be replaced between 55 years and 85 years. Furthermore, the plan for ED1 has been based not only on the output from the age based statistical model but also compared to historical replacement rates, fault rates and condition of the oldest 10% of the population to determine the right outputs to use for investment forecasts.

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## Appendix 10 Material Changes Since July 2013 ED1 Submission

The changes between the July 2013 submission and the March 2014 re-submission are summarised below.

Asset Replacement (CV3)

| Asset Type | Action | Change Type | 2013 Submission | 2014 Submission | Difference |
|---|---|---|---|---|---|
| 6.6/11kV Distribution Transformers | Replace | Volume (Additions) | 920 | 920 | 0 |
| | | Volume (Removals) | 920 | 920 | 0 |
| | | Investment (£m) | 12.52 | *11.32 | (1.20) |
| | | UCI (£k) | 13.60 | 12.31 | (1.29) |

Table 16 – Material Changes to July 2013 ED1 Submission (CV3)

*[Source: ED1 Business Plan Data Tables following the OFGEM Question and Answer Process / 21st February 2014 ED1Business Plan Data Tables]*

The reduction in investment between the 2013 and 2014 submission is due to £1.2m of distribution transformer costs being re-mapped to CV6 (civils) to take into consideration plinth replacement. The total investment for the replacement of distribution transformers, excluding fault restoration costs is £11.68m (as shown in Tables 1 and 2 of this document). This is split into the following tables:

- £10.48m maps to CV3 (asset replacement as shown in Table 16 above); and
- £1.20m maps to CV6 (plinth replacement).

There is a further £0.84m mapping to CV3 (*totalling £11.32m) for consequential costs from major projects.

Faults (V4b/CV15a)

| Asset Type | Action | Change Type | 2013 Submission | 2014 Submission | Difference |
|---|---|---|---|---|---|
| 6.6/11kV Distribution Transformers | Replace | Volume (Additions) | 120 | 120 | 0 |
| | | Volume (Removals) | 120 | 120 | 0 |
| | | IInvestment (£m) | Changes to capitalised fault restoration expenditure can be found in Document 14: EPN I&M and Faults | | |

Table 17 – Material Changes to July 2013 ED1 Submission (V4b)

*[Source: ED1 Business Plan Data Tables following the OFGEM Question and Answer Process / 21st February 2014 ED1Business Plan Data Tables]*.