TransGrid Revenue Proposal
2018/19 – 2022/23

Appendix E

Aurecon:

Efficiency of capital expenditure

Independent Review of TransGrid's CAPEX Plan

FINAL Report

TransGrid

25 January 2017

Revision: 3

Reference: 253542

Bringing ideas to life

Document control record

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This report has been prepared to assist TransGrid to determine the appropriateness and robustness of its proposed revenue to be sought in relation to its capital expenditure from 1st July 2018 to 30th June 2023. The review was conducted on the basis of compliance with the requirements under the National Electricity Rules (NER) Chapter 6A.6.7 (Forecast Capital Expenditure) and the definition of good electricity industry practice. This report covers a particular and limited scope as defined by TransGrid and should not be read as a comprehensive assessment of proposed expenditure.

This report relies on information provided to Aurecon by TransGrid. Aurecon is not liable for any errors or omissions in the information provided, nor for the use of any information in this report by any party other than TransGrid and / or for any purpose other than the intended purpose.

In particular, this report is not intended to be used to support business cases or business investment decisions nor is this report intended to be read as an interpretation of the application of the NER or other legal instruments.

Except where specifically noted, this report was prepared based on information provided by TransGrid prior to 23 November 2016 and any information provided subsequent to this time may not have been taken into account.

As far as it is practical to do so, Aurecon has read, understood and complied with Federal Court Practice Note CM7 in relation to the preparation of this report.

Executive summary

TransGrid is due to submit its revenue proposal for the next regulatory control period in early 2017. For the next regulatory period, TransGrid's capital expenditure will be dominated by replacement or refurbishment expenditure rather than expenditure on network capacity enhancement. Aurecon has been engaged by TransGrid to review its capital expenditure framework.

TransGrid has made significant changes to its project assessment methodology since the previous revenue proposal. It has improved the methodology for assessment of risk and has built risk costing into base-case pre-investment conditions as well as reduction in risk following asset renewal.

Considerable effort has been devoted to developing risk based assessments of asset condition with asset replacement being driven by risk cost modelling.

Aurecon's review of the revenue proposal capital expenditure forecast has been undertaken while the documentation is still in course of preparation and so Aurecon notes that the documentation as reviewed was in some instances unavailable or incomplete. Aurecon does not believe that this has materially affected its review.

Key messages

TransGrid has developed risk over time modelling for major assets and developed tools to ensure that investment is focused on managing the key risks and failures that lead to them. Portfolio analysis and prioritisation is now enabled by the risk assessment methodology.

For replacement expenditure, TransGrid has developed a number of building blocks that are used to determine the required spend including asset criticality, asset health and network risk assessment methodology. These building block models are used to determine asset risk and criticality for replacement. The evaluation of potential replacement options includes the risk benefit derived for each option, with the recommended option generally being the option that has the greatest net present value.

Risk impacts are also considered as key inputs to potential benefits associated with asset investments within the planning, project delivery and asset operating lifecycle phases. Benefits assessed for project evaluation include reduction in risks as well as reduction in costs.

Aurecon's understanding of the overall process used for the development of capital works projects was formed through review of relevant framework documents and the application of the framework to a sample of project specific documents.

For REPEX, TransGrid's expenditure forecast starts with the determination of various inputs such as asset condition assessment, asset age profiles and asset criticality calculations. TransGrid then builds up the REPEX plan through the preparation of asset class renewal strategy documents. In parallel with the "bottom up" approach, TransGrid has also built a "top down" model utilising an enhanced version of the AER REPEX Model. Using this model, TransGrid can review various scenarios such as trend analyses, project deferral assessments and the effects of the plan on long term sustainability for its network.

The process for AUGEX is managed differently since it needs to address the required network capacity to meet projected needs. Inputs for this process include AEMO and DNSP demand forecasts, capacity of the existing network such as equipment and line ratings, generation development scenarios including potential retirements of existing generation, DNSP Joint Planning, constraint analysis with peer TNSP's, transmission reliability standard and NER requirements.

For capacity augmentations, TransGrid considers alternative transmission network options as well as non-network options that meet identified needs. Project evaluation includes treatment of risk associated with non-investment (base case) as well as energy not supplied. The evaluation also includes the predicted change in risk cost following implementation of the preferred option.

The present Transmission Reliability Standard is being reviewed by IPART (the NSW Independent Pricing and Regulatory Tribunal) with the final version of the new standard expected to be available by end of 2016. The new Transmission Reliability Standard is intended to apply for the regulatory control period from 1 July 2018 to 30 June 2023 and is expected to stipulate at each bulk supply point:

- the required level of redundancy to be in place,
- the ability for TransGrid to plan to have some expected unserved energy at each bulk supply point
- the ability for TransGrid to meet the requirements for redundancy and expected unserved energy using any combination of transmission network assets, non-network solutions or agreements with distribution network service providers to use part of the attached distribution network.

The needs for the transmission network are in transition as substantial retirement of existing generation is likely within the next decade. A significant number of new renewable generation projects are likely to be developed, though transmitting the new sources of generation to the loads is likely to introduce new challenges to the operation of the main transmission network.

It is Aurecon's view that TransGrid's framework for the preparation of its capital expenditure plan for the 18/19 to 22/23 regulatory period will result in a CAPEX forecast that is in accordance with good electricity utility practice and will meet the capital expenditure criteria as set out in 6A.6.7 of the National Electricity Rules.

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1 Introduction

1.1 Background

TransGrid is the operator and manager of the high voltage electricity network in New South Wales and the Australian Capital Territory. As such, TransGrid is a transmission network service provider (TNSP) regulated under the National Electricity Law (NEL) and the National Electricity Rules (NER).

Chapter 6A of the NER sets out rules for the economic regulation of prescribed transmission services and negotiated transmission services provided by TNSPs. This regime requires the AER to determine the revenue allowed to be earned by TransGrid for prescribed transmission services during each regulatory year, in accordance with the post-tax revenue model, described in Chapter 6A of the NER for each regulatory control period. In addition, a pricing methodology, negotiating framework and negotiated transmission service criteria must also be determined by the AER. The process for making a transmission determination is set out in Part E of Chapter 6A of the NER.

TransGrid is currently preparing its revenue reset proposal for the next regulatory period (18/19 to 22/23). TransGrid's proposed CAPEX spend is a critical component of the revenue proposal.

1.2 Specified scope

Aurecon was requested to review TransGrid's proposed CAPEX for the 18/19 to 22/23 regulatory period to provide an expert view on the following, with consideration against good industry practice[1] and with consideration of the capital expenditure criteria as set out in 6A.6.7 of the National Electricity Rules:

<u>Replacement Expenditure (REPEX)</u>

- The appropriateness of TransGrid's fundamental building blocks for REPEX – being the Criticality Framework, Asset Health Framework, Network Risk Assessment Methodology and its application
- The appropriate level of the REPEX spend with regard to top down REPEX modelling and other trend based approaches

[1] The exercise of that degree of skill, diligence, prudence and foresight that reasonably would be expected from a significant proportion of operators of facilities forming part of the power system for the generation, transmission or supply of electricity under conditions comparable to those applicable to the relevant facility consistent with applicable regulatory instruments, reliability, safety and environmental protection. The determination of comparable conditions is to take into account factors such as the relative size, duty, age and technological status of the relevant facility and the applicable regulatory instruments. (Definition from National Electricity Rules Version 82, page 1157)

Augmentation Expenditure (AUGEX)

The augmentation plans and associated expenditure is to be reviewed with particular focus on the following aspects:

- The appropriateness and robustness of TransGrid's augmentation plans, taking into consideration:
  - Demand forecast for 2016 - 2026
  - Capacity of the existing network
  - Generation outlook (including retirements)
  - Reliability criteria
- The consideration of alternative options including non-network options, option assessment criteria and selection of preferred option
- The treatment of risk associated with non-investment (base case) including energy not supplied
- The robustness of the process followed and the diligence in following the process in determining the preferred option
- The appropriateness of the triggers identified for the contingent projects

Further, where possible, assessment of the exhaustiveness of the portfolio of the augmentation projects should be made, taking into consideration:

- The uncertainty associated with the demand forecast, generation outlook
- The likely revision of the (n-x) reliability standard to an economic reliability standard by IPART

1.3 Aurecon's authority and approach

As an engineering consulting firm that has significant experience in power transmission and distribution, Aurecon is well positioned to perform a detailed review of TransGrid's processes and outputs related to its CAPEX forecasts. We have worked closely with TransGrid and other electricity utilities in Australia for more than 15 years. This provides us with good insights into its culture, processes and practices.

In addition, Aurecon was the technical and environmental due diligence advisor to the consortium that successfully acquired the 99 year lease of TransGrid from the NSW Government. Shortly after the transfer to the new owner, we provided some feedback to TransGrid relating to our findings and also facilitated a workshop for TransGrid senior executives and group managers. This has allowed Aurecon to take part in, and understand, TransGrid's journey towards being a more efficient and effective transmission company.

For this review, Aurecon selected its project manager, verifier and subject matter experts specifically based on their experience with TransGrid and other transmission utilities as well as their significant technical expertise in the subject matter.

Aurecon approached the review using the following process:

- Produce a document map covering the flow of information from the overarching policies through inputs / assumptions, planning process, project assessments and CAPEX forecast in order to assess the completeness of the process
- In depth review of documentation covering the three primary areas driving the forecasting process; namely, risk assessment methodology, asset management strategy and project justification strategy
- Targeted reviews of documentation covering various topics considered important to the review
- RFIs submitted to TransGrid covering clarifications and additional documentation requests

- Attend clarification meetings with TransGrid to confirm and further enhance our understanding of processes
- Produce a draft report for review by TransGrid as an opportunity to further clarifications
- Final report verified by senior Aurecon staff

1.4 Timeframe

The review took place during the months of October and November 2016, two months ahead of the due date for TransGrid's submission to the AER (31 January 2017).

1.5 Structure of report

This report presents Aurecon's findings in relation to the scope summarised above. These findings are provided at a high level within Sections 2 to 5, providing comment on the overarching approach and methodologies, and then more specifically within Sections 6 and 7 relating to the REPEX and AUGEX detailed processes and projects. Sections 3, 4 and 5 deal specifically with three areas of importance; namely, risk, asset management and project justifications.

2 TransGrid's approach to CAPEX

2.1 Overarching policies

TransGrid manages its CAPEX program through a suite of policies, procedures, frameworks and guidelines.

At the highest level, TransGrid's Asset Management Policy affirms its commitment to manage "*its assets across the complete asset lifecycle in a safe, efficient, co-ordinated, and environmentally sensitive way that serves the needs of its stakeholders, customers and electricity end-use consumers, and optimises the long-term return on investment for its owners.*" This document sets a good foundation for the management of the NSW transmission assets.

Other TransGrid documents used to support the implementation of the Asset Management Policy include the following:

- Asset Management System Description
- Prescribed Capital Investment Framework
- Prescribed Capital Investment Procedure
- Prescribed Capital Investment Benefits and Optimisation Procedure
- Prescribed Capital Investment Governance Arrangements
- Prescribed Capital Investment Assessment Guidelines
- Network Asset Criticality Framework
- Asset Health Framework
- Network Risk Assessment Methodology
- Briefing Note - REPEX Model Methodology
- Asset Management Strategy & Objectives

2.2 Development of REPEX and AUGEX forecasts

The development of TransGrid's REPEX and AUGEX forecasts are directed by the overarching documents referred to above.

For REPEX, this starts with the determination of various inputs such as asset condition assessment, asset age profiles and asset criticality calculations. TransGrid then builds up its REPEX plan through the preparation of asset class renewal strategy documents. In concert with the "bottom up" approach, TransGrid builds a "top down" model utilising an enhanced version of the AER REPEX Model. Using this model, TransGrid can review various scenarios such as trend analyses, project deferral assessments and the effects of the plan on long term sustainability. The outputs for these analyses are then used to provide some high-level calibration to the bottom up process.

Specific projects and programs are identified and assessed following the outcomes of the asset class renewal and maintenance strategies. The specific projects and programs are evaluated through a number of stages.

The process for AUGEX is managed differently since it has to address network capacity to meet projected needs. Inputs for this process include AEMO and DNSP demand forecasts, main and subsystem ratings as well as generation development scenarios, DNSP Joint Planning, constraint analysis with peer TNSPs, reliability standard and NER requirements. Using these inputs, 12 area plans are produced, following which specific projects are identified and assessed.

Figure 1 shows a map of the subset of TransGrid documentation that makes up the above process and that Aurecon's subject matter experts reviewed.

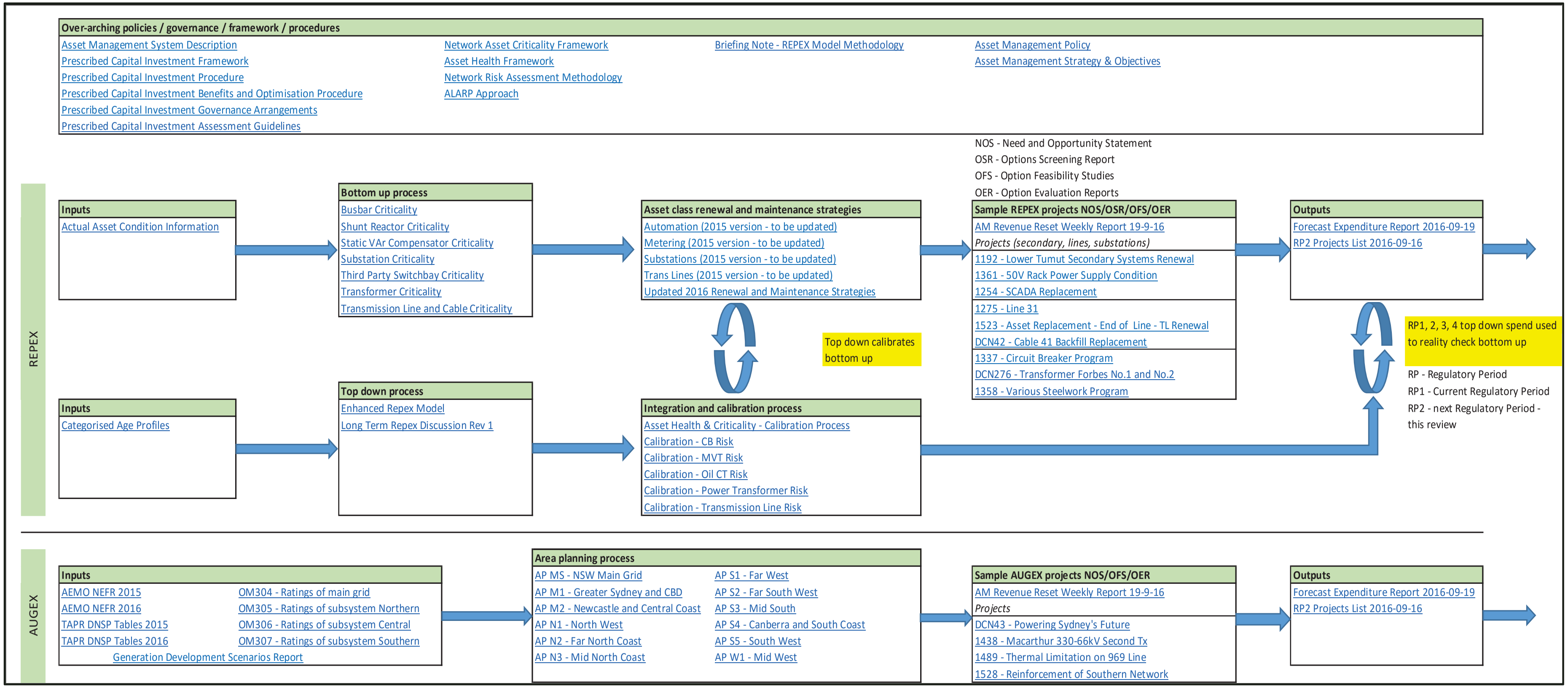

Figure 1: Documents reviewed by Aurecon

2.3 Changes since the 2014-18 revenue determination

The AER Final Determination for 15/16 to 17/18 raised a number of issues regarding TransGrid's proposed replacement capital expenditure (REPEX). Some extracts from Appendix 6 of the AER determination are reproduced below.

Our concerns with TransGrid's forecasting methodology and key assumptions are material to our view that we are not satisfied that its proposed total forecast CAPEX reasonably reflects the CAPEX criteria.

We conclude that TransGrid's forecasting methodology predominately relies upon a bottom-up build (or bottom-up assessment) to estimate the forecast expenditure and that the top-down constraints imposed by their governance process are insufficient for us to be able to conclude that the forecasts are prudent and efficient. Bottom up approaches have a tendency to overstate required allowances as they do not adequately account for inter-relationships and synergies between projects or areas of work. In the absence of a strong top-down challenge of the aggregated total of bottom-up projects, simply aggregating such estimates is unlikely to result in a total forecast CAPEX allowance that we are satisfied reasonably reflects the CAPEX criteria.

In constructing our alternative estimate, we have addressed the concerns we have with TransGrid's forecasting methodology and key assumptions. Specifically, we have undertaken a top-down assessment by applying our assessment techniques of economic benchmarking, trend analysis and an engineering review. We have also addressed the deficiencies in TransGrid's key assumptions about demand and customer forecast and forecast materials escalation rates and labour escalation rates.

The AER did not accept TransGrid's proposed REPEX and security and compliance CAPEX. Instead it included an alternative reduced estimate for REPEX, security and compliance CAPEX. The AER's reduction reflected its conclusions that:

- Risk assessment was conservative
- Network Investment Risk Assessment Methodology was not suitable, was conservative and systematically overstated risk
- Asset health not defined or well understood
- There was no common approach to the definition and ranking of critical assets
- Risk levels not defined or well understood
- Limited consideration of changing risk over time, timing of investment, and impact of deferral
- Investment options not based on addressing key failure modes and hazards
- No portfolio analysis, prioritisation or optimisation (and impact on performance)

Since the last AER determination, TransGrid has spent considerable effort developing a risk based methodology and applying its risk assessment methodology to determine asset replacement or refurbishment requirements.

The improved risk assessment methodology (RAM) developed for major assets:

- Is asset focused
- Considers asset health (probability of failure)
- Considers criticality (consequence of failure)

- Quantifies risk into measurable terms
- Allows risk level to be monitored and reviewed
- Consistently applied through a risk assessment tool

TransGrid has also developed risk over time modelling for major assets and developed tools to ensure that investment is focused on managing the key risks and failures that lead to them. Portfolio analysis and prioritisation is now enabled by the risk assessment methodology.

For its new revenue proposal, TransGrid has compared its proposed REPEX expenditure derived from a bottom-up approach with that estimated using top-down methods. The TransGrid analysis of the two methods give results that overall are within 10% of each other. This comparison is discussed in more detail in Section 5.

3 Risk methodology

3.1 Overview

This section summarises the observations and recommendations strictly limited to TransGrid's approach and methodology adopted in terms of **risk assessment** when read in conjunction with the good electricity utility practice and CAPEX criteria as set out in 6A.6.7 of the National Electricity Rules.

The section is the combined output of a desktop review of several documents and systems that have been utilised by TransGrid (as per section (2) (1)) to inform the 18/19 to 22/23 CAPEX estimate. Aurecon has previously undertaken a review of TransGrid's Investment Risk Tool (IRT) which is documented in the RAM as a "tool". Professional observations from that review are included in this section to substantiate the IRT's relevance and where appropriate, paraphrased outputs are included as they may apply to the 18/19 to 22/23 CAPEX estimate.

A view is expressed with respect to *AS-5577: 2013, Electricity network safety management systems* with specific emphasis on the operational philosophy to achieve As Low as Reasonably Practicable (ALARP) requirements. It is imperative to note that "ALARP thinking" is tied in with key principles from *AS/NZS 31000: 2009, Risk management – principles and guidelines*, namely:

a) Creates and protects value

b) Is an integral part of all organisational processes

c) Is part of decision-making

d) Explicitly addresses uncertainty

e) Is systematic, structured and timely

f) Is based on the best available information

g) Is tailored

h) Takes human and cultural factors into account

i) Is transparent and inclusive

j) Is dynamic, iterative and responsive to change

k) Facilitates continual improvement of the organisation

3.2 Context

The ***Management System Document - Prescribed Capital Investment Framework*** (Revision 1, 22 August 2016) provides an appropriate level of context in terms of how risk assessment is utilised as a key informant to decision making. From a scope perspective, the framework supports a better understanding of how proposed capital portfolios impact the six corporate risk categories, namely:

a) System (reliability)

b) Financial

c) Operational

d) People (safety)

e) Environmental

f) Reputational

Risk impacts are also considered as key informants to potential benefits associated with asset investments within the planning, project delivery and asset operating lifecycle phases. Such benefits need to be read in conjunction with the Corporate Benefits Management Framework which denotes:

- Reducing risks
- Reducing costs and
- Increasing revenues.

At a contextual level, a "need" is defined as a "reduction in risk from an unacceptable level to an acceptable level". It is important to note that the Prescribed Capital Investment Framework makes specific allowance for 'risk' as a source of information to drive financial investment under the "using" and "based on" artefacts within the greater framework which supports the Financial Investment Policy. This is best described by the framework overview whereby the "needs" are clearly stated. This section therefore considers the approach and methodologies adopted by TransGrid to fulfil the "needs" (primary source being the Management System Document – Network Asset Risk Assessment Methodology (RAM) (Revision 0, 17 December 2015).

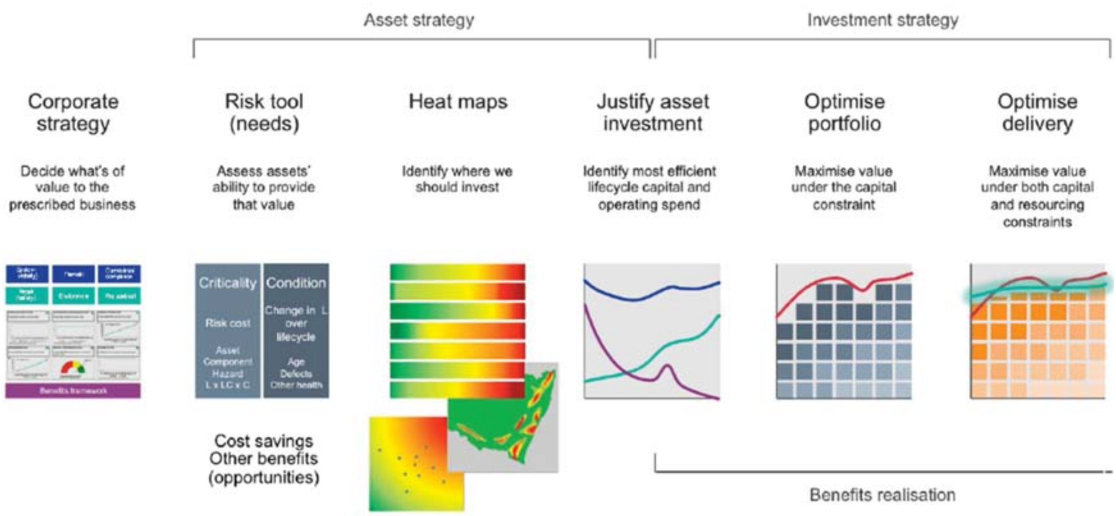

Figure 2: Framework overview

Source: Management System Document - Prescribed Capital Investment Framework (Revision 1, 22 August 2016)

3.3 Quantifying risk - Probability of Failure (PoF) and Consequence of Failure (CoF)

Section 6, of the Risk Assessment Methodology states that *"Risk is quantified by multiplying likelihood and consequence. The monetary value of risk (per year) for an individual asset failure resulting in a Key Hazardous Event, is the likelihood (probability) of failure (in that year with respect to its age), as determined through modelling the failure behaviour of an asset (Asset Health), multiplied by the consequence (cost of the impact) of the Key Hazardous Event occurring, as determined through the consequence analysis (Asset Criticality). Where multiple key hazards are applicable to an asset, the value of risk for each of these are summed to give the total value of risk associated with an asset. The equation for this quantitative risk assessment methodology is shown below".*

Furthermore, by forecasting the likelihoods and consequence costs into the future, an annual forecast of the value of risk of an asset failure resulting in a Key Hazardous Event is determined.

$$\text{Monetised value of risk (\$)} = \sum_{K=0}^{\gamma} P(\alpha_K).(\$C_P.\beta_P + \$C_E.\beta_E + \$C_S.\beta_S + \$C_F)$$

Where:

$P(\alpha_K)$ *is the likelihood of failure attributable to failure mode K*

$\$C_P$ *is the people safety consequence cost*

$\$C_E$ *is the envirnoment consequence cost*

$\$C_S$ *is the system impact consequence cost*

$\$C_F$ *is the financial consequence cost*

β_P *is the likelihood of the people safety consequence occuring*

β_E *is the likelihood of the environment consequence occuring*

β_S *is the likelihood of the system impact consequence occuring*

The above extract from the RAM, Section 6 in effect states that quantification is calculated by asset per hazard event. The Network Asset Health Framework provides methodologies and processes applied to calculate the current and future effective age of individual network assets, and the effective age and **probability of failure** mappings for each network asset class. The following databases have been reviewed in formulating an opinion regarding "cost estimate" at a REPEX and Forecast level.

- 18/19 to 22/23 Projects List 2016-09-16
- Top Down Analysis - Enhanced Repex Model and
- Forecast Expenditure Report 2016-09-19

The PoF is defined as "the chance of a hazardous event occurring".

Section 5 of the RAM states *"The aim of defining the scope of each broad area of consequence is to ensure the impact of a consequence (<u>including the attributed monetary value</u>) is <u>only considered once</u> when determining the total consequence of a failure resulting in a hazardous event. <u>This avoids inadvertent overstating of consequence and risk</u>".*

The first observation to note is that TransGrid focusses its cost estimate for assets that are anticipated (PoF) to result in catastrophic failure, as a consequence of a hazard event. The CoF (potential cost) is ascribed to the effect of a component failing (eg loss of power to the customer) and not the replacement cost of the asset. A second observation is that the financial estimate ascribed to a catastrophic failure is informed by referenced historical data. These estimates are a combination of deterministic and stochastic methods. By way of example, Weibull curves are utilised, with the best fit algorithm, to arrive at an estimate for PoF.

In light of the above approach, the Good Electricity Utility Practice and the CAPEX criteria as set out in 6A.6.7 of the National Electricity Rules, the following area in particular needs consideration:

(c) (3) a realistic expectation of the demand forecast and cost inputs required to achieve the capital expenditure objectives.

It is appropriate to deduce that TransGrid is focussing primarily on assets that can cause **catastrophic failure**, noting strong redundancy is in place for non-catastrophic hazards. It is important to reflect on what this implies in terms of the CAPEX estimate:

Catastrophic failure is viewed as the initiating event resulting in the CoF which includes “Unserved Energy” (noting other consequences as well however, unserved energy attracts the greatest cost). TransGrid has redundancy measures in place which typically corresponds to effective and efficient asset management to ensure its users are supplied with energy. Furthermore, repairs are in effect limited to hours or days for many asset classes, which ensures service delivery, is for the most part, operational. However, if it is a replacement (due to catastrophic failure), then the time to replace the asset is expected to be of a longer duration. Inherently, the PoF increases as simultaneous failure of assets (components) within the impacted asset class becomes more probable due to replacement/repair time. In such instances, the TransGrid risk methodology is robust and flexible enough to consider failure modes by component over and above the catastrophic failure scenario(s) which results in asset optimisation and reduces costs.

TransGrid uses the 'most likely' values to inform CoF, which is an acceptable method, however further accuracy can be obtained by using an estimate which comprises a reasonable view to the lowest possible CoF, most likely CoF (current case) and the maximum CoF tied to PoF per asset class, eg, Monte Carlo Analysis.

3.4 Investment Risk Tool (IRT)

At a high level, the most prominent aspects of the tool that are value adding relate primarily to tables which contain data that can be ‘used’ and tables that are used to ‘capture’ data as well as queries which ‘link’ relation tables and/or queries. There are a number of positive aspects related to the IRT and these comments are made in the context of the tool being part of a continuous improvement journey. The structure of the tables and the way in which the database was constructed is sound and logical, and appropriate risk categories have been employed (refer to section 6.3 for further detail regarding risk categories). Of great importance is the quality of the data captured.

Based on the desktop review, the following positive aspects are highlighted:

- Logic and layout
- Regular use
- Number of risk assessments
- Potential uses for business intelligence

From a structural perspective, tools such as the IRT, typically consist of the following parts:

- Tables which were set up in the IRT and contain data that is used during the risk assessment(s). By way of example, this could include tables such as ‘tblConsequences’ which contain a list of 20 types of consequences that are used by means of drop-down boxes during a risk assessment(s).
- Tables which contain data captured during a risk assessment(s), i.e. the table ‘tblRiskAssessment’
- Queries which link various relational tables and/or queries
- Queries which are used to calculate CoF
- Reports

Issues involving the identification and quantification of risks related to asset management of electricity transmission networks are not unique to TransGrid and challenges related to maintenance and re-investments are high on the agenda of electricity organisations in many countries (Nordgård, 2010, p. 16).

The logic used in the RAM is that ‘sources of risk’ may lead to ‘risk events’ which may have ‘consequences’. To prevent these consequences from occurring, the sources of the risk need to be addressed by implementing suitable treatment plans. As such, treatment plans may include the need to accept, mitigate, avoid or transfer the risk. There are several methods in which risks can be described by using risk meta-language (as proposed by Hilson), an example of this is as follows:

Due to being at the end of its lifecycle and a lack of maintenance, a transformer might fail which will lead to power outages and dissatisfied customers.

Although the sources of the risk (in the example, lack of maintenance) are not specifically identified, the existing controls, as identified in the Asset Class Strategies, have been included in the calculation of the CoF.

4 Asset management methodology

4.1 Asset management overview

TransGrid has developed an asset management system that satisfies the elements of "*ISO 55001 Asset management – Management systems – Requirements*". It is expected that by being able to satisfy the requirements of ISO 55001 and applying these principles to asset management within the organisation, TransGrid is promoting good practice within the organisation.

Aurecon notes that, based on our experience, other utilities have not achieved TransGrid's level of maturity in the application of ISO 55001 within their respective organisations.

4.2 Asset management policy

Document is a key statement of corporate intent ✓

The asset management policy is consistent with the requirements of ISO 55001, although it does not explicitly reference the standard.

There is no reference to TransGrid's expectation in adopting or complying with any specific standard(s) in relation to Asset Management, even though TransGrid was one of the first to be accredited to ISO 55001.

The policy states that TransGrid will comply with "all legal, regulatory, safety and environmental requirements placed upon it".

4.3 Asset management system description

Provides a good overview of TransGrid's asset management system and document hierarchy ✓

This document is well written and contains numerous elements of an ISO 55001 compliant Strategic Asset Management Plan (SAMP).

The document contains a description of TransGrid's physical assets covered by the asset management system, and a description of TransGrid's activities for each part of the asset's lifecycle with defined asset management system boundaries.

We note that chapter 8 details TransGrid's intention for alignment with "Good Industry Asset Management Practice", while Appendix C maps the 71 "shall" clauses in ISO 55001 to the TransGrid asset management systems and details the relevant documents and the responsible manager for their delivery.

4.4 Asset management strategy and objectives

Document sets the strategic approach to asset management and overarching approach ✓
Whole of life asset management, from planning to retirement ✓

Our review of this document found that it adequately expanded the ideas outlined in the Asset Management Systems document.

The lifecycle stages discussed being:

- Plan
- Design
- Build
- Operate
- Maintain
- Renew
- Dispose

Each of these stages are well described and provide additional detail of TransGrid's strategies and expectations in managing the various aspects of the asset lifecycle.

4.5 Asset class renewal and maintenance strategies

Clear articulation of class issues and trends to provide context for REPEX spend ✓

The following documents were reviewed in detail by Aurecon:

- Transmission Line Renewal and Maintenance Strategy Rev 2, 2 August 2015
- SSA Strategy - Renewal and Maintenance - Metering Systems Rev 1, June 2015
- Substations Renewal and Maintenance Strategy Rev 2, 13 July 2015
- SSA Strategy - Renewal and Maintenance - Automation Systems Rev 1, July 2015

The Asset Class Renewal and Maintenance Strategies that Aurecon reviewed contained previous information in regards to expenditure timing, but were considered to be generally good quality documents with some minor editorial issues.

The documents generally contained a clear articulation of TransGrid's understanding of the risks, asset class issues and maintenance requirements. We noted that these documents clearly linked the asset class issues to TransGrid's risk framework and also continued the linkage to specific asset and detailed the proposed CAPEX mitigation strategies and its current status (as of 2015) of these strategies.

Subsequently, revised Renewal and Maintenance Strategies (2016) have been provided to, and reviewed at a high level by Aurecon. The revisions do not materially alter the findings of this report.

5 Project justification methodology

5.1 Inputs and assumptions

With an ageing network, much of TransGrid's capital expenditure for the next regulatory period will centre on asset replacement or refurbishment. Little capital expenditure will be required for capacity driven augmentations.

Modelling for risk assessments is undertaken using deterministic and stochastic inputs, however current modelling is limited to an estimated CoF dollar figure as opposed to a range of financial exposure (Minimum – Most Likely – Maximum) tied to a frequency of occurrence within an assets operational life as part of this 18/19 to 22/23 forecast.

TransGrid makes reference to several thresholds and data sets that inform PoF and CoF which are credible and has calibrate its models through review of outage data and equipment failure records. The overall quality of data captured is of a high standard and is considered to be relatively accurate.

TransGrid has several other systems in place that calibrate with ISO31000:2009 and AS-5577: 2013, Electricity network safety management system requirements.

5.2 Asset health and criticality

5.2.1 Risk factors and Likelihood of Consequence

Selection of environmental risk values (bushfire consequence and Likelihood of Consequence, environmental ranking and clean-up costs) ✓

TransGrid utilises historical data to inform risk values attributed to environmental impacts eg. clean-up costs. This approach is based on the logic that it is primarily a known potential consequence, that is, a discrete input. As such, the input is based on the "most-likely" value for CoF whilst the LoC is based on Weibull curves. It is anticipated that over time TransGrid will incorporate other stochastic modelling techniques such as Monte Carlo Analysis, Bayesian Networks, Fault Tree or Event Tree Analysis in order to add an even greater level of confidence when estimating the environmental risk values.

Selection of safety consequence and LoC ✓

TransGrid utilises historical data to inform risk values attributed to safety impacts. This approach is based on the logic that it is primarily a known potential consequence, that is, a discrete input. As such, the input is based on the "most-likely" value for CoF whilst the LoC is based on Weibull curves. Other stochastic modelling techniques such as Monte Carlo Analysis, Bayesian Networks, Fault Tree or Event Tree Analysis will add a greater level of confidence when estimating the environmental risk values.

5.2.2 Asset health

Choice of values and weighting to derive Asset Health ✓

The concept of developing a Health Index (HI) and relating the HI to an estimated remaining life has been used extensively in the electricity industry.

The choice of the parameters, weightings and normalisation factors used to calculate the HI for each component of the network varies considerable between network operators.

It is expected that the operators understand and select these parameters or factors based on their detailed knowledge of the network assets and their operation.

We believe that the document could be improved if TransGrid included an explanation of how the normalisation factors used in the transformer HI calculations were developed.

5.2.2.1 Observation on the calculation of selected Health Indices

A.2 Power Transformer & Oil filled Reactor

Normalisation Factor

"Table 12.1: Transformer defects and associated weightings" introduces the concept of Normalisation and Weighting Factors.

Health Index parameters

The HI includes a parameter titled "Cumulative Defect Cost". The parameter is calculated using the Cumulative Defect Cost which has been normalised by dividing the total by $100,000 (TransGrid determined value).

After discussions with TransGrid personnel we understand that the purpose of this parameter is to quantify the severity of the defects that impact transformer life. The use of the cumulative costs assumes that a higher cost represents more severe life impacting defects and ignores the potential effects of refurbishment that may actually extend transformer life.

Aurecon recommends a minor improvement in the future, namely, that TransGrid scales the defect count to account for severity of effects on asset life, but remove the defect counts where refurbishment has improved asset life.

A.3 Circuit Breaker

Cumulative Defect Cost - note the above comments.

A.8 Protection Relay

The HI includes a parameter which considers the "Availability of spares".

Availability of spares is a criticality issue and not relevant to HI, the impact of replacement lead times should be evaluated in the asset risk profile.

Aurecon had discussions with TransGrid in which they highlighted that this factor was included to cover maintainability issues where the relays were no longer supported by the OEM, and where there are issues with calibration and the detectability of failure due to this lack of support.

We agree that a maintainability parameter could be included in a Health Index, and suggest that TransGrid use another term rather than “Availability of spares” and that the parameter is calculated based the importance of OEM support, lack of calibration and detectability of failure.

A.7 Transmission Line

The transmission line evaluation develops Probability of Failure rates (POF) and is based on a weighted asset location for transmission line towers and poles, it also considers the assets and sub component condition.

Editorially the description of the processes used to develop the transmission line failure rate make it appear more complicated than it really is. This complication is caused by the naming conventions used i.e. ideal age, ideal effective age, worst ideal effective age etc. We note that details provided in Appendix B complements the explanation of the process being used. [Network Asset Health Framework Rev 0 30/09/2016]

Use of asset data ✓

The TransGrid document – Asset Health & Criticality – Calibration Rev 0 26/10/2016 - states that the defects / failure data being used for Weibull curves has been extracted from historical record (mainly Ellipse CMMS) and reviewed to ensure that non-failure replacements are excluded from the reliability data sets.

Reliability techniques for PoF calculations ✓

The majority of the reliability analyses has been developed within the propriety software “Availability Workbench”.

The resultant output produced a series of Weibull functions (both 2 and 3 parameter) that predict the PoF in a time series. All solutions have a high correlation factors. PoF could be improved in future by introducing Monte Carlo analysis which would provide a higher level of confidence to the probability determination.

Where Weibull functions were found to be inappropriate, TransGrid applied a non-linear regression model to represent the develop data set. These solutions also have high correlation factors.

5.2.3 Equipment criticality

Equipment criticality values are suitable ✓

Equipment criticality has been determined for a range of asset classes, including busbars, transmission lines and cables, power transformers, third party switch bays, substations, shunt reactors, static var compensators. These criticality spreadsheets monetarise criticality and are able to rank the criticality for each item of equipment within each asset class.

At a meeting with TransGrid on 27 October, 2016, TransGrid confirmed that the criticality methodology includes risks to TransGrid only. Loss of TransGrid supply on a radial feeder, or at a single transformer substation has a significant impact on the supply provided by TransGrid, though does not necessarily impact an end user if alternative supply is available through the distribution network.

Aurecon considers that the overall approach used by TransGrid to assess criticality is reasonable. The calculated criticalities are useful for ranking assets within and across asset classes as well as justifying capital expenditure where the combination of the criticality and the risk costs are high.

Methodologies for calculating electricity not supplied (ENS), value of customer reliability (VCR) and market benefits are suitable ✓

Methodologies for calculating electricity supply at risk and unserved energy are well documented and the methods used by TransGrid are broadly similar to that used by other utilities. Unserved energy is an input to risk cost and is described in more detail in Section 7 of this report.

5.2.4 Network risk assessment methodology

Clear documentation and advice on how ALARP / SFAIRP is treated ✓

AS 5577: 2013, Electricity Network Safety Management Systems (ENSMS) has reference. An operational philosophy at TransGrid has been adopted to achieve As Low as Reasonably Practicable (ALARP) requirements as per Agenda Item 2a (ALARP Briefing Note). The Asset Management Policy does not specifically make reference to ALARP or AS 5577 however a clear commitment to operating safely is provided "We will not compromise safety".

From the documentation reviewed it is unclear on how the Asset Management System integrates with ENSMS requirements as stated in AS 5577 read in conjunction with AS/ANZ 31000 given the ENSMS incorporates the principles contained in AS/ANZ 31000. At a practical level however it is clear that TransGrid undertakes a level of cost and benefit analysis to determine the level of investment required to reduce the potential level of risk exposure to an ALARP base. A range of disproportionality multipliers are provided, consistent with other utilities in Australia which is accepted by the reviewer to be correct.

Key hazard identification and control mapping is robust and fit for purpose ✓

The RAM, Section 5.1, provides the methodology for key hazard identification using Bow Tie analysis whereby causes are pre-empted via a skilled and experienced asset management team using Failure Modes Effectiveness Analysis (FMEA) techniques as detailed in the Failure Modes Effectiveness Analysis Framework document. The level of detail contained in Appendix A – Key Hazardous Events is of an appropriate level and is consistent with risk techniques as contained in AS/ANZ 31010, however the approach could be improved to align with TransGrid's Asset Management Strategy and Objectives document dated 3 November 2016 noting it is a supporting referenced document as per Section 5.1 of the RAM. Furthermore, the list of key hazardous events contained in the Asset Management Strategy and Objectives document, Appendix A6 is limited to conductor drop, structure fall over, uncontrolled discharge/contact with electricity, unauthorised entry and contaminant or pollutant release which are all already contained in Appendix A of the RAM so the value proposition is negligible.

Treatment of risk associated with non-investment (base case) ✓

The RAM makes no specific reference to treatment and/or treatment plans, however one of the tools mentioned in the RAM, Section 5.6, refers to the Investment Risk Tool (IRT) which has been reviewed in detail. The logic used in the risk management process is that sources of risk may lead to risk events which may have consequences. To prevent these consequences from occurring, the sources of the risk need to be addressed by implementing suitable treatment plans. As such, treatment plans may include the need to accept, mitigate, avoid or transfer the risk.

There are several methods in which risks can be described by using risk meta-language (as proposed by Hilson), an example of this is as follows:

Due to being at the end of its lifecycle and a lack of maintenance, a transformer might fail which will lead to power outages and dissatisfied customers.

Although the sources of the risk (in the example, lack of maintenance) are not specifically identified, the existing controls, as identified in the Asset Class Strategies, have been included in the calculation of the CoF.

5.2.5 Calibration of asset health / criticality

Total reliability, safety and environmental risk across major asset classes sensible at a network level ✓

With reference to the Management System Document – Network Asset Criticality Framework (NACF) TransGrid has gone to great lengths to provide credible referenced sources to validate potential CoF values, albeit erring towards worst case scenarios as supported by one of the key elements of the NACF, namely a likelihood based element to assess the likelihood of the worst case consequence occurring. Whilst the consequence magnitude should not be underestimated (or overestimated) a realistic estimate is deemed advisable. When the stakes are high, as is the case with several key hazardous events, a range of techniques as well as industry expertise is suggested to arrive at a cost of risk estimate that is credible and realistic. To this point, McKinsey (2011) paraphrased "on the one hand, risk models overemphasize historical data and fail to detect problems that should be recognized as advance warning of the looming crisis. On the other hand, managers' overall risk mind-set place excessive confidence in the models and underestimate the importance of individual judgment and personal responsibility".

For the purposes of this review, it is noteworthy that TransGrid has provided referenced sources to inform the consequence values. Aurecon recommends the future implementation of stochastic modelling techniques beyond the equations contained in the NACF, cross-referenced with sound judgment within TransGrid's defined Roles, Responsibilities and Accountabilities, Table 6.1 of the NACF.

5.2.6 Application to projects

Assess above values in their application to a range of proposed projects across asset classes. All values should appropriately reflect project scenarios. ✓

In the documentation review, it is evident that asset health has been used as an input to base case risk cost, though the asset health index is not shown directly. A base case pre-investment risk cost is included for projects that is derived from the asset health.

The variations in risk are evident with replacement projects within the one asset class. The circuit breaker replacement program is a good example of how monetarised value of risk is able to prioritise replacement. TransGrid has ranked circuit breaker replacement needs by risk cost, with the circuit breakers with highest risk cost being prioritised. The risk cost ranking also shows that a number of circuit breakers have only marginal benefit of replacement.

5.3 REPEX models

5.3.1 Australian Energy Regulator REPEX model

Consistency with AER principles ✓

The AER has a REPEX model for replacement capital expenditure[2] that was originally developed for the 2011-2015 regulatory control period for distribution utilities in Victoria.

The AER REPEX model is based on analysis of aggregate replacement needs across a population of assets given the age of assets. The AER REPEX model is oriented towards age based replacement for specific asset categories and is more suited to distribution networks that typically have large populations of very similar assets within each asset class.

By comparison, transmission networks generally have much smaller populations of assets with a greater variance between assets within the same asset class. For transmission assets, while the risk of failure is generally low, the consequence of failure is large due to the importance individual transmission assets have for the secure supply of electricity to large geographical areas. The AER REPEX model acknowledges that it is good practice to plan to replace assets prior to their end of technical life such that replacement occurs at a time that minimises overall risk and operating cost. For transmission, the remaining life of an asset is normally a function of the asset condition and therefore the useful life of a population of similar assets will vary.

TransGrid has enhanced the AER REPEX model to develop a REPEX model that determines asset risk cost using an assessment of failure modes, criticality, asset condition and a range of risk components. TransGrid does not use the calibration process proposed by the AER as it is not considered appropriate for transmission assets due to the statistically small populations of assets inherent in the asset classes for a TNSP's network.

It is noteworthy that other Australian TNSPs[3] apart from TransGrid have also modified the AER model to develop their own REPEX models that are more suited to the needs of transmission networks.

5.3.2 Top-down and bottom-up REPEX model

Comparison of top-down Repex model with bottom-up Repex model ✓

In assessing the appropriateness of the proposed REPEX expenditure for the next Regulatory Control Period, TransGrid has provided Aurecon with data on its proposed long-term replacement capital expenditure. This data includes a consideration of top-down vs bottom-up expenditure calculations. It is worth noting that:

- Top-down expenditure generally relies on predictive modelling and trend analysis
- Bottom up expenditure forecasts are determined from the overall number of replacement or refurbishment projects required in a period

Top-down expenditure forecasts are more suited to assessing long-term trends across asset classes, while the project specific bottom-up expenditure is more useful for estimating year by year requirements.

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[2] Electricity Network Service Providers Replacement Expenditure Model Handbook, AER, November 2013
[3] Replacement Expenditure (Repex) Modelling, an Overview, Powerlink Queensland, February 2016

The overall replacement expenditure forecasts from the two different methodologies is shown below. TransGrid has used the same unit prices for both the top-down and bottom-up forecasts to enable better comparison between the two methods.

Category	Top-Down REPEX Forecast	Bottom-Up REPEX Forecast
Substation Equipment	$299M	$245M
Substation Civil Infrastructure	$62M	$47M
Substation AC/DC Systems	$43M	$33M
Secondary Systems Equipment	$187M	$162M
Transmission Line Assets	$290M	$221M
Security Assets	$11M	$36M
Total	**$893M**	**$708M**

Table 1 Bottom up vs top down expenditure

Source: Long Term Renewal Capital Expenditure (REPEX) Discussion Rev 1

The majority of replacement expenditure shown in Table 1 across the asset categories shows reasonable correlation between the top-down and bottom-up forecast.

5.3.3 Long term REPEX trend

18/19 to 22/23 spend in the context of RP1, RP3 and RP4 ✓

TransGrid has provided data concerning its proposed REPEX expenditure to evaluate its projected long term REPEX trends. Although Aurecon has reviewed the data in the form provided by TransGrid, Aurecon has not independently reviewed the base from which the data has been derived. The year by year top-down replacement expenditure by asset class shown in Figure 3.

The year by year bottom up REPEX expenditure varies from year to year and reflects the nature and type of replacement projects proposed to be undertaken in that year. A bottom-up analysis is expected to have some yearly expenditure fluctuations as the overall expenditure is made up of discrete projects with specific replacement dates.

The top-down replacement expenditure is more useful to assess trends as expenditure appears more uniform and is not distorted by project specifics.

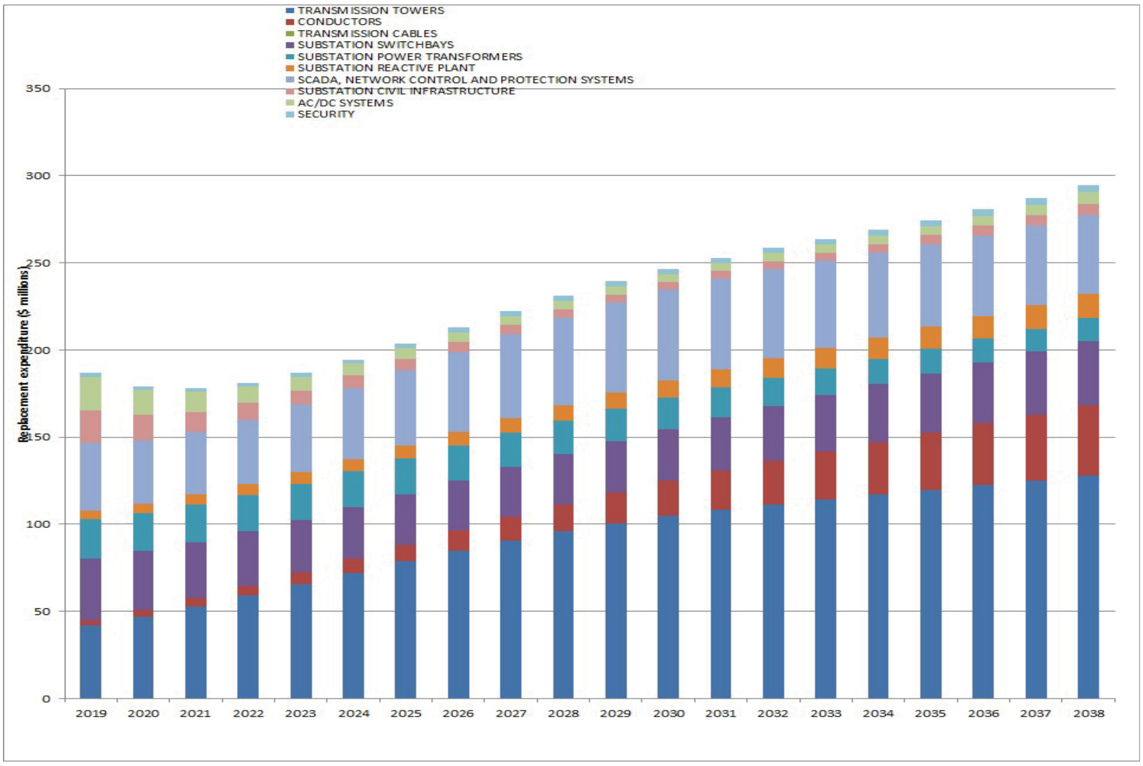


Figure 3: Top-down REPEX forecast

From Figure 3 it is evident that significant increases in replacement expenditure for transmission line towers and conductors is to be undertaken over the next twenty years. While the increase shown with the top-down model gradually increases over a number of years, the actual variation will be more 'lumpy' as TransGrid has adopted a strategy of undertaking periodic refurbishment to prudently manage the risks associated with its transmission lines.

Replacement expenditure on the majority of other asset classes is expected to be relatively constant over the next twenty years.

5.3.4 Deferral risk

Risks of deferral articulated ✓

TransGrid has not provided data concerning the effect that deferral of asset replacement would have on change in risk as the risk cost is only shown at the date that replacement is determined to be required. The 'run to fail' base case for each project provides some indication of risk that is present if replacement does not occur, though this risk is only shown for the date at which replacement is required. In practice, for long life assets the risk of failure only changes slowly year by year as assets deteriorate.

By way of example, while substation steelwork is a relatively long life asset, gradual deterioration of steelwork and foundations occurs progressively due to environmental factors. TransGrid has adopted a 10% loss of steel as the trigger point at which refurbishment is required and has calculated a base case risk cost at this point. In practice, the risk of failure would be expected to increase gradually year by year, though assessing the yearly change in risk would be difficult to quantify.

The application of risk methodology has enabled TransGrid to identify sources of high risk on its network and enabled expenditure to be focussed on areas where risk is greatest. This has for example enabled TransGrid to prioritise circuit breaker replacements.

Prudent management of risk indicates that replacement/refurbishment should be undertaken at a time when risk of failure is still relatively low due to the significance that failure has on security of supply on a transmission network.

Network Risk given 18/19 to 22/23 spend ✓

TransGrid is forecasting some increase in average asset age over the next regulatory period even though replacement expenditure is forecast to increase from present levels. While some overall deterioration in asset health is expected, the asset criticality and asset health index modelling undertaken by TransGrid has enabled replacement expenditure to be targeted to assets where the greatest improvement in benefit is expected to be achieved.

One example of targeted expenditure to minimise risk is the calculated risk benefit for circuit breaker replacement. This project separately calculates pre-investment risk for each circuit breaker and the replacement project has prioritised for replacement the circuit breakers with the highest base case pre-investment risk.

Change in risk for lower spends ✓

For replacement projects, TransGrid examines a range of options, and the evaluation of options considers the post completion net present value and the corresponding risk. Some replacement options have lower capital cost, though are not preferred by TransGrid since the post completion risk cost of that option is higher.

For the Lower Tumut secondary systems replacement project, the capital cost to replace all the secondary systems in situ was estimated at $8.0M and post project risk cost calculated at $0.06M. The partial replacement capital cost was $4.4M and post project risk cost $0.8M. The overall NPV of the in-situ replacement was $2.29M while the NPV for the partial replacement was $0.3M. TransGrid concluded that the higher capital cost in-situ replacement represented better value as the NPV was higher and the post-project risk cost lower.

A partial replacement of secondary systems at Lower Tumut switching station could be implemented for lower capital cost than full replacement, though the reduction in risk is less with partial replacement and no technology benefits would accrue without full replacement.

5.3.5 Effects of 18/19 to 22/23 REPEX on long term sustainability

Asset failure trends ✓

TransGrid's Asset Management Strategy provides data on asset failure trends. Review of this data indicates:

- Loss of supply events have been relatively stable over the last 12 years, though there are fluctuations from year to year. While key hazardous events such as conductor drop and structure failures are relatively consistent, unauthorised entry events have shown some decline in recent years.

- The STPIS (Service Target Performance Incentive Scheme) performance measures indicate relatively consistent results over the last ten years. TransGrid data is available for incorrect operational isolation of equipment, protection system failures, outage duration and line, transformer and reactive plant outage rates.
- There has been some reduction in incorrect operational isolations of primary and secondary equipment. While other measures show variations year by year, they do not have discernible trends.

TransGrid is forecasting some increase in average asset age over the next regulatory period even though replacement expenditure is forecast to increase from present levels. The impact of the proposed replacement expenditure on asset age is shown in Figure 4 below.

Age trends ✓

The REPEX expenditure within any one regulatory control period needs to be assessed in the context of long term trends. TransGrid has provided an analysis of the impact of its proposed top down expenditure forecast on age trends for its different asset classes. The expenditure proposed by the top-down modelling shows an overall increase in average age across all asset categories and hence even with the proposed replacement expenditure, TransGrid is forecasting some deterioration in overall asset health. The long-term trends in asset age is shown in Figure 4 below.

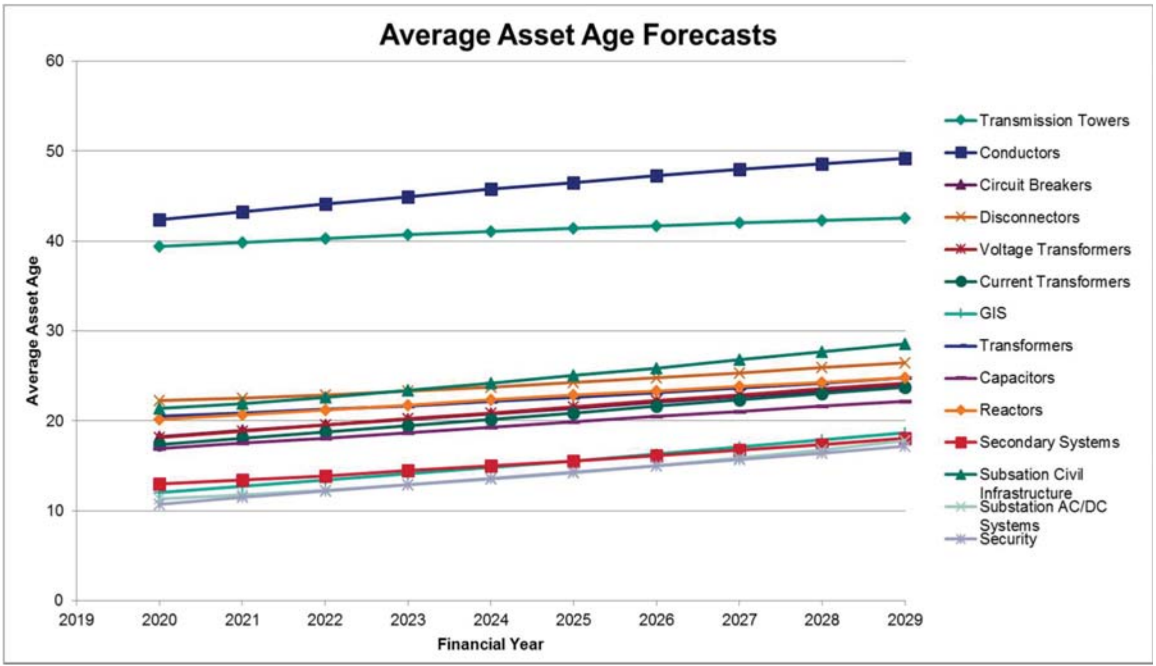


Figure 4: Trends in average asset age

In practice, TransGrid uses asset health as the underlying driver for asset renewal/replacement, though the analysis provided has used asset age as a proxy for asset health since asset age is easier to analyse to assess long term trends.

The asset classes with the longest asset life as shown in Figure 4 are transmission line towers and conductors. Notwithstanding the increased refurbishment expenditure for transmission line assets, the asset lives are projected to increase over the next twenty years before stabilising.

Residual life ✓

The replacement expenditure forecast provided by TransGrid indicates that average asset age is expected to increase slightly for all asset classes over the next twenty years. While average asset age is forecast to increase, TransGrid plans to manage its assets to ensure that equipment continues to operate safely, reliably and in an environmentally sustainable manner.

Asset health indices for each asset class, enable TransGrid to determine residual life of its assets. The asset health index for an asset class is derived from the key parameters that determine asset condition and have been calculated for power transformers, oil filled reactors, circuit breakers, instrument transformers - oil CT, MVT and CVT, disconnector, surge arrester, transmission line and protection relays.

TransGrid is able to use the health index to compare natural age of items of equipment with the calculated age for the specific type of asset to assess expected residual life. Ageing factors that may cause ‘age shifting’ for an asset can be used to predict future asset health. Nominal asset life is a key input to asset health as the difference between the actual age and calculated age can be used to predict residual asset life.

The asset health index modelling is being development even further with health indices being developed for transmission lines on a span by span basis, as well as for capacitors and cables.

5.4 Comparison with Powerlink Queensland approach

The AER is presently reviewing the Regulatory Submission by Powerlink Queensland[4] including its proposed replacement expenditure, so as to determine Powerlink’s revenue allowance for the 18/19 to 22/23 period. Powerlink has also adopted a risk based approach to capital works and so some of the Powerlink documentation was reviewed to compare its approach with TransGrid’s approach.

The AER engaged EMCa Consultants to review Powerlink’s revenue submission. EMCa noted that Powerlink follows a four-step approach to developing and approving projects:

A. Needs identification – which includes consideration of asset health, condition and risk assessment (for non-load driven projects); Condition Assessment Reports (CAR) and Risk Spreadsheets (RS) are identified artefacts;

B. Develop options - which includes development of an Investment Options Paper (IOP) which captures the detailed analysis of the investment need and feasible investment options;

C. Confirm option and define project – which includes preparation of a Project Scope Report and a Project Proposal Report (PPR). The latter ‘is to provide detailed cost and qualitative delivery information for the selected option. It also conducts a deliverability analysis against the general constraints of the option, including outlining resource requirements’; and

D. Approve Project – The key approval document is the Business Case.

This four-step approach is broadly similar to that adopted by TransGrid.

[4] Powerlink Revenue Proposal to AER 18/19 to 22/23. Review of Forecast Non-load driven capital expenditure in Powerlink’s Revenue Proposal by EMCa

The EMCa review noted that the risk assessment process used by Powerlink can produce a very wide range of outcomes, with risk costs ranging from a few dollars to billions of dollars and noted that this can result in an assessment that does not provide focus and is difficult to communicate.

EMCa also concluded that the Powerlink approach for risk assessment was adequate for choosing between identified options, though had reservations about Powerlink's aggregation of risks.

The TransGrid approach to risk provides relatively consistent results where supply reliability is the dominant component of risk as the value of customer reliability provides a means of costing reliability. However, where the risk cost is dominated by safety and environmental risk, the results vary much more widely. Aurecon's review of TransGrid's risk cost approach draws similar conclusions to the EMCa positive observations.

In Powerlink's submission to the AER, Powerlink included a review by AMCL[5] of its approach to risk.

The Powerlink approach by asset class was to consider a range of failure modes for each asset class:

- Transmission lines
  - Tower collapse
  - Conductor drop
  - Earthwire drop
- Substation bays
  - CT failure
  - CB failure
  - Bay structure collapse
  - Power transformer failure
- Secondary Systems
  - Failure to perform and obsolescence

The AMCL review noted that

- The risk approach adopted by Powerlink was consistent with leading industry practice for electricity transmission networks
- Their risk assessment methodology with risk cost broadly reflects the real cost and likelihood of asset failures. Adopting a risk assessment process brings with it complications, particularly with data quality and increases the reliance of data and the management of data.
- Further development of the end to end process and how it is applied required further development.

The AMCL observations are considered applicable to TransGrid's approach. TransGrid has made considerable progress with the application of risk management, though ongoing improvements are still expected as the asset management skills and tools evolve. TransGrid appears to have built on the earlier Powerlink experience where possible to further refine its approach.

[5] 18/19 to 22/23 Powerlink Queensland Revenue Proposal Appendix 5.08

6 REPEX expenditure

6.1 Project development process

Aurecon's understanding of the overall process used for the development of capital works projects was formed through review of relevant framework documents and the application of the framework to project specific documents. The project documentation reviewed was chosen by Aurecon. A similar project/program evaluation process has been used for both REPEX and AUGEX. The overall process appears to be soundly based and includes:

- A Needs Statement that identifies the rationale and requirements for a project
- An Options Screening Assessment (since July 2016) to outline potential options to address the need and formalise requests for options feasibility studies
- Options Feasibility Study reports to describe overall scope and costings for various options examined
- An Options Evaluation Report that reviews the feasible options and determines a preferred solution
- Following the evaluation report, project commencement decision gate 1 is reached. Approval at this stage enables preliminary design work, community consultation, property acquisition and RIT-T as appropriate
- The next step is a Request for Project Scoping, followed by a project scoping study which leads to a project approval decision gate. Approval at this decision gate enables the issue of a Project Approval Document.
- Options Screening Reports, where required, describe all of the options considered and also the specific options to be examined in detail

While sound, the present process could be further refined by having a single options study report that describes and costs all of the options examined, including the options that are not evaluated in detail. At present, each of the feasibility study option reports describe only the option being examined in that report and consequently contain considerable repetition across each option report.

Aurecon does not believe that the abovementioned improvement opportunity materially affects the CAPEX forecast.

6.2 Review of specific REPEX projects

6.2.1 General

Project Documentation for a number of TransGrid asset replacement or asset refurbishment projects was provided to Aurecon for review. This documentation enabled a more detailed examination of TransGrid's approach to the development and evaluation of these projects. These projects are representative of the REPEX projects proposed to be undertaken by TransGrid in the next regulatory period. The projects reviewed in detail were:

- Lower Tumut Secondary systems replacement (Project 1192)
- SCADA EMS NM4 replacement (Project 1254)
- 31/32 line Refurbishment (Project 1275)
- Circuit breaker replacement (Project 1337)
- Substation steelwork replacement (Project 1358)
- 50 volt Rack Power Supply Replacement (Project 1361)
- Tower Grillage Foundation Refurbishment (Project 1523)
- Forbes No.1 and No.2 transformer replacement (Project DCN276)

These projects are representative of the types of replacement projects planned by TransGrid for the next regulatory control period. The projects selected represent only a small proportion of the approximately 200 replacement projects planned.

The projects reviewed in detail are described in the following sections.

6.2.2 Project 1192 - Lower Tumut Secondary Systems Renewal

The Needs Statement identifies ageing secondary systems at a key switching station in the Snowy Mountains area of southern NSW.

The options examined for Lower Tumut secondary systems replacement are:

A. Replace secondary systems in new Secondary Systems Buildings for an estimated cost of $15.0M
B. Replace secondary systems within the existing building for an estimated cost of $9.1M, though the evaluation report uses a different base year to cost this option at $8.0M. Replacing all of the secondary equipment at the one time is noted to provide some technology benefits.
C. Replace individual systems (where required) on a like for like basis and reuse existing cabling where possible for an estimated cost of $4.4M with a further $0.8M required to replace the remaining secondary systems over the following 15year lifecycle to 2038 of the replacement secondary systems. This option does not assume any technology benefits.
D. Replace secondary systems in new SSBs using IEC 61850 type technology for an estimated cost of $13.1M

There are some discrepancies between costings in the individual feasibility studies and the evaluation report due to the different base years used across the various documents provided to Aurecon.

The overall scope of options B and C is fairly similar in respect to the number of protection panels, meters, VF inter-trips and RTU equipment being replaced as option C involves replacing 17 protection panels vs 19 protection panels being replaced with option B. The principal difference between the two options occurs through the technology benefits possible as option B replaces all of the control and protection at the one time. Option B also modernises the automation philosophy to current design standards and provides additional operational benefits as well as including some additional cabling and switchyard AC/DC supply works.

The evaluation report indicates that the overall capital cost for option C to replace all of the secondary systems over the 15 year life of the new secondary systems is significantly cheaper than the Option B cost, which involves replacement of all of the secondary systems during 18/19 to 22/23.

The evaluation report recommends option B as this option has a higher NPV of $2.29M by comparison with option C, which has a NPV of $0.30M. Both option A and option D have negative NPV and are not recommended.

Aurecon agrees with the scope of replacing all of the secondary systems in the one project as this enables technology benefits and also the removal of the non-TransGrid standard 250 volt DC system.

Aurecon notes that TransGrid has refined its approach to secondary systems replacements from that adopted in recent years to implement more cost effective renewal strategies.

6.2.3 Project 1254 - SCADA EMS NM4 Replacement

The SCADA EMS system is a vital tool that enables TransGrid to efficiently operate and maintain its high voltage network, provide real-time visibility of the network status and indicate when elements are defective. The SCADA platform also acts as a concentrator to enable generator and network data to be passed on to AEMO for use in operating the National Electricity Market.

TransGrid's existing ABB NM4 SCADA platform was commissioned in 2015. The Needs Statement notes that previous SCADA systems had a lifecycle of approximately 7 years with a five-year period required to implement a new system. The Needs Statement also notes that the existing system uses Windows XP and has point to point RS-232 communications protocols rather than IEC61850.

The feasibility study estimates a cost of $15M for a replacement system.

The evaluation report indicates that replacement of the SCADA system reduces the risk cost from a base case $1.78M per annum to $0.095M per annum. The evaluation report indicates that the replacement of the SCADA system has a negative NPV for all discount rates.

While the NPV is negative, the evaluation report recommends proceeding with this project so as to enable critical ongoing compliance with the National Electricity Rules' requirements for remote monitoring and control capabilities.

Although the previous SCADA replacement project was implemented over a five-year time frame, such a period appears to be an excessively long implementation period. SCADA technology is rapidly changing technology and a long implementation period risks installing equipment that is reaching obsolescence before installation is complete.

While Aurecon agrees that SCADA replacement is required during the 18/19 to 22/23 regulatory period, further examination of the project is warranted to determine means by which the five-year implementation period could be reduced.

6.2.4 Project 1275 - 31/32 Line Refurbishment

Transmission line 31/32 is a 330 kV double circuit line 171 kilometres in length that connects Bayswater power station with Regentville substation in Western Sydney. The line was completed in 1969 and comprises 456 steel lattice tower structures. The Needs Statement indicates that condition assessments of this line were performed in 2015 and identified corrosion of steel at the footings, corrosion of earth strap, some issues with foundations, rusting of tower steel members, corroded fasteners, corrosion of insulator pins and deterioration of vibration dampers.

The corrosion of tower steel members at ground line, corrosion of steel members and corrosion of earth straps has impacted only a relatively small proportion of the transmission line structures. On the other hand, the insulator pin corrosion and vibration damper deterioration is much more widespread. Deterioration of the insulators and vibration damper have different causes to the steelwork issues and refurbishment works for the two issues are unrelated. This arises as the insulator replacement will need to be undertaken from the tower or from elevated work platforms, while the ground line works would be done by different crews at ground level.

The widespread nature of the corrosion of the insulator pins leads to an increased risk of separation of the insulator string following a high voltage fault and consequently increases the risk of a conductor dropping to the ground.

Two options to refurbish the line were considered; run till fail or refurbish, with the refurbishment cost estimated at $4.6M. The Options Study identified the scope of works required to remediate the transmission line.

The proposed refurbishment reduces the calculated risk cost from $7.33M to $5.96M per annum with the majority of the risk cost improvement due to the improvement in line reliability.

Although insulator pin corrosion is the only deterioration mechanism identified in the Needs Statement, it is not the only mechanism whereby insulators deteriorate as the porcelain insulation itself also deteriorates with time, particularly when operating at high electrical stress. The refurbishment project proposes to replace the majority of the insulators on the line.

Independent assessment by Aurecon indicates that refurbishment of the transmission line is warranted.

Aurecon agrees with the evaluation report's conclusion that refurbishment is required.

6.2.5 Project 1337 - Circuit Breaker Replacement

High voltage circuit breakers are key equipment for the operation and protection of TransGrid's high voltage network. The Needs Statement indicates that around 280 circuit breakers, being approximately 15% of the total circuit breaker population are approaching end of life. The Needs Statement indicates a risk cost of $31.7M.

The Needs Statement identifies specific circuit breakers and indicates that replacement requirement is primarily based on age and/or condition of equipment.

The aged circuit breakers were placed in three groups to enable three replacement options to be considered.

- Where the associated current transformers needed to be replaced as well and the CB and CT can be replaced together with a dead tank circuit breaker. The cost to replace this group was estimated at $26.05M.
- Where the associated current transformers needed to be replaced as well, with replacement on a like for like basis with a separate circuit breaker and CTs. The cost to replace this group was estimated at $29.23M.
- Locations where only the circuit breaker required replacement. The cost to replace this group was estimated at $48.28M.

The advantages of options A and B are that some cost efficiencies can be gained by combining replacement works for both sets of equipment. The option to replace the individual CB and CT with a dead tank circuit breaker provides additional savings as dead tank circuit breakers are cheaper than the combined cost of separate CBs and CTs.

The Options Evaluation Report concludes that a variety of replacement strategies is warranted by combining CT replacement with the circuit breaker replacement where possible.

Although the Needs Statement lists 280 circuit breakers to be replaced, the evaluation report proposes to replace only 246 circuit breakers, though some replacements were noted to have been moved into the 2013-2018 period due to asset condition.

A NPV evaluation for each circuit breaker is included in the evaluation report, with reliability being the main driver for the variance in NPV for each circuit breaker requiring replacement. The report indicates that replacement is likely to prioritise those circuit breakers with a high replacement NPV. A significant number of circuit breakers have a relatively low NPV post-replacement so the benefit arising from their replacement is relatively small, nevertheless, still a positive NPV. While more than 100 circuit breakers each have a replacement NPV over $0.5M, approximately 50 circuit breakers each have a replacement NPV less than $30,000.

6.2.6 Project 1358 - Various Locations Steelwork Replacement

Many TransGrid substations have large steel gantry structures that terminate incoming transmission line connections, or terminate internal strung bus connections. The Needs Statement identifies corrosion of substation gantry steelwork including holding down bolts, base plates and gantry members at seven substation sites. The assessment is based on a 10% loss of steelwork as being the justification point where refurbishment of steelwork is required which is a reasonable and prudent conclusion. The total risk cost across the seven substation sites was calculated at $934.1M. It is noted that the evaluation report has a base case risk cost of $133.1M per annum.

A number of refurbishment options were examined including:

A. Do nothing and run to fail
B. Remediate holding down bolts and steelwork in situ at an estimated cost of $33.9M
C. Remediate holding down bolts and steelwork in situ and concrete encase footing at an estimated cost of $52.5M
D. Steelwork repair and replacement of holding down bolts for an estimated cost of $55.8M
E. The complete replacement of gantries and foundations was not examined in detail due to the high cost of this option

Although options C and D have a significantly greater capital cost than option B, all three options have very similar NPV and the same residual risk cost. If the benefit obtained from each option is the same, the only differentiator becomes the capital cost.

The evaluation report concluded that the lowest cost option was preferred which is a sound conclusion.

Independent assessment by Aurecon of steelwork condition indicates that remediation works on substation gantry structures is warranted.

6.2.7 Project 1361 – 50 Volt Rack Power Supply Condition

The 50 volt Rack Power Supply systems are used across the TransGrid communications network to provide a continuous supply of power to communications equipment. The availability of these systems is crucial to enable communications systems to operate to enable power system network data to be transferred at all times and particularly when system faults and contingencies occur.

The Needs Statement identifies 192 x 50 volt rack power supply systems (RPS) with an install date between 2002 and 2016, though the Needs Statement also indicates that 213 systems are installed. The Needs Statement does not provide a more detailed breakdown of equipment age.

The options study costed the replacement of 130 of the RPS systems over the five-year regulatory period at a cost of $8.07M. The project cost is based on progressive replacement over the five-year regulatory period with replacement generally a like for like replacement.

The evaluation report noted that the economic life of an RPS system is 10 years, though some refurbished systems are in service that are older than 10 years. Failure of the 50 volt RPS systems is usually progressive, so the capacity of an aged system becomes progressively impaired by the partial failure of some cells in the battery system. The condition of each RPS system is assessed during annual site inspections and replacement is undertaken prior to complete failure.

The RPS systems are generally duplicated at each site, and so partial degradation of one system is not likely to have an immediate critical impact on the communications system.

The cost of all of the systems requiring replacement over the five-year regulatory period is included in this project and a staged replacement of RPS systems is planned.

Aurecon agrees with TransGrid's assessment that the 50 volt RPS systems identified for replacement are to be replaced during the regulatory period and understands that these are to be replaced progressively over the regulatory period.

6.2.8 Project 1523 - Tower Grillage Foundations

TransGrid's older transmission line towers were constructed with grillage foundations where the footings comprise galvanised steel members formed into a grill and buried. This design practice was discontinued in the early 1960's, so this type of foundation is only found on TransGrid towers more than 50 years old. Some years ago, sacrificial anodes were installed on many of these towers in order to extend the life of the in-ground steel, though the anodes are believed to have only limited effectiveness.

Field assessments indicate that some corrosion of steel grillage foundations is occurring and the foundations require remediation to remain serviceable. As corrosion varies with soil type, towers were categorised in two groups, with 1,992 towers assessed as being located in normal soils and 510 towers assessed as being installed in soils expected to be aggressive.

Two remediation options were examined, one involving replacement of sacrificial anodes on 1,955 towers in regular soils and concrete encasing foundations on a further 547 towers expected to be located in aggressive soil. This option was estimated to cost $92.6M using 15/16 costings.

A second option examines replacement of sacrificial anodes on 1,955 tower and installing new towers on 547 towers. This option was estimated to cost $165.9M using 15/16 costings.

The options evaluation report uses updated information as it identifies 2,048 towers located in soils classified as non-aggressive and 313 towers classified as installed in aggressive soils. The estimated cost for the option to replace anodes and concrete encase foundations has been revised to $62.2M in 16/17 dollars and the option to replace anodes and replace towers is estimated at $100.6M in 16/17 dollars.

Although not mentioned in the evaluation, the option to replace towers in aggressive soils is understood to also include some consideration as to whether the tower is a tension or a suspension tower. It is generally more difficult to replace a tension tower with a new tower adjacent to the old tower due to the impact a relocated tension tower has on deviation angles. Replacing suspension towers does not generally have the same constraint.

Independent evaluation by Aurecon of the condition of transmission line grillage foundations indicates that some corrosion of grillage foundations has occurred and that significant work is required to refurbish tower foundations.

Aurecon agrees with TransGrid's assessment in the options evaluation report that the lowest capital cost option, being to replace anodes and concrete encase foundations be undertaken.

6.2.9 Project DCN276 - Forbes No.1 and No.2 Transformer Replacement

The Needs Statement (NS-DCN276) indicates that the substation presently has 2 x 132/66 kV 60 MVA transformers. The peak load for the substation is 35 MVA, so replacement need is not driven by substation loading. The Needs Statement identifies asset condition issues with both transformers and indicates that oil quality is managed by operating the transformers on fixed tap. Considerable carbon particles have contaminated the windings. Operation of the transformer on fixed tap increases the need for Essential Energy transformer tap change operations to manage voltages.

The Needs Statement shows risk costs of $200k for one transformer and $134k for the second transformer.

Two options were examined, one to replace both transformers with new transformers at a (non-escalated) capital cost of $8.9M and a second option to purchase one new transformer and relocate a surplus Wagga transformer at a capital cost of $7.74M.

A third option to refurbish the existing transformers was discarded as the cost was quoted at 90% of the cost of new transformers.

The Options Evaluation Report indicates the capital cost of the two options is $8.5M for two new transformers and $7.30M for one new and one relocated transformer.

The Evaluation Report indicates that the NPV of both options is approximately the same, but the evaluation report prefers to install two new transformers for other reasons that are not considered in the feasibility study that were not costed.

Overall, the cost difference between the two options is relatively small, and Aurecon agrees that there are some risks with relocating a transformer.

6.3 Observations from review of REPEX projects

TransGrid has made significant improvements in the way that risk is used in project evaluation.

TransGrid applies risk cost methodology to its assessment of projects and has put a monetised cost of risk to the evaluation of alternatives. The evaluation of risk is also included in the assessment of net present value for each project option and where an option has a negative net present value, the option is discarded or justified on a non-financial basis.

TransGrid's assessment of net present value for a project includes not only the capital cost of an option, but the change in risk cost, with ranking determined by the option that gives greatest positive net present value. This compares with the more conventional, and less comprehensive approach to net present value evaluation that commonly only includes capital and operating costs.

The difference in risk cost between base case and asset replacement/refurbishment is clearly evident and used in the project justification.

There are some limitations with this approach as some aspects of risk are not readily able to be monetarised, or are difficult to monetarise accurately. A consequence of these limitations could be that those projects evaluated with a negative NPV may still be planned to be included in the replacement expenditure for other reasons. While these reasons are sound, this indicates that the risk cost has not covered all aspects of a project. The Forbes transformer replacement evaluation determined that two the options examined had very similar NPV, though the option with higher capital cost was preferred for un-costed reasons. Some risks are also acknowledged to be difficult to monetarise. Aurecon's assessment of these projects is that TransGrid has adequately justified the non-financial reasons for proceeding with these projects.

The application of risk cost has been used to determine priorities for replacement of equipment of similar asset class, and so a priority ranking of circuit breaker replacements is readily apparent by the different risk costs associated with each circuit breaker. Of the 240 circuit breakers to be replaced, over 100 circuit breakers have a replacement NPV greater than $0.5M, while more than 50 circuit breakers have a replacement NPV less than $30,000. It is apparent that there are significant variations in benefit of replacing some circuit breakers with some having only marginal overall benefit.

With ageing equipment, the change in risk cost is relevant to determining the optimum replacement date as risk cost will increase with time as equipment ages and equipment failure rates increase. For some asset classes with long service lives such as transmission lines or power transformers, risk cost is expected to change relatively slowly, while digital/microprocessor equipment such as protection relays have much shorter lives.

Over time it is expected that TransGrid will incorporate the effect of aging assets into the risk cost calculation so that the most economic replacement/refurbishment date can be determined. It is also acknowledged that sufficient data may not be available at this time to accurately quantify changes in risk with increasing age of equipment.

7 AUGEX expenditure

7.1 Inputs and assumptions

7.1.1 Demand forecasts

Demand forecast for 2016-2026 ✓

TransGrid uses AEMO state-wide energy and demand forecasts published in its 2016 Electricity Forecasting Report (NEFR). The NEFR develops forecasts for three economic scenarios, described as strong, neutral and weak. While AEMO does not provide a likelihood for these three scenarios, the neutral scenario is the most commonly used load forecast scenario.

The AEMO neutral scenario forecasts virtually no growth in overall energy consumption over the next ten years. For demand, AEMO also forecasts minimal growth for summer or winter demand over the next decade. Maximum network demand over the next ten years is forecast to be less than the historical maximum demand recorded in NSW in 2010/11.

Apart from the AEMO state-wide energy and demand forecasts, AEMO and the NSW distributors also prepare demand forecasts for each bulk supply point. TransGrid reviews the NSW distributor's bulk supply point forecasts and uses the distributor forecasts to publish bulk supply point forecasts in the TransGrid annual planning report.

While the state-wide demand forecast shows minimal growth overall, demand growth is not uniform across NSW. Some bulk supply points in outer Sydney have annual growth rates approaching 4%, while others elsewhere in NSW have minimal or even negative annual growth rates.

7.1.2 Network capacity

Capacity of the existing network ✓

TransGrid has developed twelve area plans to describe the requirements for different geographical portions of its network.

Comparatively few augmentations are required to the NSW network over the next regulatory period as demand is forecast to have only minimal growth over the period.

The performance of the NSW main grid is dependent on power transfers through interconnections, changes in overall load as well as the locations where electricity is generated. While network load is relatively steady, some coal-fired generation in the next ten years is likely to be retired and most likely replaced by new renewable generation projects. However, as the new renewable generation is unlikely to connect to the same connection points at which existing generation is being retired, the transmission network can expect to see some change in its utilisation. For the NSW main grid, the main grid plan modelled a number of changed generation scenarios, such as increased renewables from a renewables cluster in southern NSW, from a renewables cluster in northern NSW and from a renewables cluster in western NSW.

For each of these renewable clusters, the most onerous constraints on TransGrid's network were identified in the report along with QV and PV margins at a selection of points on the network. The analysis indicated that some additional reactive plant may be required at some stage at strategic locations within the NSW transmission network to facilitate the connection of new renewable generation.

Capacity augmentations and additional reactive plant to TransGrid's main grid is largely dependent on the timing and location of new renewable generation projects.

The area plans are further described below.

Generation outlook (including retirements) ✓

Electricity generation in NSW and elsewhere in the Australian national electricity market is in transition with the retirement of coal-fired generation and the development of new renewable generation projects. For this regulatory submission, TransGrid engaged Ernst and Young to produce a report describing electricity generation development scenarios for the period 18/19 to 22/23.

This report examined:

- Demand growth
- Impact of renewables, penetration and emission response
- Interconnector augmentation
- Small scale distributed energy resource uptake including storage

Ernst and Young used both a top down approach and a bottom up approach to assess generation requirements. The top down approach examined external drivers and generation outlooks, while the bottom up approach examined possible new generation projects and possible retirements of existing generation. This report also relied on AEMO's forecasts.

The report noted that NSW currently has a low penetration of renewables and so there was considerable scope for new renewable projects.

Ernst and Young considered there was a relatively small likelihood of interconnector upgrades and assigned a 15% likelihood of a NSW-Victoria upgrade and 10% likelihood of a QNI upgrade. In both cases, the interconnector upgrade envisaged was relatively modest. However, since the Ernst and Young report was prepared, closure of the Hazelwood power station in Victoria by end March 2017 has been announced and further upgrades to the South Australian interconnection are being examined. Both of these developments may impact on the need for TransGrid to undertake upgrades to its transmission network in Southern NSW.

A high probability that some coal fired plant would be retired in the next ten years was noted by Ernst and Young, though the extent of generation retired is expected to depend on demand growth and increased penetration of renewables to meet RET requirements.

The Ernst and Young report identified a total of 77 potential new generation projects in NSW with a combined capacity of 13.7GW. Almost half of the possible new generation capacity was wind generation. These projects were also ranked according to likelihood of proceeding, with a large number of projects being considered low probability.

New renewable generation capacity is likely to be connected in NSW due to the current RET requirements and the forecast retirement of Liddell Power Station. Retirement of generation in other states may also impact the development of new renewable generation projects in NSW. Aurecon agrees with Ernst and Young's conclusion given the most recent AEMO demand forecasts.

7.1.3 Reliability criteria and unserved energy

Likely revision of the (n-x) reliability standard to an economic reliability standard by IPART ✓
Reliability criteria ✓

The present NSW Transmission Reliability Standard was published in 2010 and specifies the network infrastructure that TransGrid must provide to achieve the required level of redundancy based on specified demand forecasts. The present Reliability Standard is being reviewed by IPART (the NSW Independent Pricing and Regulatory Tribunal) with the final version of the new standard expected to be available by end of 2016.

The new standard is intended to apply for the regulatory control period from 1 July 2018 and is expected to stipulate:

- The required level of redundancy that must be in place to support continued supply of electricity in the event that part of the transmission network fails
- An ability for TransGrid to plan to have some expected unserved energy at each bulk supply point with an allowance for unserved energy provided at each supply point.
- Provision to allow TransGrid to meet the requirements for redundancy and expected unserved energy using any combination of transmission network assets, non-network solutions or agreements with distribution network service providers to use part of the attached distribution network.

The new standard is not intended to prescribe how TransGrid must invest. Instead TransGrid is required to plan to meet the standard by determining the most cost effective solutions through the evaluation of network and non-network options.

For the Inner Sydney area, the IPART draft recommendation is that the amount of unserved energy allowance should be 0.6 minutes per year, at average demand to apply across the five Inner Sydney bulk supply points (Beaconsfield, Haymarket, Rookwood Rd, Sydney North and Sydney South). As the total unserved energy allowance is small, the proposed standard is not likely to result in a significant change to the level of reliability experienced by customers.

For a number of other supply points where TransGrid has radial connections without redundancy, a range of unserved energy allowances is proposed. The differences in the expected unserved energy allowance between the different bulk supply points is intended to reflect the value different customers place on reliability, the cost of providing it and customers' willingness to pay for it.

The pending issue of the new Transmission Reliability Standard represents a potential risk to TransGrid as its submission to the AER is due by the end of January 2017. There would not be much time available for TransGrid to adapt its planning approach in the light of the new planning standards, particularly if there are any changes from the draft standards. Nevertheless, TransGrid has reviewed its proposed projects for compliance with the new standard and so changes to TransGrid's planned capital expenditure in light of the new planning standard is expected to be relatively modest.

7.1.4 Value of customer reliability

Reliability values are suitable (choice of Value of Consumer Reliability, interruption duration, Likelihood of Consequence due to redundancy) ✓

In developing the new transmission reliability standard, IPART gave consideration to the value customers place on reliability with Value of Customer Reliability (VCR) being expressed as a dollar value per kWh of energy not delivered.

The terms of reference under which IPART has undertaken the review of transmission reliability standard require IPART to have regard to the most recent values of VCR published by AEMO. The most recent values published by AEMO[6] recommended the following values.

AEMO VCR Results, $2014-15 ($/kwh)

Residential	$26.53
Commercial	$44.72
Industrial	$44.06
Agricultural	$47.67
Direct Connect	$6.05
Aggregate, NSW including direct connects	$34.15

TransGrid also engaged HoustonKemp to estimate VCRs for the inner Sydney and Sydney CBD areas. The HoustonKemp report considers that the VCR for Inner Sydney is much higher than the value of VCR developed by AEMO. The HoustonKemp report recommended VCR is:

Inner Metropolitan	$90
CBD	$150-$192 ($170)

IPART has acknowledged that there is some uncertainty as to the most appropriate value to use for Value of Customer Reliability. In undertaking its review of the NSW Transmission Reliability Standards, IPART noted that the AEMO estimates are calculated from a very small sample size, are overly dependent on the methodology used, do not include important customers such as the Australian Stock Exchange, NSW Parliament, and large financial institutions and do not adequately capture low probability but high impact supply interruptions.

While IPART adopted the AEMO values for the majority of its analysis, IPART considers that special circumstances may apply in relation to the nature of customers in inner Sydney such that VCR values for the rest of NSW are not as relevant.

IPART noted that high VCR customers would be likely to invest in their own back-up supply arrangements in order to ensure that their need for high reliability was met. If this were the case, high reliability customers may actually have a very low VCR (lower post-investment VCR) than those customers without back up arrangements in place (higher pre-investment VCR).

The optimisation model adopted by IPART has concluded that a VCR of $90/kWh was appropriate for Inner Sydney, consistent with the HoustonKemp analysis rather than the AEMO values.

[6] AEMO, Value of Customer Reliability Review – Final Report, September 2014

Although the IPART review of Transmission reliability standard is not yet complete, TransGrid has commenced using the IPART recommended value for VCR in its more recent option evaluations. While it is noted that some of TransGrid's earlier reports used different figures for VCR, this is understandable since the IPART review has only recently published recommended VCR figures.

IPART is proposing to undertake a new assessment of VCR following the completion of the transmission reliability standard review.

TransGrid's Options Evaluation Report for project DCN43 Supply to Inner Sydney uses the latest IPART conclusions regarding the HoustonKemp value for VCR.

7.2 Planning process

7.2.1 Network area plans

Appropriateness and robustness of area plans ✓

Area plans have been developed by TransGrid for each geographic portion of its network. These area plans describe capacity of supply points in each area, planned augmentation works, asset renewal works, emerging constraints and technical features of the supply point including N-1 capacity and transmission line capacity. Some of the key features of each area plan are summarised below.

- Greater Sydney and CBD

  Greater Sydney comprises two main supply areas, supply to inner Sydney and supply to greater western Sydney, with the needs of each area being quite distinct. Aurecon notes that significant load growth is expected in Western Sydney and to meet this growing need, a number of augmentation projects are planned for Western Sydney in the near future.

  For the inner Sydney supply the retirement of ageing 132 kV Ausgrid owned cables will reduce the overall network capacity. The retirement of these ageing cables is likely to drive significant new cable development under medium to high load growth scenarios.

- Newcastle and Central Coast

  With minimal load growth forecast, there are minimal committed transmission augmentations in this area though there are some proposed distribution augmentations that reflect urban growth in some areas.

- NSW Main Grid

  Operation of the NSW main grid is likely to be impacted by changes in generation patterns as new wind/solar renewable generation is commissioned and older coal fired plant is retired. The Liddell and Vales Point power stations may both be decommissioned within the next 10 years.

  Analysis of different southern NSW dispatch scenarios indicates that the most onerous thermal constraints apply in the Yass-Marulan-Bannaby-Sydney West corridor.

  For some northern NSW dispatch scenarios, overloading of the Mt Piper to Wallerawang 330 kV lines was observed.

  Connection of Silverton Wind Farm (if it proceeds) will place some stresses on the far western NSW network.

  For PV stability analysis, the power margin for the Sydney Region progressively reduces with increasing load such that additional reactive plant may be required at key points to ensure system security.

- North West

  The thermal rating of 969 line is a potential constraint on the operation of the North West 132 kV network. Power flows on the Queensland – New South Wales interconnector also have some impact on the operation of the North-West 132 kV system.

  TransGrid is presently rebuilding Tamworth 132 kV substation and will connect the White Rock Wind Farm to its 132 kV network in 2017. TransGrid has considered establishing a Renewable Energy hub substation along the Armidale to Dumaresq 330 kV transmission line to facilitate the development of a number of wind farms on the northern Tablelands.

- Far North Coast

  Some renewable energy connections are proposed for the far north coast system.

  Dynamic line ratings are proposed to be installed on a number of transmission lines.

  Few augmentations are planned in the next regulatory period, though some may be required in the longer term.

- Mid North Coast

  Some capacity may be required in the Taree area under high load growth scenarios.

  The future of the Tomago Aluminium Smelter will have some bearing on overall demand in this region.

  A number of transmission lines have been identified to have low spans (spans where conductors infringe on standard design ground clearances).

- Far West

  The far western part of TransGrid's network may be affected by the proposed Silverton Wind Farm.

- Far South West

  Limited changes are proposed to this portion of the TransGrid network as minimal demand change is forecast.

- Mid South

  There are a number of transmission line remediation projects proposed in the Southern NSW network and dynamic line rating is proposed for a number of lines.

  No capacity augmentations are committed in the Southern NSW area.

- Canberra and South Coast

  Some capacity augmentations are required to address growing urban load in the Canberra area. TransGrid has rebuilt Cooma 132kV substation and major renewal works are proposed in the next regulatory period for the Canberra area including the establishment of a new Stockdill 330kV substation to meet the requirements of the ACT Government.

- South West

  There are a number of wind farm projects proposed in the southern Tablelands area.

  Refurbishment of a number of transmission lines is proposed in the next regulatory period.

- Mid West

  Some solar projects may be connected in the mid west portion of NSW in the next few years. Minimal demand growth is forecast in the next regulatory period.

TransGrid is presently rebuilding Orange 132 kV substation and transformer refurbishments are proposed at a number of other sites.

These area plans provide considerable technical information concerning each part of the TransGrid network. The area plans are fairly comprehensive, though as the area plans are high level documents, they intentionally do not list all of the renewal works, such as secondary systems replacements or other minor works planned in each area.

The consideration of alternative options including non-network options, option assessment criteria and selection of preferred option ✓

A number of the augmentation projects included an assessment of non-network solutions. The non-network solutions considered include curtailment of load, embedded generation and energy storage.

The new NSW Transmission Reliability Standard, which is expected to be published at the end of 2016, will explicitly enable TransGrid to meet the requirements for network reliability by either using transmission assets or by implementing non-network solutions such as back-up power generation or agreements with distribution service providers to part of an attached distribution network.

Aurecon expects that this new standard will provide opportunity for greater flexibility on the part of TransGrid to meet its supply reliability obligations than is available with the present reliability standard.

TransGrid is currently including non-network solutions in the options feasibility studies being examined for a number of augmentation projects and TransGrid's assessment of these non-network solutions forms part of its options evaluation reports.

TransGrid currently has in place some non-network solutions that involve supply curtailment to mining loads in the event of critical contingencies at a time of high network demand. These supply curtailment arrangements have enabled the deferral of augmentation to the 969 132 kV transmission line between Tamworth and Gunnedah in northern NSW.

Treatment of risk associated with pre-investment (base case) including energy not supplied ✓

TransGrid identifies load at risk for a range of credible network contingencies as part of its planning processes. Load at risk, failure probability and probable outage duration are used to determine unserved energy which, when combined with VCR can determine pre-investment base case risk cost for the portion of its network being examined.

Load at risk includes consideration of loads that may be supplied from alternate sources within the distribution network.

TransGrid has analysed outage rates and restoration time data on its network for transmission lines, cables, transformers and switch bays and used this data to calculate failure rates and restoration times. For transmission lines and cables, failure rate is per 100 km per decade, while for transformers and switch bays the failure rate is per population per decade. Restoration time data has been analysed to determine mean, standard deviation and percentile distributions. The statistical analysis of restoration times show a large difference in restoration times between the mean and median value. The relatively small amount of 220 kV and 500 kV equipment on TransGrid's network and the consequential smaller number of outages at these voltages gives less reliable data than that for its 330 kV and 132 kV equipment.

Aurecon considers that the network reliability data is comprehensive, and enables accurate assessment of failure rates and restoration times for its network so that unserved energy can be estimated reliably.

For the pre-investment base case, the cost of unserved energy component of risk is generally the dominant component of overall risk cost.

Robustness of the process followed, and the diligence in following the process, in determining the preferred option ✓

The process used by TransGrid to assess needs for augmentation to its network has multiple stages. This staged process includes:

- Establishing the needs
- Identifying solution options, options screening and short listing
- Scoping and costing of options, including non-network solutions
- Evaluating options to determine a preferred solution.

This process is relatively robust as each TransGrid prescribed project is governed by this process. The staged approval process is described in the TransGrid *Prescribed Capital Investment Procedure.*

The examination of options and evaluation of project options provides a more transparent process to demonstrate that the option with the greatest net present value is adopted.

Project approvals are also subject to a rigorous governance process described in its *Prescribed Capital Investment Procedure*. This includes a staged approval process with Decision Gate stages to manage the decision-making governance process in which appropriate documentation is required to enable a project to proceed to the next stage.

In addition to TransGrid's internal processes, the National Electricity Rules include processes such as the RIT-T, the application of which TransGrid has incorporated into its *Prescribed Capital Investment Procedure*.

The processes used by TransGrid is thorough and appears to have been followed in the project documentation reviewed by Aurecon.

Appropriateness of the triggers identified for the contingent projects ✓

Clause 6A.8.2(d) of the National Electricity Rules governs the application of contingent projects. A contingent project is one in which a TNSP may, during a regulatory control period, apply to the AER to amend a revenue determination that applies to that TNSP where a trigger event for a contingent project has occurred.

Contingent projects are typically used for network augmentation projects where the need for a project is only triggered when some threshold event (or events), that necessitates the project being implemented, occurs.

Aurecon has reviewed TransGrid Project 1528 to reinforce the southern NSW network, a project that is contingent on either additional renewable generation being connected in southern NSW, or upgrades to the Victorian interconnector, before proceeding. The triggers described by TransGrid in its evaluation of this contingent project are considered to be appropriate.

7.3 Other considerations

Uncertainty associated with the demand forecast, generation outlook ✓

Recently published demand forecasts show little or no demand growth due to factors such as the higher cost of electricity, declining demand from major industrial users and better end use efficiency. Embedded generation particularly from roof-top solar generation has also had some impact on demand in the last five years. The absence of demand growth has reduced or eliminated the need for most capacity augmentations, except for some locations where demand growth is occurring due to increasing urban development.

The changing generation outlook, with likely retirement of existing coal-fired generation and growth in renewable generation projects creates considerable uncertainty with the future role of the transmission grid in NSW. The connection of new renewable generation is occurring at locations remote from the conventional thermal generation and so transmission network needs are evolving.

7.4 Review of sample AUGEX projects

7.4.1 General

To examine the approach used by TransGrid to examine potential constraints on its network due to growing demand, Aurecon reviewed the following augmentation projects:

- Constraints on network between Macarthur and Nepean (Project 1438)
- Thermal Rating of 969 line (Project 1489)
- Reinforcement of Southern NSW network (Project 1528)
- Capability of Cable 41 (Project DCN 42)
- Supply to Inner Sydney (Project DCN 43)

Details of these projects will be covered in the following sections.

7.4.2 Project 1438 - Constraints between Macarthur and Nepean

The south-western area of Sydney is supplied by a 330/132/66 kV substation at Macarthur that was commissioned in 2009. The load in this part of Sydney is growing at 3.9% per annum due to increasing urban and industrial development. The substation is unusual in that while there are two transformers, one provides 66 kV supply and the second 132 kV supply with alternate supply provided from within the Endeavour Energy network. The load growth in this area is more rapid than other parts of NSW and joint planning studies by TransGrid and Endeavour Energy have identified an emerging constraint with the 330/66 kV capacity of Macarthur substation.

The Needs Statement identifies 124.5 MW of load at risk based on load forecasts by Endeavour Energy. The Needs Statement indicates that the risk cost, primarily due to value of customer reliability is $13.7M, though doesn't state the year this cost applies. The needs statement indicates that Endeavour Energy has advised that the augmentation is required by 2020.

A feasibility study examines an option to install a second 330/66 kV transformer at Macarthur substation, which was costed at $8.6M. The options evaluation also includes evaluation of some Endeavour Energy works to increase the transfer capacity between Macarthur and Ingleburn or to install an additional 132 kV transformer at Nepean substation. Both of these Endeavour Energy options were rejected as not being feasible by TransGrid due to the higher risk of unserved energy and also since these options only partially addressed the constraint.

Much of the risk cost appears to be due to risk of unserved energy. The evaluation report does not indicate how the unserved energy risk cost changes year by year even though, with growing demand, the unserved energy cost is expected to grow year by year.

There is little doubt that a capacity augmentation will be required at Macarthur substation in the near future due to the growing demand in the south-west Sydney area. An analysis of year by year changes in unserved energy and consequent change in risk cost would help to confirm the date that the augmentation is economically justified.

While the Options Evaluation Report identified a likely preferred solution, the evaluation report noted that the final preferred option will be determined from a RIT-T evaluation.

Based on the information reviewed by Aurecon, Aurecon agrees that installing a second 330/66kV transformer at Macarthur substation appears the most cost effective solution to relieve this constraint.

7.4.3 Project 1489 - Thermal Rating of 969 line

TransGrid's 969 line is a 132 kV line that connects Tamworth substation to Gunnedah substation. The transmission line was commissioned in 1965 and is noteworthy for having a conductor that is smaller than that on most other 132 kV lines.

The Needs Statement identifies load at risk due to the thermal constraint imposed by the rating of 969 line with the critical contingency being an outage of the adjacent Tamworth to Narrabri 968 line. The proposed connection of additional industrial loads in North West NSW will increase the load at risk. Load at risk on this network is presently managed by load shedding two recently connected mine loads under contingency conditions.

The risk cost is dominated by value of unserved energy through risk of unavailability of the parallel 968 Tamworth to Narrabri line. The annual risk cost for the present network and existing loads is $1.06M, which increases to $14.39M if a number of proposed industrial loads are connected.

Potential options identified to relieve the constraint include:

- Reconductoring the line with a higher temperature conductor. This option involves reconductoring 48 of the 65 kilometres of the line with a high temperature conductor at a 16/17 capital cost of $5.72M.
- Non-network solutions including the use of battery storage technology and paying the mines to accept reduced reliability
- Installing a new phase shifting transformer
- Relocating the Armidale-Kempsey 965 line phase shifting transformer
- Provision of a series reactor on the line
- Constructing a second 132 kV line between Tamworth and Gunnedah

Of these options, only the reconductoring and non-network solution options were examined in detail as the other options were either expected to cost significantly more than the reconductoring option, or they provided a smaller increase in line rating.

The Options Evaluation Report used a risk cost of $14.39M (calculated on the assumption that mining loads proceed) for the do-nothing case, being a risk cost for an unplanned outage of another parallel 132 kV line.

The Options Evaluation Report indicates that the NPV for the reconductoring option is $95.58M, which is mainly due to avoiding risk of unserved energy.

A RIT-T investment test is not required as the augmentation cost is less than $6M.

The Options Evaluation Report concluded that reconductoring 969 line was the preferred solution.

Based on the information reviewed by Aurecon, this proposed solution appears to be the most cost effective solution to relieve this constraint.

7.4.4 Project 1528 - Reinforcement of Southern Network

This project was identified by TransGrid as a contingent project.

The project identifies that a shortfall of generation capacity is expected in NSW if the announced retirement of Liddell power station occurs in 2022. After the retirement of Liddell, the other remaining generation in NSW and full interconnector support is not expected to be able to meet the forecast NSW demand. The AEMO 2015 Electricity Statement of Opportunities indicates that unserved energy in NSW could exceed the reliability standard from 2021 under the high demand scenario, and from 2022 under the medium scenario mainly due to the withdrawal of Liddell generation capacity.

The needs statement identifies a number of new renewable generation projects that may be developed in southern NSW. Dispatch scenarios for this new renewable generation indicates that a number of 330 kV transmission lines between Yass/Canberra and Sydney could constrain power transfer from southern NSW to Sydney.

Three options to augment the southern NSW network were examined that would increase transfer capacity by between 170 MW and 1,000 MW with estimated costs for the options ranging between $56.7M and $375M. A fourth non-network option involving generation runback and load curtailment was also considered.

The evaluation report notes that there is only limited spare transfer capacity available between southern NSW and Sydney to transmit the output from additional renewable generation and that increased transmission capacity may give market benefits to the NEM.

The evaluation report identifies that the upgrade is contingent on the following triggers:

- More than 350 MW of new generation is committed to be connected in southern NSW
- NSW import from southern interconnectors is to be increased by more than 350MW due to committed expansion of the southern interconnectors

The project would be subject to a RIT-T process that would identify the preferred option as the expected investment would exceed $5M.

Aurecon considers that the triggers are appropriate triggers for this contingent project.

7.4.5 Project DCN42 - Capability of Cable 41

The thermal rating of underground cables is strongly dependent on the thermal properties of the backfill used around the cable when it is installed. While the cable has provided many years of reliable service, recent studies have indicated that there is considerable uncertainty concerning the thermal properties of the backfill. Detailed thermal rating studies for the 330 kV cable have been undertaken for a range of assumed moisture content in the backfill. The Needs Statement recommended feasibility studies to replace the backfill so the cable rating can be restored to its original design rating.

Measurements of cable outer sheath temperature over a two-year period at a monitoring point in Forest Road near Bonds Road indicated that the maximum temperature the cable outer sheath had reached was 37°C. At the time the maximum outer sheath temperature was recorded, the cable load was 430 MVA, which is a higher loading than normal.

The Needs Statement indicated that the cable oil system is in good condition as only a small number of minor oil leaks have been reported over the 37 year service life of the cable. Although the condition of the cable insulation is unknown, cable insulation tests are planned to be carried out on a section of cable in late 2016.

One option examined involves the removal of existing backfill above the cable cover slabs (the protective concrete slabs immediately above the cable) and to reinstate with thermal stabilised backfill. The options study identified the sections installed beneath roadways, in bushland, parks, tunnels and bridges and proposed different remedial works for the various sections. As excavation and reinstatement was to only occur to the top of the cable cover slabs, the work was proposed to be done while the cable was energised. The cost of this option was estimated at $127M as it involved replacing the back fill over the majority of the 19.7 km route length. The cable route was noted to have a significant number of crossings by other services.

A second option examined involves excavation and replacement of the backfill down to the cable itself and replacing the cable cover slabs. This option would require work to be done under outage conditions and was costed at $154M.

This project makes little sense as the cost to remediate the backfill is extremely high since the civil works are similar to that required to install a new cable yet the remediation works are being carried out on a cable that is 37 years old. The risk and disruption involved in excavating and reinstating backfill along the cable route appears very high for the benefits. Evaluation of this project is included in TransGrid's evaluation of supply to inner Sydney.

Aurecon now understands that TransGrid is not planning to proceed with remediation of the cable backfill.

7.4.6 Project DCN43 - Supply to Inner Sydney

Supply to inner Sydney relies on TransGrid cables 41 and 42 and a number of Ausgrid-owned 132 kV cables that operate in parallel with these 330 kV cables. The Needs Statement indicates:

- A number of 132 kV Ausgrid owned cables are approaching end of life and are likely to be retired in the near future.
- Ausgrid has reduced the thermal rating of a number of its 132 kV cables as has TransGrid with cable 41 due to uncertainty with the condition of the cable backfill
- The retirement of some of the 132 kV cables will reduce the overall supply capacity to inner Sydney and present load forecasts indicate that additional supply capacity will be required at some stage in the 2020s.

A number of options were examined to provide adequate capacity to inner Sydney including:

- Option 1: install two 330 kV cables in stages, retire Cable 41 and decommission Ausgrid cables in two stages at a cost of $329M
- Option 2: operate Cable 41 at 132 kV, install two 330 kV cables in stages and decommission Ausgrid cables in two stages at a cost of $337M
- Option 3: install two 330 kV cables at once, retire Cable 41 and decommission Ausgrid cables in one stage at a cost of $309M
- Option 4: remediate Cable 41, install two 330 kV cables in stages and decommission Ausgrid cables in one stage at a cost of $455M
- Option 5: remediate Cable 41, install two 330 kV cables at once (initially operating at 132 kV) and decommission Ausgrid cables in two stages at a cost of $450M

- Option 6: remediate Cable 41, install two 330 kV cables at once and decommission Ausgrid cables in one stage at a cost of $436M

The evaluation report indicates that the preferred option will be determined through a RIT-T process, though TransGrid considers that option 3 is likely to be the preferred network solution.

There is some scope to defer the project through non-network solutions, though deferral is likely to only be for one or two years. Non-network options include embedded generation, energy storage and voluntary curtailment of load.

7.4.7 Observations

The future needs for bulk electricity supply to inner Sydney is extremely complex as the supply network comprises a strongly meshed cable network owned by TransGrid and Ausgrid, with capacity needs being driven by both the staged retirement of ageing 132 kV assets and future demand growth. All network solutions to augment the network have long lead times and very high capital cost.

The evaluation report includes an evaluation of expected unserved energy, asset unavailability and value of customer reliability. The economic evaluation determined that the NPV of each option was virtually identical, so overall capital cost becomes the only significant differentiator across the options.

To provide better understanding of Cable 41's insulation condition, TransGrid is planning to perform some tests on the cable in the near future. While the 330 kV cable is now 37 years old, provided the cable insulation tests are satisfactory, the cable is expected to remain serviceable for a number of years. Options to retire the cable appear to have little justification at this stage.

Depending on the outcome of the insulation tests, the retirement of cable 41 may not be required. Although the thermal properties of the backfill is not as effective as designed, the cable itself would still perform reliably. Downgrading the cable to 132 kV operation would have merit if the insulation properties are found to be deteriorating. Operating the cable at 132 kV will give approximately 40% of the MVA capacity on the cable that it would have if it were to continue to operate at 330 kV.

On the other hand, progressive retirement of the Ausgrid fluid filled 132 kV cables has stronger justification as all of these cables are much older than 41 cable, generally are in poorer condition, there is an increased risk of fluid leaks and maintenance costs are high. Fluid leaks pose an environmental contamination risk and substantial expenditure would be required to improve the reliability of the 132 kV cables. New cables to replace the existing Ausgrid cables are expected to be justified.

Examining options to install a new 330 kV cable from Rookwood Road substation to Beaconsfield substation has considerable merit as this supply point diversifies the origin of 330 kV supply to inner Sydney. Rookwood Road substation is also closer to Beaconsfield substation than Sydney South substation which is where the present cable 41 supply to Beaconsfield originates.

Remediating backfill on cable 41 makes little sense as the project does not appear to be cost effective. The civil works required to remediate the backfill are similar to those required to install a new cable, there is considerable risk involved in excavating and backfilling major roads along the route and at the end of the project, the 37 year old cable will itself be unchanged.

Cable thermal ratings are normally based on conservative assessments of backfill thermal resistivity, as the potential for thermal runaway with underground cables necessitates some conservatism. The rating for cable 41 is significantly constrained for the thermal properties of the backfill when the backfill is fully dried out and ambient temperatures are high. Most of the time, the cable backfill has some moisture present, so the actual rating will be better than the present rated value.

7.4.8 Comment on AUGEX projects

The process followed by TransGrid to determine potential solutions to relieve capacity constraints on the NSW network, identifies needs, costs options including non-network solutions and evaluates the options to determine the most cost effective solution. The overall process is sound.

The pre-investment base case calculates risk for unserved energy. TransGrid presently determines year by year MVA capacity and costs unserved energy at the date augmentation is required.

The evaluation for inner Sydney supply includes a complex method to evaluate of cost of unserved energy, which Aurecon considers to be good practice. The complexity of supply to Inner Sydney is expected to result in considerable scrutiny from the AER to demonstrate that the solution adopted is the most cost effective.

TransGrid intends to use a similar planning approach to that used to plan the Victorian network in their detailed justification to be reported in project assessment draft report (PADR).

8 Conclusion

TransGrid is due to submit its revenue proposal for the next regulatory control period by early 2017. For the next regulatory period, TransGrid's capital expenditure will be dominated by replacement or refurbishment expenditure rather than expenditure on capacity enhancement of its network.

While documentation for the revenue proposal is still being prepared, it is apparent that considerable effort has been devoted to developing risk based assessments of asset condition with asset replacement being driven by risk cost modelling.

Aurecon's review of the revenue proposal capital expenditure has been undertaken while the documentation is still in course of preparation and so notes that the documentation as reviewed is not necessarily final.

For replacement expenditure, TransGrid has developed a number of building blocks that are used to determine the required spend including:

- The Criticality Framework
- Asset Health Framework
- Network Risk Assessment Methodology

These building block models are used to determine asset risk and criticality for replacement. The evaluation of potential replacement options includes the risk benefit derived for each option, with the recommended option being the option that has the greatest value

The appropriate level of the REPEX spend developed using bottom up project requirements has been compared with proposed expenditure with regard to top down REPEX modelling and other trend based approaches.

To address future needs for the transmission network, TransGrid has developed twelve geographically based augmentation plans for its network, one covering the main transmission grid and the remaining eleven covering different regions of NSW. These area plans list bulk supply point capacities, emerging constraints, major replacement works and potential augmentations.

Augmentation expenditure takes into account:

- Demand forecast for 2016 - 2026
- Capacity of the existing network
- Generation outlook (including retirements)
- Transmission Reliability criteria

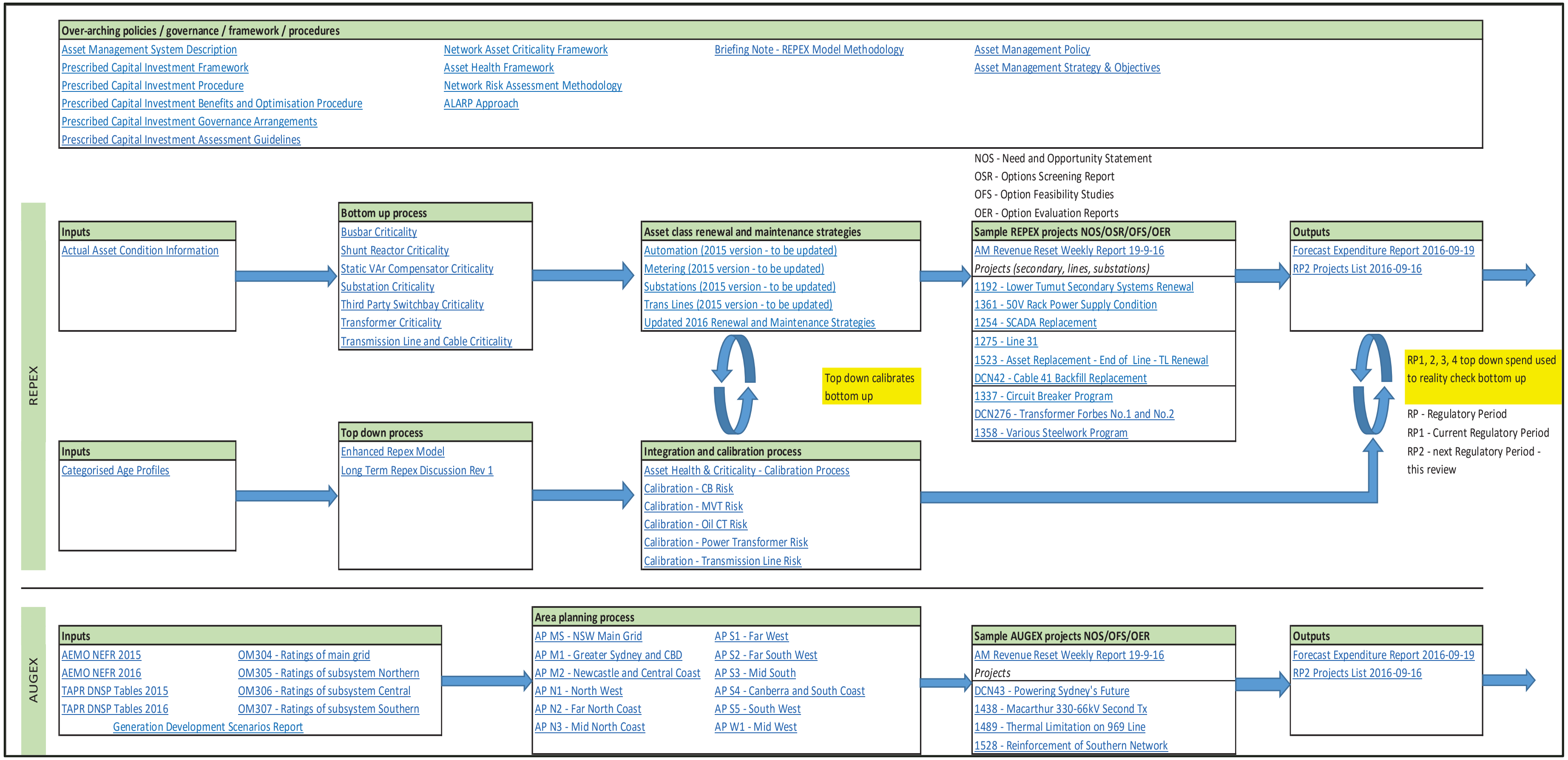
In assessing capacity augmentations, TransGrid has developed a process that considers alternative transmission options and non-network options that meet identified needs. The review process includes assessment of each option so as to select a preferred option. The treatment of risk associated with non-investment (base case) including energy not supplied is included in the option evaluation process as is the predicted change in risk cost following the implementation of the proposed solution.

TransGrid processes for evaluation of potential solutions to network needs are relatively robust. For contingent projects, the triggers identified are appropriate triggers.

Based on our review, Aurecon believes that TransGrid's framework for the preparation of its capital expenditure plan for the 18/19 to 22/23 regulatory period will result in a CAPEX forecast that is in accordance with good electricity utility practice and will meet the capital expenditure criteria as set out in 6A.6.7 of the National Electricity Rules.

Appendices

Appendix A
Reviewed documents


Over-arching policies / governance / framework / procedures
Asset Management System Description
Prescribed Capital Investment Framework
Prescribed Capital Investment Procedure
Prescribed Capital Investment Benefits and Optimisation Procedure
Prescribed Capital Investment Governance Arrangements
Prescribed Capital Investment Assessment Guidelines
Network Asset Criticality Framework
Asset Health Framework
Network Risk Assessment Methodology
ALARP Approach
Briefing Note - REPEX Model Methodology
Asset Management Policy
Asset Management Strategy & Objectives
NOS - Need and Opportunity Statement
OSR - Options Screening Report
OFS - Option Feasibility Studies
OER - Option Evaluation Reports
REPEX
Inputs
Actual Asset Condition Information
Bottom up process
Busbar Criticality
Shunt Reactor Criticality
Static VAr Compensator Criticality
Substation Criticality
Third Party Switchbay Criticality
Transformer Criticality
Transmission Line and Cable Criticality
Asset class renewal and maintenance strategies
Automation (2015 version - to be updated)
Metering (2015 version - to be updated)
Substations (2015 version - to be updated)
Trans Lines (2015 version - to be updated)
Updated 2016 Renewal and Maintenance Strategies
Sample REPEX projects NOS/OSR/OFS/OER
AM Revenue Reset Weekly Report 19-9-16
Projects (secondary, lines, substations)
1192 - Lower Tumut Secondary Systems Renewal
1361 - 50V Rack Power Supply Condition
1254 - SCADA Replacement
1275 - Line 31
1523 - Asset Replacement - End of Line - TL Renewal
DCN42 - Cable 41 Backfill Replacement
1337 - Circuit Breaker Program
DCN276 - Transformer Forbes No.1 and No.2
1358 - Various Steelwork Program
Outputs
Forecast Expenditure Report 2016-09-19
RP2 Projects List 2016-09-16
Top down calibrates bottom up
RP1, 2, 3, 4 top down spend used to reality check bottom up
RP - Regulatory Period
RP1 - Current Regulatory Period
RP2 - next Regulatory Period - this review
Inputs
Categorised Age Profiles
Top down process
Enhanced Repex Model
Long Term Repex Discussion Rev 1
Integration and calibration process
Asset Health & Criticality - Calibration Process
Calibration - CB Risk
Calibration - MVT Risk
Calibration - Oil CT Risk
Calibration - Power Transformer Risk
Calibration - Transmission Line Risk
AUGEX
Inputs
AEMO NEFR 2015
AEMO NEFR 2016
TAPR DNSP Tables 2015
TAPR DNSP Tables 2016
OM304 - Ratings of main grid
OM305 - Ratings of subsystem Northern
OM306 - Ratings of subsystem Central
OM307 - Ratings of subsystem Southern
Generation Development Scenarios Report
Area planning process
AP MS - NSW Main Grid
AP M1 - Greater Sydney and CBD
AP M2 - Newcastle and Central Coast
AP N1 - North West
AP N2 - Far North Coast
AP N3 - Mid North Coast
AP S1 - Far West
AP S2 - Far South West
AP S3 - Mid South
AP S4 - Canberra and South Coast
AP S5 - South West
AP W1 - Mid West
Sample AUGEX projects NOS/OFS/OER
AM Revenue Reset Weekly Report 19-9-16
Projects
DCN43 - Powering Sydney's Future
1438 - Macarthur 330-66kV Second Tx
1489 - Thermal Limitation on 969 Line
1528 - Reinforcement of Southern Network
Outputs
Forecast Expenditure Report 2016-09-19
RP2 Projects List 2016-09-16

Appendix B
Engagement scope

Expert Terms of Reference

Review of 2019-2023 CAPEX Requirements

TransGrid

2019- 2023 Revenue Determination

17 August 2016

Contents

1. Background

TransGrid is the operator and manager of the high voltage electricity network in New South Wales and the Australian Capital Territory. As such, TransGrid is a transmission network service provider (TNSP) regulated under the NEL and the NER.

Chapter 6A of the NER sets out rules for the economic regulation of prescribed transmission services and negotiated transmission services provided by TNSPs. This regime requires the AER to determine the revenue allowed to be earned by TransGrid for prescribed transmission services during each regulatory year, in accordance with the post tax revenue model, described in Chapter 6A of the NER for each regulatory control period. In addition, a pricing methodology, negotiating framework and negotiated transmission service criteria must also be determined by the AER. The process for making a transmission determination is set out in Part E of Chapter 6A of the NER.

TransGrid has a right to apply to the Australian Competition Tribunal (Tribunal) for merits review of a "reviewable regulatory decision" under section 71B of the NEL. The scope of and process for merits review of reviewable regulatory decision is set out in Division 3A of Part 6 of the NEL. The transmission determination that the AER is required to make in relation to TransGrid's revenue is a "reviewable regulatory decision" amenable to review.

TransGrid is currently preparing its revenue reset proposal for the next regulatory period. TransGrid's proposed CAPEX spend is a critical component of the revenue proposal

2. Scope of work

Aurecon is requested to review TransGrid's proposed CAPEX for the 2019-2023 regulatory period to provide an expert view on the following, with consideration against good industry practise[7] and with consideration of the capital expenditure criteria as set out in 6A.6.7 of the National Electricity Rules:

2.1 REPEX

- the appropriateness of TransGrid's fundamental building blocks for REPEX – being the Criticality Framework, Asset Health Framework, Network Risk Assessment Methodology and its application

[7] The exercise of that degree of skill, diligence, prudence and foresight that reasonably would be expected from a significant proportion of operators of facilities forming part of the power system for the generation, transmission or supply of electricity under conditions comparable to those applicable to the relevant facility consistent with applicable regulatory instruments, reliability, safety and environmental protection. The determination of comparable conditions is to take into account factors such as the relative size, duty, age and technological status of the relevant facility and the applicable regulatory instruments. (Definition from National Electricity Rules Version 82, page 1157)

- the appropriateness of the REPEX with regard to top down REPEX modelling and other trend based approaches.

Bottom up Building Block Scope

Item No.	Focus Area	Key Items for Consideration
1.1	Criticality	• Reliability values (choice of Value of Consumer Reliability, interruption duration, Likelihood of Consequence due to redundancy) • Selection of environmental risk values (bushfire consequence and Likelihood of Consequence, environmental ranking and clean up costs) • Selection of safety consequence and LoC • Justification of other values • Methodologies for calculating ENS, VCRs and market benefits
1.2	Asset Health	• Choice of values and weighting to derive Asset Health • Use of asset data • Reliability techniques for PoF calculations
1.3	Network Risk Assessment Methodology	• Clear documentation and assessment of how ALARP / SFAIRP is treated • Key hazard identification and control mapping is robust and fit for purpose • Algorithm for calculating risk is good practice
1.4	Calibration of Asset Heath / Criticality	• Total reliability, safety and environmental risk across major asset classes is sensible at a network level

The above values should be assessed in their application to a range of proposed projects and across asset classes. All values should appropriately reflect project scenarios.

Top Down Assurance Scope

Item No.	Focus Area	Key Items for Consideration
2.1	Top down REPEX Model	• Consistency with AER principles • Unmodelled component acceptable
2.3	Long term REPEX Trend	• RP2 spend needs to be seen in the context of RP1, RP3 and RP4
2.4	What if we don’t?	• Risks of deferral articulated • Network Risk given RP2 spend • Change in risk for lower spends
2.5	Effects of RP2 on long term sustainability	• Asset failure trends • Age trends • Residual life

Asset Management Review

Item No.	Focus Area	Key Items for Consideration
3.1	Asset Management Policy	• Document is key statement of Corporate intent
3.2	Asset Management Strategy and Objectives	• Document sets the strategic approach to Asset management and overarching approach • Whole of life asset management, from planning to retirement
3.3	Asset Class Renewal and Maintenance Strategies	• Clear articulation of class issues and trends to provide context for REPEX spend

2.2 AUGEX

The augmentation plans and the associated expenditure is required to be assessed, in particular addressing the following aspects:

- The appropriateness and robustness of TransGrid's augmentation plans, taking into consideration
  - o Demand forecast for 2016 - 2026
  - o Capacity of the existing network
  - o Generation outlook (including retirements)
  - o Reliability criteria;
- The consideration of alternative options including non-network options ,option assessment criteria and selection of preferred option;
- Treatment of risk associated with non-investment (base case) including energy not supplied;
- Robustness of the process followed, and the diligence in following the process, in determining the preferred option;
- Appropriateness of the triggers identified for the contingent projects.

Further, where possible, assessment of the exhaustiveness of the portfolio of the augmentation projects should be made, taking into consideration:

- uncertainty associated with the demand forecast, generation outlook; and
- likely revision of the (n-x) reliability standard to an economic reliability standard by IPART.

3. Information provided by TransGrid

The expert is encouraged to draw upon the following information which TransGrid will make available:

- Criticality Framework
- Asset Health Framework
- Network Risk Assessment Methodology
- TransGrid's REPEX model
- Asset Management Policy
- Asset Management Strategy and Objectives
- Asset Class Renewal and Maintenance Strategy
- Demand forecast
- Generation outlook
- Network ratings
- Area Plans which cover the capability of the existing network and potential augmentation opportunities
- Sets of investment documents (selected by the consultant)

4. Other information to be considered

The expert is also expected to consider the following additional information:

- Such information that, in expert's opinion, should be taken into account to address the questions outlined above;

5. Proposal requirements

The service provider is requested to provide a proposal addressing the project brief, including:

- Approach to the engagement, including any suggested changes to the brief or value-adds;
- High level project plan with milestone dates;
- Estimated effort and elapsed duration for the engagement;
- Proposed internal personnel, including CVs;
- Proposed subcontractors;
- Capped price.

6. Reports

Progress reports will nominally be fortnightly or as otherwise agreed.

7. Deliverables

At the completion of its review the Expert will provide an independent expert report which:

- is of a professional standard capable of being submitted to the AER and published in the public domain with no confidentiality provisions.It must also be prepared on the understanding that it may be referenced in an appeal under merits review, should this eventuate;
- in case where analysis is undertaken or models are used, sufficient detail of the analysis must be provided to meet the requirements of the National Electricity Rules Schedule S6.1.1 (2) and (4), Schedule S6.1.2 (2), (3) and (5), Schedule S6A.1.1 (2) and (4), and Schedule S6A.1.2 (2), (3) and (5). These schedules require a Revenue Proposal to include methods for developing forecasts, methods for developing forecasts of key variables and key assumptions that underlie forecasts. Specifically, the use of "black box" analysis is precluded.
- contains a section summarising the Expert's experience and qualifications, and attaches the Expert's curriculum vitae (preferably in a schedule or annexure);
- identifies any person and their qualifications, who assists the Expert in preparing the report or in carrying out any research or test for the purposes of the report;
- summarises TransGrid's instructions and attaches these terms of reference;
- includes an executive summary which highlights key aspects of the Expert's work and conclusions; and
- (without limiting the points above) carefully sets out the facts that the Expert has assumed in putting together his or her report, as well as identifying any other assumptions made, and the basis for those assumptions.

The Expert's report will include the findings for each of the parts defined in the scope of works (section 2).

8. Timetable

The Expert's report will deliver the draft final report to TransGrid by 30 September followed by the final report by 14 October.

9. Terms of engagement

The key terms of the engagement are as follows:

a) You must not accept any other appointment or retainer to provide assistance or services to any other party in relation to this matter or the events surrounding this matter. You must at all times avoid any real or apparent conflict of interest between TransGrid's interests in relation to this matter and the interests of any other person.

b) You confirm that you have disclosed to us all information that is material to your engagement as an expert in this matter, including but not limited to:

   i. The nature of any services that Aurecon is currently providing, or may have previously provided, to TransGrid to the extent relevant to this engagement;

   ii. Any holding of securities in TransGrid or any of its related bodies corporate that are held by your immediate family or any company in which you or a member of your immediate family has a material financial interest; and

iii. Your qualifications and experience, in so far as they are relevant to this matter.

c) You will tell us about any matters of the sort listed above that arise, become known to you or significantly change after the date of this letter.

The terms on which the Expert will be engaged to provide the requested advice shall be as provided in accordance with the TransGrid's Q214/13 arrangements applicable to the Expert.

10. Remuneration

TransGrid will pay you for time spent on this matter in accordance with the instructions of TransGrid at the agreed rates in Q214/13.

1. Attachment 1 - Federal Court Practice Note CM7

EXPERT WITNESSES IN PROCEEDINGS IN THE FEDERAL COURT OF AUSTRALIA

Commencement

1. This Practice Note commences on 4 June 2013.

Introduction

2. Rule 23.12 of the Federal Court Rules 2011 requires a party to give a copy of the following guidelines to any witness they propose to retain for the purpose of preparing a report or giving evidence in a proceeding as to an opinion held by the witness that is wholly or substantially based on the specialised knowledge of the witness (see Part 3.3 - Opinion of the Evidence Act 1995 (Cth)).

3. The guidelines are not intended to address all aspects of an expert witness's duties, but are intended to facilitate the admission of opinion evidence[8] and to assist experts to understand in general terms what the Court expects of them. Additionally, it is hoped that the guidelines will assist individual expert witnesses to avoid the criticism that is sometimes made (whether rightly or wrongly) that expert witnesses lack objectivity, or have coloured their evidence in favour of the party calling them.

Guidelines[9]

2. General Duty to the Court

1.1. An expert witness has an overriding duty to assist the Court on matters relevant to the expert's area of expertise.

1.2. An expert witness is not an advocate for a party even when giving testimony that is necessarily evaluative rather than inferential.

1.3. An expert witness's paramount duty is to the Court and not to the person retaining the expert.

3. The Form of the Expert's Report[10]

3.1 An expert's written report must comply with Rule 23.13 and therefore must

(a) be signed by the expert who prepared the report; and

(b) contain an acknowledgement at the beginning of the report that the expert has read, understood and complied with the Practice Note; and

(c) contain particulars of the training, study or experience by which the expert has acquired specialised knowledge; and

[8] As to the distinction between expert opinion evidence and expert .assistance see Evans Deakin Pty Ltd v Sebel Furniture Ltd [2003] FCA 171 per Allsop J at [676]

[9] The "*Ikarian Reefer*" (1993) 20 FSR 563 at 565-566.

[10] Rule 23.13.

(d) identify the questions that the expert was asked to address; and

(e) set out separately each of the factual findings or assumptions on which the expert's opinion is based; and

(f) set out separately from the factual findings or assumptions each of the expert's opinions; and

(g) set out the reasons for each of the expert's opinions; and

(ga) contain an acknowledgment that the expert's opinions are based wholly or substantially on the specialised knowledge mentioned in paragraph (c) above[11]; and

(h) comply with the Practice Note.

3.2 At the end of the report the expert should declare that "[the expert] has made all the inquiries that [the expert] believes are desirable and appropriate and that no matters of significance that [the expert] regards as relevant have, to [the expert's] knowledge, been withheld from the Court."

3.3 There should be included in or attached to the report the documents and other materials that the expert has been instructed to consider.

3.4 If, after exchange of reports or at any other stage, an expert witness changes the expert's opinion, having read another expert's report or for any other reason, the change should be communicated as soon as practicable (through the party's lawyers) to each party to whom the expert witness's report has been provided and, when appropriate, to the Court[12].

3.5 If an expert's opinion is not fully researched because the expert considers that insufficient data are available, or for any other reason, this must be stated with an indication that the opinion is no more than a provisional one. Where an expert witness who has prepared a report believes that it may be incomplete or inaccurate without some qualification, that qualification must be stated in the report.

3.6 The expert should make it clear if a particular question or issue falls outside the relevant field of expertise.

3.7 Where an expert's report refers to photographs, plans, calculations, analyses, measurements, survey reports or other extrinsic matter, these must be provided to the opposite party at the same time as the exchange of reports[13].

4. Experts' Conference

3.1 If experts retained by the parties meet at the direction of the Court, it would be improper for an expert to be given, or to accept, instructions not to reach agreement. If, at a meeting directed by the Court, the experts cannot reach agreement about matters of expert opinion, they should specify their reasons for being unable to do so.

J L B ALLSOP
Chief Justice
4 June 2013

[11] See also Dasreef Pty Limited v Nawaf Hawchar [2011] HCA 21.
[12] The *"Ikarian Reefer"* [1993] 20 FSR 453 at 565.
[13] The *"ikarian Reefer"* [1993] 20 FSR 563 aat 565-566. See also Ormrod *"Scientific Evidence in Court"* [1968] Crim LR 240.

Appendix C

CV's of report Contributors

Carl Badenhorst Technical Director Energy Services

Program and Project Director with over 20 years related experience, including significant international experience in South Africa, Canada and Australia. Excellent project management skills with extensive management, planning and financial experience. Strong background in power transmission and distribution projects, including advisory services. Registered Certified Practicing Project Director (AIPM) and a Project Management Professional (PMI).

Qualifications

Executive MBA, Simon Fraser University

BSc, Electrical Engineering, University of Capetown

Advanced Diploma of Project Management, University of New England

Certified Practising Project Director (AIPM)

Project Management Professional (PMI)

Certified Practising Project Director (CPPD) - Certified Practising Project Director

Project Management Professional (PMP)

Specialisation

Transmission and Distribution

Project and Program Management

Advisory Services

Years in industry

20+

Experience

2012 – Present
Aurecon Australia Pty Ltd, Sydney, Australia
(A global organisation offering engineering, management and specialist technical services to public and private sector clients)
Project Director, Transmission and Distribution

- Responsible for the overall delivery of a program of transmission and distribution projects to various clients including TransGrid, Ausgrid, Endeavour Energy, Essential Energy, ActewAGL, ElectraNet and Zinfra.
- Lead the team that provided Technical and Environmental advice to the successful purchasers of TransGrid, the NSW Transmission organisation

Nov 2009 – 2012
Endeavour Energy, Sydney
(One of three electricity distributors in New South Wales, providing transmission and distribution of power to over 2 million people)
Program Director, Major Projects

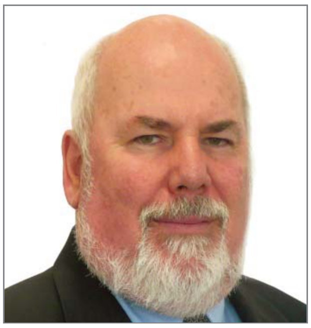
- Responsible for managing a branch consisting of approximately 30 project management staff leading the delivery of $0.8b of transmission and distribution capital works within the five year regulatory period.
- Ensured that the organisation's safety values were considered the highest priority in both project delivery and the operation of the branch
- Grew the branch from approximately 15 to 30 project management staff including senior PMs, PMs, schedulers, analysts and administrative staff
- Managed a portfolio of approximately 50 active major projects in various phases ranging from initial planning to final close-out. Individual projects ranged in value from $1m to $100m, and included zone and transmission substations plus the associated transmission and distribution feeders
- Managed compliance with Project Management Policies
- Assisted the Project Management Office (PMO) in the development of the Project Management Policies and Procedures.
- Managed a capital budget of approximately $200m per financial year
- Identified and documented the key issues and risks present within the portfolio and ensured that adequate mitigation strategies and treatment plans were established
- Provided commercial and contract management support to Project Managers as required.

September 2008 – October 2009
ABB, Brisbane, Australia (Global organisation providing power and automation products and services)
Manager – Substation Services

- Responsible for developing the substation service business within the Power Systems group of ABB Australia.
- Worked with existing and potential clients to develop contracts for the provision of substation maintenance services.
- Formed a team to manage the ongoing implementation of these contracted services.
- Developed strategies to grow the service business in a sustainable manner.

August 2000 – April 2008
BC Hydro, Vancouver, Canada
(Provides electricity to domestic, commercial and industrial customers in British Columbia including generation, transmission and distribution of power)
Substations Engineering Division Manager (Feb 2007 – Apr 2008)
Project Manager (Aug 2000-Jan 2007)

- Responsible for managing the division consisting of approximately 90 professional, technical and administrative staff providing a variety of internal and external services on transmission substation capital and maintenance projects. Services include planning, design and maintenance engineering..
- Ensured that safety was considered and incorporated in all divisional activities and services
- Ensured adherence to applicable practices and standards, including project management practices
- Ensured successful delivery of the overall portfolio of work performed by the division
- Attracted, retained and developed critical staff to deliver services. Successfully retained 21 employees in order to deliver the significantly increased capital program
- Negotiated and recommended individual and long term strategic commercial agreements and contracts
- Successfully managed the organisation's $2.8b per year Revenue Requirements Application to the BC Utilities Commission. Achieved a favourable negotiated settlement (the largest settlement achieved under the auspices of the BC Utilities Commission)
- Managing the Phase II BCTC Transition project (established the business relationship between BC Hydro and the newly formed BC Transmission Corporation)
- Provided leadership and mentoring in the development and ongoing activities of the Distribution Engineering Project Management Team
- Managed distribution electrical projects, typically ranging from $300k to $5m, from planning to commissioning and close-out, within time, cost, and performance constraints
- Managed the interconnection of Independent Power Producers to the distribution network



Kim Francis Senior Asset Services Engineer

Over 39 years experience in the Asset Management and Risk Management within Water, Gas, Defence, Mining and Heavy Industry. Experience covers operations and maintenance management, maintenance improvement and risk management at senior levels in private and public enterprises.

Strong technical leadership skills, particularly with Asset Management and Risk Management

Qualifications

Bachelor of Engineering (Mechanical Engineering)

MBA

Specialisation

Asset Management

Risk Management

Years in industry

39

Experience

July 2010 – Present
Aurecon Australia Pty Ltd
Senior Asset Services Engineer, Asset Services

Public Transport Victoria – myki Ticketing Assets

Developed expected life analysis, asset replacement and obsolescence modelling for selected range of myki ticketing assets

Project- Glencore – SAP Data Cleansing

Manage the site Pulse data cleansing activities and develop data tables in preparation for SAP conversion. Sites: Bulga, Ravensworth, Liddell, Mangoola, Tahmoor and Ulan

Project - SA Power Networks – Asset Management Plans and Replacement Strategies

Develop strategies for maintenance and replacement of Underground Cables, Conductors and Substation Transformers in their distribution network, covering the period between 2014 and 2024.

Asset Management Plans were developed in IIMM (2011) format for the strategies and identified works for asset specific plans to support SA Power Networks reset submission for the 2015-2020

Project – Defence Support Group – Base Engineering Assessment Program (HMAS Albatross, RAAF Williamtown, RAAF edinburgh, Larrikeya Barracks and Lavarack Barracks)

Developed and piloted a methodology to assess the existing Condition, Capacity and Compliance (CCC) status of each base's electrical, gas, ICT, hydraulics (potable and non-potable and waste) and fuel farm engineering services. This methodology is being applied to all major Defence bases.

Project - Dyno Nobel - Asset Management Gap and Implementation

Lead the site team for the Asset Management Gap Analysis and subsequent follow up implementation project to address gaps (current gaps).

Project - Pacific National - Asset Management Gap and Implementation

Lead the site team for the Asset Management Gap Analysis and subsequent follow up implementation project to address gaps (current gaps).

Project - Macarthur Water - Strategic Asset management Plan Due Diligence Review

Lead the Aurecon team to review the existing Asset Management and capital investment plans and provide an assessment for their capacity to meet ongoing asset management requirements for the plant.

January 2007 - July 2010

WorleyParsons - Senior Asset Services Engineer, Asset Services

Project - Vale Integra Coal Operations - Underground Mine VPSM Phase 1 Implementation

Lead the site team for the development of the asset management documentation, including policies, processes, procedures and training packages to align the Integra site with Vale Asset Management System (VPSM) and actions identified in the Maintenance Excellence Index audit.

Project - Vale Carborough Downs Coal VPSM Phase 1 Implementation

Lead the site team for the development of the asset management documentation, including policies, processes, procedures and training packages to align the Carborough Downs site with Vale Asset Management System (VPSM) and actions identified in the Maintenance Excellence Index audit. Supervised the reliability improvement team creating Preventive Maintenance schedules for the new Longwall miner.

Project - Newcastle Coal Infrastructure Group - Independent Engineers for Financiers

WorleyParsons acts as the Independent Engineer to the Senior Agent and Newcastle Coal Infrastructure Group (NCIG) for Coal Export Terminal Project being developed by NCIG.

Reviewed Maintenance Management development and plans, commissioning plans and completed an Operation Readiness Audit.

Senior Project Engineer, Asset Services

Project – Department of Defence: Audit of Fixed Plant and Equipment Comprehensive Maintenance Contracts. (Regions: ACT/Southern NSW, Southern Victoria, River Murray Valley, Western Australia and Northern Territory / Kimberley).

Audit Defence’s Comprehensive Maintenance Services (CMS) contractors on their asset management plans, maintenance plans, maintenance execution and legislative compliance in accordance with the contractual requirements.

Complete gap analyses on the contractors’ plans, performance and benchmarked performance for each region against industry best practice. Recommend improvement opportunities.

Project - Phoenix (Facilities Restructure) - Onesteel/Smorgon

Program Controller - management of numerous projects associated with Onesteel – Smorgon Steel merger related to changing the business facilities footprint. This included the closure or upgrade of various production facilities throughout Australia and realignment of the supply chain logistics between the production and distribution centres. Initial predicted savings $37M pa achieved savings $49.9M pa.

Project - Tomago Aluminium - Plant Facilities Maintenance Projects 2009

Assist client identify and prioritise the plant facilities maintenance projects for calendar year 2009, to conform to a budget of $2 million.

Kim Francis Senior Asset Services Engineer

Project - Newcastle Port Corporation - K2 Berth Upgrade

Develop tender, manage site inspections, evaluated tenders, made recommendations, and contract formation for Kooragang No.2 berth (mixed cargo) Upgrade, facilitated risk and constructability studies. Works covered installation of 2 dolphins and mooring bollards and associated equipment on a contaminated site.

Project - Orica (Kooragang Island), Tomago Aluminium and Hydro Aluminium

Minor projects management, plus risk and constructability workshop facilitation (numerous projects).

Senior Assets Engineer, Hunter Water Corporation

Duties included:

Develop asset management plans for electrical and mechanical assets.

Develop maintenance strategies for electrical and mechanical assets based on RCM/FMECA principles and asset risk profiles.

Develop SOPs and inspection standards for the operations and maintenance of assets.

Develop decision support systems for asset replacement or rehabilitation using RCA and failure history analysis.

Manage the Computerised Maintenance Management System.

Manage upgrade of CMMS from MIMS to Ellipse.

Participate in WSAA Asset Management benchmarking audits (AQUAMARK).

Manage the operation and maintenance of a Private Irrigation Scheme including subcontractors.

Senior Liaison Officer, Agility Management, Sydney NSW

Duties included:

Develop Safety and Operating Plans for AGL and Australian Pipeline Trust assets.

Liaise with the relevant State government departments about the plans.

Training employees in Safety and Operating Plan requirements.

Manage annual auditing function for these plans.

Conduct risk assessment risk and formal safety assessment workshops.

Develop trunk pipeline asset management plans.

Various Roles, BHP Rod, Bar and Wire Products, Steelmaking.

Maintenance Technology Engineer:

Duties included:

Investigate the application of new Maintenance Technologies in the department.

Gap Analysis of equipment performance using failure data, identify areas of improvement and implement improvements.

Conduct and participate in HAZOP studies and Manufacturing Reliability Studies .

Implement a Computerised Risk Management system.

Train all employees in DuPont Safety Methods.

Maintenance / Environmental Engineer

Duties included:

Plan shutdown work and maintenance work for the gas cleaning plants.

Manage a fully coordinated approach to maintenance of the primary and secondary fume systems encompassing mechanical, electrical & process engineering work.

Manage the fume plant maintenance budget for electrical and mechanical work.

Develop SOPs and inspection standards for the operations and maintenance of the Fume systems.

Develop KPI's to monitor fume plant performance and adherence to licence agreement and improve plant performance.

Ensure all areas of Steelmaking comply with EPA licences.

Develop the Steelmaking Environmental Assurance Manual.

Implement the Environmental Assurance and Environmental Improvement Programs.

Shift Campaign Manager

Duties included:

Manage capital campaign work for the secondary fume, main lance and sub lance upgrade installation. Project value $28 million.

Co-ordination of contractors' activities to ensure minimum impact on operational requirements, and being able to safely complete the project within budget and on time.

Technical Auditor, BHP - Corporate

Duties included:

Review management systems and identify areas of management improvement throughout the BHP companies in Australia.

Detailed system analysis and compliance testing of the business management systems.

Develop recommendations for senior management on system improvements.

Peter Hulbert Market Director Energy - Australia & NZ

Peter is a senior Executive with particular expertise in the development and delivery of power generation solutions from planning through to operations and maintenance using various contracting and implementation arrangements. He has extensive experience in gas turbine and combined cycle power plant design, erection, commissioning and maintenance.

He has spent a substantial part of his career involved in the development and structuring of new projects as well as the transaction processes around changes of capital asset ownership through privatisation of public sector assets and private sector sales and investments.

Qualifications

BSc (Hons) Mechanical Engineering, University of Sussex, 1986

MBA, Deakin University, 2006

Chartered Engineer, United Kingdom

Member, Institution of Mechanical Engineers, United Kingdom

Member of the Institution of Engineers Australia

Registered Professional Engineer Queensland

Chartered Professional Engineer

Chartered Engineer (CEng) - Engineering Council of the United Kingdom (ECUK)

Chartered Professional Engineer (CPEng) - National Professional Engineers Register (NPER)

Managing Successful Programmes (MSP) - APM Group, Australia

Registered Professional Engineer (RPEQ) - Board of Professional Engineers of Queensland (BPEQ)

Specialisation

Project development activities, transaction advisory, project management, project implementation

Years in industry

30

Experience

Experience

2015 to present – Market Director Energy, ANZ and Asia

Responsible for the delivery of Energy services in ANZ and Asia

2011 to 2015 – Service Group Leader, Energy Services

Responsible for the management of the Energy Business Units and delivery of Energy Services across Aurecon's global business

2008 to 2010 – Development Manager, Energy

Responsible for the sustainable strategic development of Aurecon's Energy business

2004 to 2008 – Manager Energy Queensland, Principal

Responsible for a the management of Aurecon’s Energy Business Unit in Queensland

2000 to 2004 – Project Development Engineer and Senior Associate

Key project experience

- Reviewer for team providing technical and environmental due diligence services and future business optimisation advice for the successful acquisition of the TransGrid transmission system in NSW. Leading to subsequent business improvement tasks.
- Reviewer for all of Aurecon’s technical and environmental due diligence activities for the NSW generator sales

– Macquarie Generation power asset sale due diligence

– Delta Electricity power asset sale due diligence

– Eraring Energy power asset sale technical due diligence

– Delta West power asset sale technical due diligence

– NSW Gentrader due diligence

- Project Director for the technical and environmental due diligence of the Burrup Fertiliser Plant in Western Australia
- Provision of expert witness services in respect of the technical aspects of a power-related taxation dispute in the Supreme Court of Victoria
- Due diligence and project development activities for the acquisition and refurbishment of Afam Power Station in Nigeria
- Development of 4 x 150 MW coal fired power station at Benga in Mozambique
- Huntly C&I Upgrade Project, New Zealand – Project Principal for team acting as Owner's Engineer for design, procurement and installation of new controls system for existing 1,000 MW coal and gas fired power station
- Asian Repowering Project – Project Principal for redevelopment studies converting existing oil fired power station to coal fired capability
- SIPCO Power Plant, Thailand – Project Principal for Owner's Engineer for 150 MW gas turbine-based cogeneration plant
- Stanwell Power Station, Queensland – Project Principal for team engineering design and installation of low NOx burners for 4 x 350 MW coal fired power station
- Callide C Power Station, Queensland – Project Principal for team providing ongoing capital, engineering and technical services for 2 x 420 MW supercritical coal fired power station
- Millmerran Power Station, Queensland – Project Principal for ongoing engineering and technical services to 2 x 420 MW supercritical power station
- Kogan Creek B Power Project, Queensland – Project Principal for team providing OE1 specification development services
- Huntly Project 40 – Project Manager for team acting as the client's project manager and engineer for 45 MW open cycle gas turbine. Scope includes definition, specification, procurement and implementation, including site management, of six contracts for the project – gas turbine, transformer, HV switchgear, 220 kV cable, balance of plant and civil.
- Huntly Energy Efficiency Enhancement Project, New Zealand – Engineering Manager and Project Principal for team acting as Owner's Engineer for 400 MW high efficiency combined cycle power station. Scope included project definition studies, EPC and O&M options and strategies, plant specification, EPC commercial and contractual terms, site geotechnical and seismic investigation, tender evaluation, EPC and maintenance contract negotiation and formation, site preparation design and works execution, design and execution of enabling works and integration of services with the existing Huntly Power Station, EPC design review, QA and inspection services, construction supervision, supervision of performance testing, acceptance, handing over and guarantee services.
- North Queensland Power Project, Queensland – Project Manager for team acting as Owner's Engineer for 375 MW advanced technology combined cycle power station. The role included project definition studies, review of EPC and operating and maintenance options and contract structures available to the Owner, specification of the plant, development of commercial terms, site geotechnical investigation, tender evaluation, and direct negotiation for EPC procurement.
- Carole Park Cogeneration Plant, Queensland – Project Manager for team acting as Owner's Engineer for 25 MW and 90 t/h gas turbine-based cogeneration facility.
- Alcoa Cogeneration Assets Sale, Western Australia – Review of contracts for the sale of 270 MW of cogeneration assets in WA on behalf of bidder.

- Optima Energy Sale, South Australia – Part of team carrying out technical due diligence for the long term lease of Torrens Island Power Station, SA.
- Taranaki Power Station, New Zealand – Part of team reviewing reliability and service history of GT26 combined cycle gas turbine unit for contractual dispute.
- Taranaki Combined Cycle power station, New Zealand – Specialist engineer and Project Reviewer for team providing technical due diligence advice to purchaser of 400 MW high efficiency combined cycle power station.
- Mount Stuart Power Station, Queensland – Project Manager for team acting as technical adviser to purchaser of this 300 MW gas turbine power station.

1986 to 1999 - Mott MacDonald Group, Brighton, United Kingdom

1994 to 1999 - Principal Engineer, Power Development Division, United Kingdom

- Huntstown Combined Cycle Power Project, Ireland – Project Manager for team acting as Owner's Engineer for the development of a 600 MW CCGT power station. The role included initial studies and project definition, obtaining permits and consents for the project, specification and tendering for the EPC contract and development of the project contracts and connection agreements.
- Electroandina Expansion Project, Chile – Project Manager for team acting as technical adviser to the Lenders for 800 MW power plant extension project consisting of two 400 MW ABB GT26 CCGT power plants at separate locations in Chile and a further separate 220 kV overhead transmission line project connecting the central and northern Chilean electricity grids.
- Sutton Bridge Combined Cycle Power Station, UK – Technical review of 780 MW Sutton Bridge combined cycle gas turbine power station. Provided technical advice to project bondholders during construction phase of project.
- Habibullah Coastal Combined Cycle Power Station, Pakistan – Lender's engineer for 130 MW CCGT power station utilising three LM6000 gas turbines in combined cycle.
- Serang Coal Fired Power Station, Indonesia – Project Manager for team acting as Lenders' Technical Adviser for 450 MW coal fired power station. Provided analysis and advice on all technical aspects of the development including plant design, environmental matters, project contracts and implementation.
- Enfield Energy Centre CCGT, UK – Lenders' engineer for Enfield Energy Centre development of GT26 gas turbine in single shaft combined cycle configuration.
- Gas Turbine-Based Power Plants, Middle East – Project Manager for team undertaking conceptual design studies to identify 550 MW, and later 1,000 MW, open and combined cycle gas turbine power station designs and options to provide secure power supplies to an industrial development in the Middle East.
- Ballylumford Power Station, Northern Ireland – Project Manager for team that carried out techno-economic review of 960 MW gas/oil fired steam power station at Ballylumford in Northern Ireland including review of plant performance and availability, working practices and manpower levels.
- Teesside Cogeneration Plant, UK – Prepared the Technical Adviser's Report to the Lenders for the refinancing of the 1,725 MW Teesside Cogeneration project developed by Enron. Plant consists of eight MW701DA gas turbines with heat recovery boilers and two steam turbines.
- Combined Cycle Power Station, Argentina – Due diligence review of a Siemens V94.2-based CCGT project in Argentina for the proposed purchase on an IPP basis by a leading international energy company.
- Laibin Coal Fired Power Station, China – Provided performance and operational aspects of Independent Engineer's assessment for 2 x 330 MW coal fired power station.

- Combined Heat and Power Projects, China – Review of project viability for three private joint venture conventional coal-fired combined heat and power projects in China on behalf of potential investor.
- Private Power Station, Pakistan – Feasibility study for 300 MW – 350 MW heavy fuel oil fired private power station in Pakistan.
- Jebel Ali Power Station, Dubai – Feasibility study for addition of back pressure steam turbines and gas turbine at Jebel Ali power station, Dubai. Advice during subsequent implementation.

1990 to 1995 - Resident Engineer, Various locations

- Paka Private Power Station, Malaysia – Commissioning Engineer responsible for commissioning and acceptance testing of 400 MW combined cycle block.
- Bermuda Electric Light Company, Bermuda – Seconded to BELCO in Bermuda to supervise installation and commissioning of two Allison aeroderivative gas turbines and one ABB industrial-type gas turbine.
- Pasir Gudang and Paka Private Power Stations, Malaysia – Commissioning engineer responsible for commissioning and performance testing of two 150 MW Siemens V94.2 gas turbines in open cycle.
- Al Ain Power Station, Abu Dhabi – Project Manager responsible for major overhauls of 12 industrial gas turbines at the power station. Work included all contractual and financial aspects of running the project along with leading a team of six engineers to supervise contractor's work on site.
- Responsible for technical and commercial finalisation of documentation for major overhauls of 12 industrial gas turbine generators at Al Ain Power Station, Abu Dhabi.
- Open Cycle Gas Turbines, Remote Areas of Abu Dhabi – Mechanical Engineer engaged in the design, specification, installation and commissioning of 3 x 20 MW gas turbine generators in the remote areas of Abu Dhabi.
- Fuel Oil Storage Facilities, Remote Areas of Abu Dhabi – Resident Engineer for construction of 8 x 650 m3 fuel oil storage tanks, fuel transfer pumps, piping, welding quality assurance and associated works in remote areas of Abu Dhabi.

1986 to 1990 – Engineer, Power Development Division, United Kingdom

- 350 MW Combined Cycle Power Station, Thailand – mechanical project engineer.
- Combined Cycle Power Station, Riyadh, Saudi Arabia – Feasibility study for 1,200 MW – 1,400 MW combined cycle power station at Riyadh, Saudi Arabia.
- Combined Heat and Power Projects, Spain – Feasibility study for the installation of gas turbine combined heat and power projects at two refinery sites in Spain.

1985, Property Services Agency, United Kingdom, Student Engineer

Publications

"The State of the Ground-Based Gas Turbine Industry". Presented at the fourth annual Industrial and Power Gas Turbine O&M Conference, 1998.

"Embedded Generation – An Overview". Presented at the Electric Energy Society of Australia seminar, Grid Connection of Embedded Generation, October 2001.

Curriculum Vitae: Mr S VAN WYK

Name of Staff	:	**VAN WYK, SIMON**
Profession	:	Technical Director Risk & Decision Analytics Consultant
Nationality	:	South African
in	:	https://za.linkedin.com/in/simonvanwyk77

Key qualifications:

Simon Van Wyk has fifteen years of Safety, Health, Environmental and Quality (HSEQ) management experience with key experience in Integrated International Management Systems (ISO 45001, ISO 14001, ISO 9001, ISO 22301 and ISO 55001). He currently leads the Risk & Decision Analytics team based in Cape Town. He has extensive expertise in Hazard Identification and Risk Assessment (HIRA) methodologies and business continuity management which include Operational Risk, Project Risk Management, Strategic Risk and Scenario Risk Assessments in accordance with the risk management principles as outlined in ISO 31000: 2009. His expertise spans Qualitative, Semi-Quantitative and Quantitative techniques such as Monte Carlo Analysis, Bow Tie Analysis and Multi Criteria Decision Analysis techniques. He has extensive experience in the environmental field having completed several Environmental Impact Assessments and has provided Specialist Risk Consulting in several sectors, most notably, the Mining, Ports/Harbours, Transport, Buildings (Skyscrapers) and Energy Sectors including Generation (Nuclear, Renewables & Coal-Fired Power), Transmission and Distribution. He is an Associate Member of the Institute of Risk Management South Africa (IRMSA), a registered Professional Natural Scientist with the South African Council for Natural Scientific Professions (SACNASP) and a Corporate Member of the Disaster Management Institute of Southern Africa (DMISA).

Employment record:

2016 – to date	Aurecon South Africa: Technical Director, Risk & Decision Analytics
2012 - 2016	Aurecon South Africa: Associate - Risk Consultant, Risk & Decision Analytics
2011 - 2012	Aurecon South Africa: Senior Risk Consultant, Operational & Project Risk Management
2009 - 2010	Aurecon South Africa: Senior Environmental Practitioner
2009	Ninham Shand, South Africa: Principal Environmental Practitioner
2002 – 2008	SHE Cape Environmental CC, South Africa: Director/Environmental Consultant
2001 – 2002	Cape Weatherwise International CC, South Africa: Environmental Practitioner
2001	Eskom Koeberg Nuclear Power Station, South Africa, Integrated Health, Safety and Environmental (HSE) Management Systems Project Team Member

Experience record:

1) Risk Management:

2016	Project Risk Manager	**The Tower: Dubai Creek Harbour (Calatrava), Dubai, UAE:** Emaar Properties is developing a new iconic structure called The Tower as part of its 6km² Dubai Creek Harbour master plan. The US$1bn skyscraper is expected to become the world's tallest building at 928m, overtaking the current world's tallest building Burj Khalifa. The Tower will serve as the central piece of the Dubai Creek Harbour master plan, which includes the development of nine different commercial districts comprising high-end residences, event spaces, galleries, hotels and other amenities. Santiago Calatrava has developed the design for the Tower, while the construction is expected to commence in 2016 and be completed by 2020 in time for the Dubai Expo 2020. The role fulfilled includes the full suite of Project Risk Management (Risk Management Plan, Risk Registers, Schedule Risk Analysis, Risk Proximity, Contingency Estimates (Monte Carlo Analysis). An innovative risk based thinking process was undertaken to define the Critical Success Factors (CSFs) which drive the projects success. This process included a semi-quantitative estimate of each CSFs criticality which allowed for a criticality ranking across the entire project.
2016	Risk Facilitation Specialist	**Winland International Financial Center, Xiamen, China:** The project is located on the Eastern Coast of Xiamen Island, the 500,000 square meter project comprises four high-rise towers containing office buildings, a serviced apartment tower, a 5-star hotel and retail space. Facilitated a Risk Workshop as well as producing a Risk Readiness Tracking Tool to proactively manage risk exposure over the project lifecyle period of 10 years. The risk workshop entailed defining project objectives, identifying risks by category as well as a qualitative risk assessment using Consequence/Likelihood criteria to produce Heatmaps and Risk Profiles to aid decision making and treatment contingency optimisation.
2016	Lead Risk Manager	**Risk Culture, Integrated Management Systems and Operational Risk Optimisation, TransGrid, New South Whales, Australia:** Appointed by TransGrid to assist its Executive Management and Group Management understand its current risk culture and risk appetite along with change management implications for its new ownership model. Services included running a two day risk workshop which focussed on risk advisory pertaining to integrated management systems and the operational risk management model maturity. Two methods were proposed namely Monte Carlo Analysis and the use of Multi Criteria Decision Analysis techniques.
2016	Lead Risk Manager	**Steenbras pumped storage main plant refurbishment, City of Cape Town, South Africa:** Appointed by City of Cape Town to undertake a risk management review for the refurbishment of the hydropower pumped storage system. The review included the determination of the current level of risk exposure, to create/protect value and to increase certainty on decision making for refurbishment options whilst taking human and environmental factors into consideration. Risk management was used as the enabler to facilitate continual improvement of the project.
2015	Lead Risk Manager	**Kingangop Wind Farm, Kenya:** Appointed by AIIM to provide a PESTLE Analysis and Project Risk Management services. The PESTEL analysis focused on identifying and examining the main macro-level external and environmental factors affecting the project that needed be taken into consideration from a strategic perspective to ensure a positive outcome. The risk management deliverables included a risk management plan, risk register, treatment plans and schedule cost risk.
2015	Lead Risk Manager	**Pier 1 Phase 2, Transnet Capital Projects, South Africa:** Appointed by Transnet Capital Projects to undertake risk management for the new proposed port expansion during the FEL-3/4 phase. The risk management deliverables included a risk management plan, risk register, treatment plans, schedule cost risk, HAZOP and value engineering assessment.
2015	Lead Risk Manager	**Rheboksfontein Wind Farm, South Africa:** The risk management deliverables included a risk management plan, risk register and treatment plans.

2015	Lead Risk Manager	**Waterberg Railway Corridor, Transnet, South Africa:** Appointed by Transnet Capital Projects to undertake risk management for the new proposed railway corridor during the FEL-3 phase. The risk management deliverables included a risk management plan, risk register, treatment plans, schedule cost risk, HAZOP and value engineering assessment.
2015	Lead Risk Manager	**Replacement of Shiploaders/Stacker-Reclaimers, Richards Bay Coal Terminal (RBCT), Richards Bay, South Africa:** Appointed by RBCT to undertake risk management for the new proposed replacement of two shiploaders and two stacker-reclaimers during the FEL-3 and 4 phase. The risk management deliverables included a risk management plan, risk register, treatment plans, schedule cost risk and management of the HAZOPs.
2015	Risk Manager	**H2NS JV Manganese Railway Corridor, Transnet, South Africa:** Appointed by Transnet Capital Projects to undertake risk management for the new proposed railway corridor during the FEL-3 and 4 phase. The risk management deliverables included a risk management plan, risk register, treatment plans, schedule cost risk, HAZOP and value engineering assessment.
2014	Lead Risk Manager	**Overvaal Tunnel, Transnet, Ermelo, South Africa:** Appointed by Transnet Capital Projects to undertake risk management for the new proposed 4km tunnel project during the FEL-3 phase. The risk management deliverables included a risk management plan, risk register, treatment plans, schedule cost risk, HAZOP and value engineering assessment.
2014	Risk Manager	**Integrated Rapid Public Transport Network, Ekurhuleni Metropolitan Municipality, Gauteng, South Africa:** Project Risk Management for the PMU (Project Management Unit) overseeing the Strategic Business Planning, Infrastructure, Legal (Bus Procurement Transaction), Operations Planning, Marketing and Communication, Industry Transition, Financial Modelling and Systems Planning workstreams. Created risk registers and ranked qualitatively to arrive at a risk profile for several workstreams. Undertook a comparative analysis across all workstreams to classify risk criticality and produced a Risk Management Plan.
2014	Risk Lead	**Gamagara River Flow Restoration Project, Anglo American (Kumba Iron Ore), Northern Cape, South Africa:** Identified and rated Critical Success Factors (Project Objectives), created a risk register and ranked qualitatively to arrive at a risk profile for several workstreams and produced a Risk Management Report for the swallet formation on the Gamagara River tying the project risks back to the Anglo Americans Enterprise Risk Management drivers.
2014	Risk Lead	**Solar Augmentation Project, Eskom, South Africa:** Identified and rated Critical Success Factors (Project Objectives), created a risk register and ranked qualitatively to arrive at a risk profile for several workstreams and produced a Risk Management Report.
2014	Risk Lead	**P-Gallery, HAZOP3 Assessment, Transnet Capital Projects, Richards Bay, South Africa:** Undertook a Hazard and Operability Risk Assessment for a new conveyor system at the Port of Richards Bay.
2014	Risk Lead	**Short Term Coal Terminal: Implementation Risk Register, Transnet National Ports Authority, Richards Bay, South Africa:** Undertook a risk workshop with the engineering team to identify, rank (Inherent + Residual) and classify risks in the form of Risk Register using risk management software.
2013	Risk Lead	**Socio-Economic Risk Assessment for the 2nd Bridge over River Niger, Nigeria, African Infrastructure Investment Managers (AIIM) representing the Ministry of Works:** Appointed by AIIM to undertake an Environmental and Socioeconomic Impact Assessment for the 2nd bridge over the River Niger between Onitsha and Asaba. The risk assessment however forms one of many specialist assessments for the SEIA focussing of risks at the construction, operational and decommissioning phases.

2013	Project Leader	**Meteorological Assessment to lower operational inefficiencies owing to inclement weather, National Contract, Transnet Port Terminals , South Africa:** Appointed by Transnet Port Terminals to determine early warning and meteorological station requirements and localities for all major ports in South Africa (Saldanha, Cape Town, Port Elizabeth, East London, Port of Ngqura, Durban and Richards Bay. The purpose of the project is to provide a meteorological solution in line with port operations to ensure maximum efficiency in terms of ship to shore and materials handling. Aurecon has both extensive operational, meteorological modelling and systems integration expertise thus offering our client a comprehensive and tailored solution to ensure operational efficiency during demanding weather conditions.
2013	Risk Lead	**In-Pit Crushing and Conveying Project, Exxaro Grootegeluk, South Africa:** Appointed by Exxaro Grootegeluk to facilitate a risk workshop and to produce a qualitative risk register and risk profile during the FEL-2 phase of the project. The risk management deliverables included setting Objectives (Critical Success Factors (CSFs)), identifying and assessing risks that could impact the success of meeting the objectives and a Qualitative Risk Profile.
2013	Risk Lead	**Political, Economic, Social, Technological, Environmental & Legal (PESTEL) Analysis, TITC, Democratic Republic of the Congo (DRC):** Appointed by TITC to undertake a full PESTEL Analysis at the business proposal phase for the establishing a national telecommunications network comprising fibre optic infrastructure throughout the DRC, including connection to the international fibre circuit and international exchanges.
2013	Project Leader	**Sishen – Saldanha Iron Ore Expansion Project, Transnet, South Africa:** Appointed by Transnet Capital Projects to undertake risk management for the proposed iron ore rail upgrade to 84mtpa during the FEL-2 phase of the project. The risk management deliverables included a risk management plan, risk register, treatment plans, schedule cost risk, HAZOP, Fire Plan and Hazard Studies.
2013 - 2012	Risk Specialist	**Review of the Emergency Management System, PetroSA, South Africa:** Appointed by PetroSA to assess their existing emergency management system for the platforms, pipelines, tank farms, depots and international operations. The project entailed a Contextual Analysis, Framework Definition, and Assessment for Effectiveness as well as recommendations.
2012	Project Leader	**Major Hazard Installation (MHI) Risk Assessments, Port of Cape Town, Western Cape, South Africa:** Appointed by Transnet Port Terminals to undertake MHI risk assessments for the Container and Agri-RORO Terminals in order to comply with the MHI Regulations as per the Occupational Health and Safety Act.
2012	Risk Lead	**Nelson Mandela Bay Municipality, Integrated Public Transport System Project, Port Elizabeth:** Undertook design phase risk assessments for the Aurecon programme management team on the IPTS Project. The risk assessment included a risk workshop setting Critical Success Factors with linkages to risks using the BarnOwl Software and Voting Devices.
2012	Risk Lead	**Nelson Mandela Bay Municipality, Integrated Public Transport System Project, Port Elizabeth:** Undertook design phase risk assessments for the Aurecon Transport Operations Centre team. The risk assessment included a risk workshop setting Critical Success Factors in line with the larger IPTS Programme with linkages to risks using the BarnOwl Software and Voting Devices.
2012	Project Leader	**Port of Richards Bay Port Expansion Project, Transnet, Richards Bay, South Africa:** Appointed by Transnet Capital Projects to undertake risk management for the proposed port expansion project during the FEL-2 phase. The risk management deliverables included a risk management plan, risk register, treatment plans, schedule cost risk, HAZOP, Fire Plan and Hazard Studies.
2012	Project Leader	**Port of Richards Bay Coal Expansion Project, Transnet, Richards Bay, South Africa:** Appointed by Transnet Capital Projects to undertake risk management for the proposed coal expansion project during the FEL-2 phase. The risk management deliverables included a risk management plan, risk register, treatment plans, schedule cost risk, HAZOP, Fire Plan and Hazard Studies.

2012	Project Leader	**Richards Bay Expansion Project, Transnet, Richards Bay, South Africa:** Appointed by Transnet to undertake risk assessments for the proposed port expansion project to 2040 during the FEL-1 phase. The risk assessments included a risk workshop using BarnOwl Software to populate a risk register. Risks included operational, accident scenarios and design level risk.
2012	Project Leader	**Aurecon, Engineering Design Team Risk Assessments, Tswane, South Africa:** Undertook design phase risk assessments for the Aurecon engineering design team on the VALE Nacala-a-Velha Project (Mozambique). The risk assessment included a risk workshop setting Critical Success Factors with linkages to risks using the BarnOwl Software and Voting Devices.
2012	Project Leader	**Operational Scenario Based Risk Assessments, NamPower, Namibia:** Appointed by NamPower to undertake scenario based risk assessments for the proposed coal-fired power station in the Erongo Region of Namibia. Activities included coal handling at port, rail wagon loading and transportation, power plant operations, ash dumps and lime stone mining activities.
2012	Project Leader	**Risk Assessment, Mogalakwena District Municipality, Mokopane:** Appointed by Mogalakwena District Municipality to undertake risk assessments for the proposed Waste Water Treatment Works (WWTW) upgrade project. The WWTW project included risk analysis both from the municipal and Lonmin Mine perspective as the project was mutually beneficial. Bow Tie Analysis and Quantitative Risk Analysis was undertaken to assess risks pertaining to this project.
2012	Project Leader	**Risk Assessment for Vessel Agents, Port of Cape Town, Western Cape, South Africa:** Appointed by Transnet Port Terminals to undertake risk assessments at the Agri-RORO Terminal for vessel agent logistics within the terminal.
2011	Project Leader	**HSEQ Risk Assessment, National Contract, South Africa:** Appointed by Transnet Port Terminals to undertake HSEQ risk assessments for all activities and associated aspects to conform to ISO 14001, OHSAS 18001, SANS 3001, ISO 9001 & ISO 31000.
2010	Project Co-Leader	**Risk Assessment for the Moatize Mine, Tete Province, Mozambique:** Appointed by VALE Mozambique to undertake scenario based risk assessments for the expansion of the coal mine and associated infrastructure (railway and associated operational equipment). The risk assessments had to meet Equator Principles for World Bank acceptance. This project entailed risk assessments for five Environmental Impact Assessments which included the coal mine at Moatize, three sections of rail totalling 950km and a new port at Nacala Bay.
2009 to 2010	Project Leader	**Situational Environmental Analysis, Cape Town, South Africa:** Appointed by Rode^{Plan} to evaluate environmental risks for the Cape Winelands District Municipality as a key informant to the Spatial Development Framework (2009/2010).
2007	Project Manager	**SHE Risk Assessment, Cape Town, South Africa:** Appointed by Nuclear Consultants International to undertake SHE risk assessments for all project activities and associated aspects to conform to ISO 14001, OHSAS 18001 and the Koeberg Nuclear Power Station Management System requirements. This deliverable included the compilation and training of staff to understand their SHE risks.
2007	Project Manager	**EMS Audit Preparation for Management System Compliance, Cape Town, South Africa:** Appointed by Transnet Port Terminals to assist in ensuring the risk assessments were updated and relevant to its activities prior to the ISO 14001 audit.
2006	Project Manager	**National Railway Safety Management System Development, South Africa:** Appointed by Transnet Port Terminals to develop a National Railway Management System in line with SANS 3000: 1 – 2005. Responsibilities included Operational Safety and Health risk assessments and training.
2006	Project Manager	**SHE Risk Assessment, Port Elizabeth, Eastern Cape, South Africa:** Appointed by Transnet Port Terminals to undertake SHE risk assessments for all activities and associated aspects to conform to ISO 14001 and OHSAS 18001. Risk Assessment training also formed part of the appointment.

2006	Project Manager	**Integrated SHE Management System Development, Rosh Pinah, Namibia:** Appointed by Skorpion Zinc (Anglo America) to undertake SHE risk assessments for all activities and associated aspects to conform to their EMS (ISO 14001 certified) and OHSAS 18001. Risk Assessment training also formed part of the appointment.
2005 to 2006	Project Manager	**SHE Risk Assessment, East London, Eastern Cape, South Africa:** Appointed by Transnet Port Terminals to undertake SHE risk assessments for all activities and associated aspects to conform to ISO 14001 and OHSAS 18001. Risk Assessment training also formed part of the appointment.
2005	Project Manager	**EMS Development, Cape Town, Western Cape, South Africa:** Appointed by Transnet Port Terminals to develop an EMS for the Multi Purpose Terminal. Responsibilities include compilation of Policies, Standards, Procedures, Guidelines, Specifications and Work Instructions as well as risk assessments and training.
2005	Project Manager	**Environmental Risk Assessment, Richards Bay, Kwazulu Natal, South Africa:** Appointed by Transnet Port Terminals to undertake environmental risk assessments for all activities and associated aspects to conform to ISO 14001. Risk Assessment training also formed part of the appointment for all shifts which included the bulk terminal and multi-purpose terminal.
2004	Project Manager	**Environmental Risk Assessment, Durban, Kwazulu Natal, South Africa:** Appointed by Transnet Port Terminals to undertake environmental risk assessments for all activities and associated aspects to conform to ISO 14001. Risk Assessment training also formed part of the appointment for all shifts which included the bulk terminal and multi-purpose terminal.
2003	Project Manager	**SHE Risk Assessment, Saldanha, Western Cape, South Africa:** Appointed by Transnet Port Terminals to undertake SHE risk assessments for all activities and associated aspects for the bulk terminal to conform to ISO 14001 and OHSAS 18001. Risk Assessment training also formed part of the appointment.
2003	Project Manager	**Environmental Risk Assessment, Saldanha, Western Cape, South Africa:** Appointed by Transnet Port Terminals to undertake environmental risk assessments for all activities and associated aspects for the bulk terminal to conform to ISO 14001 and OHSAS 18001. Risk Assessment training also formed part of the appointment.

2) Business/Corporate Health, Safety, Environmental & Quality (HSEQ) Services:

2016	Lead Risk Manager	**Risk Culture, Integrated Management Systems and Operational Risk Optimisation, TransGrid, New South Whales, Australia:** Appointed by TransGrid to assist its Executive Management and Group Management understand its current risk culture and risk appetite along with change management implications for its new ownership model. Services included running a two day risk workshop which focussed on risk advisory pertaining to integrated management systems and the operational risk management model maturity. Two methods were proposed namely Monte Carlo Analysis and the use of Multi Criteria Decision Analysis techniques.
2012	Risk Lead	**PetroSA, Emergency Management System Assessment, International:** Appointed by PetroSA to undertake full review to establish the emergency management system effectiveness for the full supply chain. Deliverables included a Contextual Analysis, Emergency Management Framework Definition, Evaluation Tool and Compliance Assessment. The scope included Head Office, Platforms, Tank Farm, Refinery, National Depots and international installations.
2011	Project Leader	**HSEQ Legal Register, National Contract, South Africa:** Appointed by Transnet Port Terminals to undertake HSEQ Legal Register & Legal Linkage for all activities and associated aspects to conform to ISO 14001, OHSAS 18001, SANS 3001, ISO 9001, ISO 31000 and national legislation.
2007	Project Manager	**Integrated SHE Management System Development, Cape Town, South Africa:** Appointed by Nuclear Consultants International to develop an integrated management system to meet the requirements of the Koeberg Nuclear Power Station Management System Requirements. Responsibilities included compilation of Policies, Standards, Procedures, Guidelines, Specifications and Work Instructions as well as risk assessments and training.

2007	Project Manager	**EMS Audit Preparation for Management System Compliance, Cape Town, South Africa:** Appointed by Transnet Port Terminals to assist in ensuring management system documentation was in line with ISO 14001 requirements prior to audit. Include the review of all Policies, Standards, Procedures, Guidelines, Specifications and Work Instructions as well as risk assessments.
2006	Project Manager	**National Railway Safety Management System Development, South Africa:** Appointed by Transnet Port Terminals to develop a National Railway Management System in line with SANS 3000: 1 – 2005. Responsibilities included integrating SANS 3000: 1 into existing Policies, Standards, Procedures, Guidelines, Specifications and Work Instructions as well as risk assessments and training.
2006	Project Manager	**Integrated SHE Management System Development, Port Elizabeth, Eastern Cape, South Africa:** Appointed by Transnet Port Terminals to develop an integrated management system for the Terminal. Responsibilities include compilation of Policies, Standards, Procedures, Guidelines, Specifications and Work Instructions as well as risk assessments and training. The management system included detailed emergency preparedness and response, business continuity management, incident investigation and response as well as monitoring and measurement protocols.
2006	Project Manager	**Integrated SHE Management System Development, Rosh Pinah, Namibia:** Appointed by Skorpion Zinc (Anglo America) to develop an integrated management system for the mine. Responsibilities include compilation of Policies, Standards, Procedures, Guidelines, Specifications and Work Instructions as well as risk assessments and training. The management system included detailed emergency preparedness and response, business continuity management, incident investigation and response as well as monitoring and measurement protocols.
2005 to 2006	Project Manager	**Integrated SHE Management System Development, East London, Eastern Cape, South Africa:** Appointed by Transnet Port Terminals to develop an integrated management system for the Terminal. Responsibilities include compilation of Policies, Standards, Procedures, Guidelines, Specifications and Work Instructions as well as risk assessments and training. The management system included detailed emergency preparedness and response, business continuity management, incident investigation and response as well as monitoring and measurement protocols.
2005	Project Manager	**EMS Development, Cape Town, Western Cape, South Africa:** Appointed by Transnet Port Terminals to develop an EMS for the Multi Purpose Terminal. Responsibilities include compilation of Policies, Standards, Procedures, Guidelines, Specifications and Work Instructions as well as risk assessments and training. The management system included detailed emergency preparedness and response, business continuity management, incident investigation and response as well as monitoring and measurement protocols.
2005	Project Manager	**EMS Development, Richards Bay, Kwazulu Natal, South Africa:** Appointed by Transnet Port Terminals to develop an EMS for the Bulk and Multi Purpose Terminals. Responsibilities include compilation of Policies, Standards, Procedures, Guidelines, Specifications and Work Instructions as well as risk assessments and training. The management system included detailed emergency preparedness and response, business continuity management, incident investigation and response as well as monitoring and measurement protocols.
2004	Project Manager	**EMS Development, Durban, Kwazulu Natal, South Africa:** Appointed by Transnet Port Terminals to develop an EMS for the Multi Purpose, Maydon Wharf and Container Terminals. Responsibilities include compilation of Policies, Standards, Procedures, Guidelines, Specifications and Work Instructions as well as risk assessments and training. The management system included detailed emergency preparedness and response, business continuity management, incident investigation and response as well as monitoring and measurement protocols.

2003	Project Manager	**Integrated SHE Management System Development, Saldanha, Western Cape, South Africa:** Appointed by Transnet Port Terminals to develop an integrated management system for the Bulk Terminal. Responsibilities include compilation of Policies, Standards, Procedures, Guidelines, Specifications and Work Instructions as well as risk assessments and training. The management system included detailed emergency preparedness and response, business continuity management, incident investigation and response as well as monitoring and measurement protocols.
2003	Project Manager	**EMS Development, Saldanha, Western Cape, South Africa:** Appointed by Transnet Port Terminals to develop an EMS for the Bulk Terminal. Responsibilities include compilation of Policies, Standards, Procedures, Guidelines, Specifications and Work Instructions as well as risk assessments and training. The management system included detailed emergency preparedness and response, business continuity management, incident investigation and response as well as monitoring and measurement protocols.
2002	Environmental Consultant	**Linking of Safety, Health & Environmental Legal Requirements, Cape Town, South Africa:** Appointed by Eskom Generation (Koeberg Nuclear Power Station) to link all SHE Legal requirements to identified impacts in terms of the SHE Management System.

3) Regulatory Processes, Environmental Impact Assessment and Environmental Management Plans:

2011 to 2013	Project Leader	**Material Supply Strategy (Borrow Pits), Western Cape:** Appointed by Provincial Government Western Cape: Transport & Public Works. My role included total project management leading three legislative processes simultaneously. The project entailed legalising borrow pits to service the gravel road network of the Western Cape (33,000km) totalling over 300 borrow pits. Legalising borrow pits entailed engagement with the geologist to identify possible material, a screening process was undertaken followed by completing Environmental Management Programmes in terms of the Minerals & Petroleum Resources Development Act, undertaking Environmental Impact Assessments in terms of the National Environmental Management Act (EIA Regulations) and rezoning land by acquiring Temporary Departures (valid for 30 years) as per the Land Use Planning Ordinance. This project was highly complex necessitating the running of multiple legal processes in parallel, engaging landowners, governmental institutions, environmental and risk assessments and report compilation. I have also written and presented multiple papers at several reputable conferences and journals regarding the complexities of this project e.g. Civil Engineering (2012) and presenting at the Road Pavements Forum (CSIR, Pretoria, 2012).
2009 to 2013	Project Leader	**Langezandt Quays, Western Cape:** Appointed by Golden Falls Trading 193 to undertake an Environmental Impact Assessment for the development of a multifunctional development in Struisbaai which comprises of a hotel, retail and fractional title ownership units.
2010	EAP[1]	**EIA for the Coal Terminal, Nacala-a-Velha, Mozambique:** Appointed by Vale to undertake an Environmental Impact Assessment for the development of a railway and new coal terminal for the export of coal from the Moatize mine (Tete Province).
2010	Project Leader	**Mbekweni Ring Road, Western Cape:** Appointed by Drakenstein Municipality to undertake an Basic Assessment for the construction of a municipal road between Jan van Riebeeck Road and Drommerdaris St, Paarl.
2010	Project Leader	**Van der Stel Street/Jan van Riebeeck Road Extension, Western Cape:** Appointed by Drakenstein Municipality to undertake an Basic Assessment for the construction of a municipal road between Jan van Riebeeck Road and Bo Dal Josafat Street, Paarl.

[1] *Environmental Assessment Practitioner*

2010	Project Leader	**Camps Bay Retreat, Western Cape:** Appointed by Camps Bay Retreat to undertake an Basic Assessment for the development of accommodation chalets as well as a nursery and security infrastructure within Earl's Dyke, Camps Bay.
2009 to 2010	Project Leader	**Carolina St. Bulk Sewer Pipeline, Western Cape:** Appointed by Lyners Engineering to undertake a Basic Assessment for the development of a 700mm bulk sewer pipeline.
2009 to 2010	Project Leader	**Bo Dal Josafat Water Main Pipeline, Western Cape:** Appointed by Lyners Engineering to undertake a Basic Assessment for the development of a bulk water main pipeline.
2009 to 2010	Project Leader	**Simondium Water Pipeline, Western Cape:** Appointed by Drakenstein Municipality to undertake a Basic Assessment for the development of a new water pipeline and associated reticulation infrastructure.
2009 to 2010	Project Leader	**Wel van Pas Water Reservoir, Western Cape:** Appointed by Drakenstein Municipality to undertake a Basic Assessment for the development of a new 3 mega litre water reservoir and associated water reticulation infrastructure.
2007 to 2008	Project Director	**50kV Electrical Feeder Line for the Sishen-Saldanha Iron Ore Export Corridor, Western & Northern Cape:** Appointed by Transnet Capital Projects to undertake a Basic Assessment for upgrade of the Electrical Feeder Line between Sishen and Saldanha as well as an EMP.
2007 to 2008	Project Director	**Phase 2 Expansion of the Sishen-Saldanha Iron Ore Export Corridor - 93MTPA, Western & Northern Cape:** Appointed by Transnet Capital Projects to undertake a EIA for the capacity upgrade of the Iron Ore Corridor from 41MPTA to 93MPTA as well as an EMP.
2007 to 2008	Project Manager	**66kV Powerline and Substation, Stillbaai, Western Cape:** Appointed by De Villiers & Moore as Hessequa Municipaility as the client to undertake a Basic Assessment and EMP.
2005 to 2008	Project Manager	**Telecommunication Base Stations, Western Cape:** Appointed by MTN to conduct multiple Basic Assessments for BTS sites throughout the Western Cape totalling fifteen sites.
2006	Project Manager	**66kV Powerline between Proteus and Vleesbaai, Mossel Bay, Western Cape, South Africa:** Appointed by Eskom Distribution to undertake and EIA and EMP for the 15km Powerline.
2005 to 2006	Project Manager	**Crayfish Holding Facility, Retail Outlet and Educational Trips, Western Cape, South Africa:** Appointed by Viakor Sewe to undertake and EIA and EMP which included an intensive Public Participation Process.
2005	Project Manager	**66kV Powerline between Vryheid and Riviersonderend, Western Cape, South Africa:** Appointed by Eskom Distribution to undertake and EIA and EMP for the 42km Powerline as well as upgrading of the Riviersonderend 66/11kV Substation.
2004	Project Manager	**66kV Powerline between Bredasdorp and Struisbaai, Western Cape, South Africa:** Appointed by Eskom Distribution to undertake and EIA and EMP for the 32km Powerline and 66/11kV Substation.

4) Institutional and Policy Development and Professional Review Services:

2009 to 2010	Project Leader	**Situational Environmental Analysis, Western Cape:** Appointed by Rode Plan with the client being Cape Winelands District Municipality to compile a situational environmental analysis with associated environmental spatial planning categories, environmental indicators and a decision making tool to assist the municipality in strategic assistance for future development within the spatial planning categories.
2007	Project Manager	**Integrated Safety, Health, Environmental & Quality Policy:** Appointed by Transnet Limited to compile an integrated SHEQ Policy in line with international management systems ISO 14001, OHSAS 18001, SANS 3000:1 and ISO 9001.
2004	Project Manager	**Integrated Safety, Health and Environmental Policy:** Appointed by Lesedi Nuclear Services to compile an integrated SHE Policy in line with international management systems ISO 14001 and OHSAS 18001.

5) Specialist Facilitation, Public Processes, Training and Social Surveys:

2016	Lecturer	**ISO31000:2009 Risk Management Methodology Lecturing, Bellville Campus, South Africa:** Appointed by Cape Peninsula University of Technology (CPUT) to train the Systems & Industrial Engineering Faculty lecturers on ISO31000:2009 – Risk Management: Principles and Guidelines supported by ISO31010:2009 – Risk Management: Tools and Techniques. The training module included approaches to grappling with “uncertainty” (qualitative and quantitative techniques), case studies, operational risk management and risk-based thinking in an Integrated Management System (IMS) context.
2016	Lead Risk Manager	**Executive Management Risk Workshop Facilitation, TransGrid, New South Whales, Australia:** Appointed by TransGrid to assist its Executive Management and Group Management understand its current risk culture and risk appetite along with change management implications for its new ownership model. Facilitated a two day risk workshop which focussed on risk advisory pertaining to integrated management systems and the operational risk management model maturity. The facilitation included using the Delphi Technique with voting devices to ensure a more engaged workshop environment and objective perspective on each criteria voted. The workshop included facilitating the determination of Business Objectives and its criticality ranking.
2010	Lecturer	**Environmental Auditing Lecturing, Stellenbosch University, South Africa:** Appointed by Stellenbosch University to train the Civil Engineering Faculty Honours Class on Environmental Auditing, Environmental Control Officer Duties and Environmental Management Systems as part of the Environmental Engineering curricula.
2008	Project Manager	**400kV Powerline with loop in and loop out plus Five Substations for the Sishen – Saldanha Railway Expansion Project, Western & Northern Cape:** Appointed by Nzumbululo Heritage Resources with Eskom Transmission as the client to undertake a comprehensive Public Participation Process as part of the EIA.
2004	Project Manager	**Crayfish Holding Facility, Hout Bay, Western Cape, South Africa:** Appointed by Bluefin Holdings to undertake a Public Participation Process in terms of the requirements as set in the RoD by DEA&DP.
2002 to 2003	Project Manager	**Environmental Awareness Training, Cape Town, South Africa:** Appointed by Transnet Port Terminals to train staff ranging from Management to Supervisory level on environmental impacts of the Ports activities.
2002	Lecturer	**Risk Assessment Methodology Lecturing, Cape Town, South Africa:** Appointed by Cape Peninsula University of Technology to lecture 4th year B.Tech Environmental Management Students.

6) Environmental Control Officer Services:

2013	Project Leader	**Koeberg Training Centre, Cape Town, South Africa:** Project management of the Environmental Control Officer as well as reviewing of monthly audit checklists.
2011	Project Leader	**Piketberg Waste Water Treatment Works, Piketberg, South Africa:** Project management of the Environmental Control Officer as well as reviewing of monthly audit checklists.
2010	Project Leader	**Aurecon Building, Century City, Cape Town, South Africa:** Project management of the Environmental Control Officer assigned to the principal contractor (Murray & Roberts) as well as reviewing of the Construction Environmental Management Plan, Method Statements and Monthly Audit Checklists.
2009 to 2010	Project Leader	**Trunk Rd 22 Extension, Western Cape, South Africa:** Project management of the Environmental Control Officer as well as reviewing of monthly audit checklists.
2009 to 2010	Project Leader	**Alphen Pumpstation, Western Cape, South Africa:** Project management of the Environmental Control Officer as well as reviewing of monthly audit checklists.
2009 to 2010	Project Leader	**Cape Flats Waste Water Treatment Works, Western Cape, South Africa:** Project management of the Environmental Control Officer as well as reviewing of monthly audit checklists.
2009 to 2010	Project Leader	**Contermanskloof Water Main Pipeline (Phase I & II), Western Cape, South Africa:** Project management of the Environmental Control Officers as well as reviewing of monthly audit checklists, alien vegetation removal co-ordination and rehabilitation supervision.
2006 to 2008	Project Manager	**132kV Blanco – Outeniqua Powerline and Substation Extensions, George, Western Cape, South Africa:** Appointed by Eskom Distribution to fulfil the ECO function as well as to Chair the Environmental Liaison Committee Meetings for the construction phase of the project. Responsibilities included site assessments to ensure compliance with the Environmental Authorisation and EMP as well as Chairing monthly ELC meetings.
2003	Environmental Consultant	**Chapman's Peak Rehabilitation Project, Western Cape, South Africa:** Appointed by The Environmental Partnership with client being PAWC to undertake the ECO function for the rehabilitation project which included supervision of the rock barring process.

Countries of work experience:

South Africa, Australia, China, Kenya, Namibia, Mozambique, Democratic République of the Congo (DRC), Nigeria (Lagos / Asaba) & Dubai, United Arab Emirates (UAE).

Education:

Current	:	PhD Engineering Management, University of Pretoria. Dissertation Topic: *Semi-Quantitative Risk Analysis as the Basis for Risk-Based Management Systems in a Port Portfolio in South Africa*
2011	:	MPhil Environmental Management *(Cum Laude)*, Stellenbosch University, Cape Town
2002	:	B.Tech Environmental Management *(Cum Laude)*, Cape Peninsula University of Technology, South Africa
2001	:	N.Dip Environmental Management, Cape Peninsula University of Technology, South Africa

Professional Affiliations:

- Institute of Risk Management South Africa (IRMSA): Associate Member
- Disaster Management Institute of Southern Africa (DMISA): Corporate Member
- South African Council for Natural Scientific Professions (SACNASP): Professional Natural Scientist
- South African Institute of Ecologists and Environmental Scientists (SAIEES): Professional Member
- Committee Member for the Western Cape branch, International Association for Impact Assessments South Africa (IAIAsa) : 2009 - 2011

Publications:

Van Wyk, S (2016) Risk – Can We Predict The Unpredictable? Should We? Just Imagine. http://www.aeol.com.au/databases/news/16/07/aurecon_risk.html

Van Wyk, S (2015) Pioneering excellence in operational and project risk management. Construction World. March 2015.

Van Wyk, S (2014) B4Risk: Integration of strategy, management systems and risk solutions. Civil Engineering. November 2014 Issue.

Van Wyk, S (2014) A critical analysis of the NEM: ICMA as it pertains to development within the coastal protection zone of proclaimed fishing harbours in the Western Cape. PositionIT (March Ed.).

Van Wyk, S (2013) Responsible Development of South Africa's Coasts. Civil Engineering Contractor. June 2013. Pg. 45 – 50.

Van Wyk, S (2013) A critical analysis of the NEM: ICMA as it pertains to development within the coastal protection zone of proclaimed fishing harbours in the Western Cape. Civil Engineering.

Van Wyk, S (2012) A New Perspective on Risk Management. Fire and Rescue International. Vol. 1 No. 8.

Van Wyk, S & Joyce, C (2012) Grappling with Risk Complexity: An insight into multi-scalar and multi-dimensional risk scenarios. Civil Engineering. July 2012 Issue.

Van Wyk, S (2012) The role that EIAs play in promoting sustainability in South Africa. Energize – Sustainable Energy. May Ed.

Van Wyk, S (2012) The Value of Risk Profiling: Case Study on Strategic Borrow Pits, Beaufort West, Western Cape. Civil Engineering. Vol. 20 No. 1.

Van Wyk, S (2012) Metamorphic Risk – Disaster vs. Operational Risk. Fire and Rescue International. Vol. 1 No. 7.

Louw, E & Van Wyk, S (2011) Disaster Risk Management: Planning for Resilient and Sustainable Societies. Civil Engineering. Vol. 19 No. 7.

Van Wyk, S (2011) The Introduction of an Environmental Aspect Assessment & Risk Management Tool: A Companion to the ISO 14001 Environmental Management Systems Standard. International Association for Impact assessments South Africa (IAIAsa) National Conference.

Shippey, K, Erasmus, D, Norman, C & Van Wyk, S (2011) Cumulative Impact: Stepping EA up for Sustainability. International Association for Impact assessments South Africa (IAIAsa) National Conference.

LinkedIn Original Posts:

September 20, 2016:	Controlling 'Controls'
September 6, 2016:	The Risk Metaverse. Gateway to an augmented reality…
September 2, 2016:	Risk Management Effectiveness Traceability and Validation, the 'Unobtanium'
August 26, 2016:	Business Risk – It's all about Social Change
July 29, 2016:	A Value Proposition for Hazard & Operability (HAZOP) and Hazard Constructability (HAZCON) Studies
July 19, 2016:	Risk – can we predict the unpredictable? Should We?
June 27, 2016:	Is Risk Binary?
June 22, 2016:	Is it plausible to prove Continual Improvement, Principle (k) of ISO31000:2009 using a Risk Register?
June 15, 2016:	Risk Managers or Uncertainty Advisors?
June 14, 2016:	A 'purple squirrel': Unobtanium?
June 13, 2016:	Does this image make you consider perception, lack of confidence or an appreciation for 'uncertainty'?
June 10, 2016:	The Day Risk Went 'Ape'...

Languages:

	Speaking	**Reading**	**Writing**
English	Excellent	Excellent	Excellent
Afrikaans	Good	Good	Average

Courses & Conferences:

20 – 21 June 2016. **Business Continuity Management: ISO22301, ISO23313, PAS200, BCI Good Practice Guidelines (2013).** Institute of Risk Management South Africa.

11 – 12 November 2015. **ISO 9001:2015 Quality Management Standard Course**. Comet Solutions. Endorsed by ECSA & SAAMA.

16 – 19 March 2015. **Hazard and Operability (HAZOP) Advanced Course**. ISHECON.

23, 24 & 26 July 2013. **BarnOwl Risk Management. Introductory, Advanced and Administrator Course.** IDI Technologies.

22 – 24 April 2013. ***@RISK 6.1 Monte Carlo Analysis Software Training***. Palisade.

8 February 2013. **Level 1 SUSOP® Training Course**. SUSOP Pty Ltd c/- Sustainable Minerals Institute, University of Queensland

November 2012. Key Note Address. Rose, D & Van Wyk, S. Road Pavements Forum. ***Impacts of new legislation and application of the Acts and Ordinances on getting approval to open borrow sources for road materials***. CSIR International Convention Centre. Pretoria.

October 2012. ***ISO31000:2009 International Risk Management Compliance Course***. Khula Development Corporation. ECSA & SAAMA Accredited.

October 2011. ***Disaster Management Institute of Southern Africa (DMISA) National Conference***. Somerset West, Cape Town.

September 2011. ***International Association for Impact Assessments South Africa (IAIAsa) National Conference***. Pietermaritzburg, Kwazulu-Natal.

May 2007. ***Occupational Health, Safety Management and Legislation Course***. LexisNexis.

Awards:

2015, Institute of Risk Management South Africa (IRMSA), ***Winner*** of the '***Risk Consultancy Services***' in the Industry Specific Risk Initiative.

2014, Institute of Risk Management South Africa (IRMSA), ***Winner*** of the '***Risk Consultancy Services***' in the Industry Specific Risk Initiative.

2013, Institute of Risk Management South Africa (IRMSA), ***Winner*** of the '***Environmental Category***' in the Industry Specific Risk Initiative.

2013, Institute of Risk Management South Africa (IRMSA), ***Runner Up*** of the '***Mining, Resources, Construction, Engineering and Related Services Category***' in the Industry Specific Risk Initiative.

2012, Aurecon Award for '***Project Delivery Excellence'*** of the Aurecon Building, Cape Town. South Africa's first 5 Star Green Building Council of South Africa certified building for sustainable development.

2002, ***Special SHE Commendation*** 'Outstanding contribution to the Implementation of the ISO & OHSAS Integrated SHE System', Eskom Generation: Nuclear Cluster

Stephen Hodgkinson Technical Director Energy Services

Qualifications

BE(Hons) UNSW 1982

Member IEEE

Member of the Institution of Engineers Australia

Specialisation

Power Systems Analysis

Transmission Lines

High Voltage Substations

Years in industry

32

Stephen has extensive experience in the electricity supply industry and has worked in both the transmission and distribution sectors. He has undertaken power system analysis studies for the South East Australian transmission system and had a lead role in the design of a number of overhead transmission lines, high voltage substations and underground cable projects with responsibility for both the broad design parameters and detailed design.

Project experience

Aurecon Australia Pty Ltd - Technical Director, Energy Services
July 2007 to November 2015

Projects include:

- Olympic Dam mine expansion project. Examined power transfer capacity for large mine project supplied by a 260 kilometre radial 275kV transmission line, including reactive plant support requirements, voltage stability, load rejection and line thermal rating.

  Carried out power system loadflow and voltage stability studies to determine network concept for connection of proposed copper mine to South Australian 275kV transmission network via a 180 kilometre 275kV transmission line.
- Electromagnetic induction studies to assess earth potential rise and touch potentials for a water pipeline in close proximity to a 132kV overhead transmission line. Determined safety requirements for pipeline.
- Power system loadflow, fault level, equipment rating and transient stability studies for the 250MW Silverton wind farm project including scoping of reactive plant requirements, voltage control, wind farm transient stability and ride through response to fault conditions on the interconnected 500/330/220kV network. Developed wind generation runback scheme to enable wind farm to be connected to a long radial network.
- Network studies to assess equipment rating, transformer requirement, reactive plant and network fault levels for a 220kV high voltage transmission network to supply the Roy Hill mine from five unit gas turbine power station.
- EMTP electromagnetic transient analysis studies to assess performance of 330kV and 275kV overhead lines to evaluate line lightning performance when the lines are fitted with surge arresters.
- Carried out design reviews for 500kV insulation designs for new transmission line project. Developed high voltage testing specification and managed high voltage tests on 500kV insulator arrangements for Halys-Blackwall transmission line. Tests carried out included radio interference, lightning impulse, switching impulse and high current test.
- Modelling of 220kV fault levels for the redevelopment of the SP Ausnet West Melbourne substation using system data for the interconnected transmission network.
- Prepared electrical designs for planned 750kilometre 330kV and 220kV double circuit transmission line project in central Queensland including studies to determine conductor requirements, insulation design, electrical clearances and lightning performance and equipment specifications.
- Hobson St 220/110kV substation GIS substation concept design. Role included design of primary layout for 220kV and 110kV gas insulated switchgear, multi-level switchgear

building, transformer enclosures and cable tunnels to integrate onto a confined CBD site and 220kV and 110kV underground cables. Role also included EMF assessment and earth grid concept design.

- Managed studies to assess surface voltage gradient and corona performance for conversion of 220kV Broken Hill single circuit overhead line to 275kV operation for proposed wind farm
- Network load flow studies and equipment ratings assessment to determine transmission augmentations required to supply a major industrial load to be connected to the north west NSW 132kV transmission network.
- For Eastlake 132/11kV substation, undertook preliminary layout of gas insulated switchgear, substation layout and overhead and underground cable concepts.
- Managed cable loading, fault level, voltage unbalance and induced voltage studies on 275kV underground cable project in Adelaide to assess impact on underground gas pipelines and telecommunications facilities.
- Tomago 330/132kV substation. Role included primary layout design, earth grid, lightning protection, short circuit terminal loads, high voltage equipment selection, insulation coordination and review of secondary systems and protection design.
- Managed studies to assess network load flow and fault levels for the concept design for proposed Sydney Metro rail system
- Queanbeyan 132/66kV substation. Role included primary layout design, earth grid, lightning protection and insulation coordination and review of protection design
- Undertook EMTP insulation coordination studies for design of 275kV substation to connect North Brown Hill Wind Farm to transmission network
- Wagga North 132/66kV, Raleigh 132/33/11kV, Boambee 132/66/11kV and Macksville 132/11kV substations. Role included primary layout design review, earth grid and lightning protection and insulation coordination design review.
- Olympic Dam Expansion. Prepared concepts for new 275kV line connections including insulation, conductors and 275/132kV substation augmentations.
- Carlingford substation. Undertook thermal rating studies for 132/66kV transformers to assess transformer overload capacity for present day loading

TransGrid – High Voltage Design Manager
1995-July 2007

- Manage a team of professional engineers and engineering officers responsible for the electrical design of overhead transmission lines and high voltage substation switchyards.

  This position was a technical specialist position that determined performance criteria for insulation coordination, electrical clearances, conductor selection, overhead line vibration design, corona performance, electrical safety, and coordination of power and telecommunications facilities. This position provided specialist advice to other groups within TransGrid as well as being responsible for development of substation and overhead line design standards and purchase specifications for insulators, conductor and optical fibre ground wires.

  Experience includes a wide range of transmission line and substation projects, including development of Bayswater and Mt Piper 500 kV substation layouts, Coffs Harbour 330 kV substation augmentation, Yass substation reconstruction.
- Queensland-NSW interconnection 330kV transmission line. Role included selection of transmission line design parameters for towers and compact poles, insulation design, transmission line lightning performance, corona design, earthing.
- Queensland-NSW interconnection 330kV substations. Role included primary layout design of rebuild of Armidale 330/132kV substation and design review for static var

compensator. Undertook primary layout design and earth grid design of new substation at Dumaresq.

- Sydney CBD Haymarket 330/132kV substation. Role included primary layout design for gas insulated switchgear and gas insulated transformers and reactors, earth grid design, 330kV and 132kV underground cable layout, 330kV cable cross bonding and earthing; mitigation of 330kV cable earth potential rise and step and touch voltages.
- Lead role on TransGrid consultancy projects for the design of the Hadspen 220/110 kV substation in Tasmania, specialist corona studies for a proposed 330 kV compact pole line for Western Power and concept design studies for the proposed Transpower New Zealand 400 kV transmission lines and substations.
- Undertook insulation coordination studies for TNB (Malaysia) 275kV and 132kV substations.
- Managed an ARC Linkage research project with Queensland University of Technology to assess aging mechanisms for composite insulators.

ECNSW/Pacific Power - Transmission Line Electrical Design

1990-1995

- Responsible for the electrical design of overhead lines, technical investigations concerning transmission line insulation coordination and line design parameters and development of line design computer software.
- Transmission line design specialist member of PPI/SECVI consultancy team for Vietnam North-South 500 kV transmission line project. Involvement included verification of the overall line design, lightning performance and field investigations in Vietnam of transmission line tower earthing.
- Undertook specialist surface voltage gradient and radio interference studies for CSIRO for the proposed Narrabri-Wee Waa 132 kV transmission line.
- Under the electrical design of the Mt Piper to Marulan 500kV double circuit transmission line including insulation coordination studies and high voltage testing of 500kV insulator string assemblies.
- Performed specialist transmission line electric and magnetic field studies for Electricity Commission submission to the 1991 Gibbs Inquiry into Electricity Transmission in NSW.

ECNSW - System Planning

1988-1991

- Load flow and transient stability studies for the interconnected NSW-SECV-ETSA transmission system. Undertook load flow and transient stability feasibility studies into proposed Queensland-NSW 330kV AC interconnection; coordinated field commissioning and power system testing of Kemps Creek SVC. Performed transient stability studies to assess transmission line coordination of line protection clearing times with system stability.
- Undertook technical and economic evaluation of future transmission system needs for metropolitan Sydney. Duties includes liaison design, project and system operation groups and with external supply authorities for joint planning requirements and load flow and fault level analysis of ECNSW transmission network.

ECNSW - Transmission Line Design

1986-1988

- Technical investigations concerning design, construction and maintenance of high voltage transmission lines. Development of line design computer software.
- Carried out technical investigations for the performance of high voltage insulators and transmission insulation coordination.

Sydney County Council - Protection Design

1985-1986

- Carried out sub-transmission protection system designs, settings and fault calculations; relay purchasing and testing; investigations into abnormal protection operations. Examined operation of 11kV feeder Sensitive Earth Leakage protection relays and their interaction with delta-star 33/11kV transformers.

Sydney County Council - Eastern Area

1983-1984

- Supervision and coordination of distribution construction and maintenance staff. Carried out design and coordination of distribution mains and substation augmentations; distribution and sub-transmission protection designs, settings and maintenance.

Sydney County Council - Distribution System Planning

1982-1983

- System Planning studies for zone substation development plans, network load forecasts; 33 kV and 132 kV power system investigations.

Sydney County Council - Engineering Cadet

1977-1982

- Engineering cadet employed on a rotational training scheme, with experience in workshops, design, system planning and electrical testing

Qualifications

MENG (Hons) Materials Design and Engineering

Chartered Engineer

Member of Institution of Engineering and Technology

Specialisation

Client relationships

Transmission Lines

Years in industry

20

Steve Redhead Technical Director Energy Services

Steve has over 17 years experience in the electricity supply industry specialising in transmission design to 500kV. He has been involved with the whole of asset lifecycle including regulation, business case development, through design process to construction supervision and commissioning. In recent years Steve has been instrumental in developing key client relationships at all levels of organisations as Client Relations Executive for a number of energy companies to trusted advisor status. He has worked on projects throughout Europe, USA Australia and NZ and brings experience of international best practice. He is also a member of the Cigre AP B2 for overhead lines.

Experience

Aurecon Australia Pty Ltd (Formerly Connell Wagner)
2007 - Present
Technical Director

- Failure analysis of 220kV tower
- Installation issues investigation with large AAAC stringing
- Detailed design of over 1000km of HV transmission line for Copperstring Project QLD
- Project manage 9000km of Overhead Line ALS data submissions on behalf of TransGrid
- Design 330kV transmission line Dumeresq - Lismore
- Design 132kV circuit turn-ins and reconfigurations for Orange North Switching station
- Design double circuit 132kV concrete pole transmission line Kempsey - Port Macquarie
- Design double circuit 132kV concrete pole transmission line Tamworth - Gunaddah
- Provide solutions to overcome clearance infringements using finite element methods for numerous TransGrid 300kV and 132kV lines
- Specification for 66kV transmission line at Daunia Mine
- Benchmark 500kV Transmission Line costing - Bannaby to Sydney 500kV Line Development
- Uprating investigation for TransGrid 330 kV Tumut - Yass line
- Uprating investigation for TransGrid 330 kV Tumut - Canberra

National Grid, Network Mapping – Design Project manager
2002 – October 2007

- Manage a team of engineers providing a complete OHL design service for existing and new build overhead lines, providing added value engineering solutions such as line analysis, line upgrading, re-routing and new build design. Based on data from ALS capture techniques and use of finite element method design software such as PLS-CADD.
- Managed ALS projects for international clients requiring financial control, specification interpretation and planning through to delivery.

- Project Managed thermal uprating program for National Grid Company 400kV and 275kV system delivering on average 8% ratings enhancement for minimal work (zero outage requirements) and on average 15% ratings enhancement using re tensioning and suspension clamp displacement techniques.
- Managed incorporation of British line design standards into PLS-CADD line design software.
- Assisted in introducing Aerial Laser survey techniques to National Grid USA. Produced specifications for complete asset management solution for Overhead Line data for NG-USA network.
- Introduced replacement Geographical Information system within National Grid, introduced at minimal cost using data captured from the aerial laser survey projects. Combined Asset Management Information and Wayleave Information systems within a GIS environment.
- Specified, and managed the IS infrastructure for Network Mapping with particular focus on data security and worldwide communications.
- Responsible for seeking and implementing new applications for captured data and managing through to product deliverable.

National Grid – Overhead Line Policy Engineer

2001 – 2002

- Development of engineering documentation and drafting of technical specifications for OHLs to facilitate the design, supply, erect and maintain strategy for NGC.
- Work with transmission design to develop long term policy and strategies for application of new technologies.
- Project management of R&D projects.
- First line technical support to maintenance staff.
- Audible noise responsibilities, in a technical advisor role.
- Produce technical specifications for OHL transmission equipment
- Project managed R&D project Composite Insulator application for 400kV overhead lines

National Grid – Scheme Support Engineer

1998 – 2001

- Provided technical advice on all transmission plant items, with particular focus on overhead line issues, inputting to multi- million pound connection and infrastructure schemes, capital asset replacement schemes and overseas projects.
- Responsible for studying new capital delivery schemes to identify technological issues such as design, rating and environmental impact. Required to liaise with other technical experts within Engineering & Technology and other operating units to provide the scheme team with relevant information within tight timescales, to allow timely completion of feasibility in order to be presented to the board for project sanction. In the case of overseas work, technological solutions were required to assist NGC in winning contracts.
- Expanded audible noise responsibilities to attending public consultations.
- Responsibility for Type Approval of new insulators and conductor fittings for use on the NGC transmission system, from UK and overseas suppliers. The work encompassed many aspects including design review, type testing, and approval of drawings/designs and subsequent test documentation.
- Responsible for project managing R&D projects including Audible noise research, which involved full scale erection trials of a triple bundle (novel for use in the UK) and developing a strategy for prevention of birds roosting on overhead line lattice steel structures. These had a combined budget of £500k and involved managing various numbers of people and cross-functional working.

National Grid - Overhead Lines and Environmental Sciences Engineer
1996–1998

- Responsible for all aspect of overhead transmission line design, with a focus on investigation of public complaints, regarding environmental issues with Overhead Lines (OHL) and instigating remedial actions to alleviate problems.
- Responsible for audible noise surveys to specify noise specifications for new or uprated plant with the intention of minimising the impact on third parties and the public. Further responsibilities included providing technical advice on audible noise for inclusion in planning applications, Environmental Statements, consent reviews and public enquiries, (and also extended to external clients as a service).
- Natural pollution testing of polymeric overhead line insulation at testing station at Dungeness. This involved, collating test data, reporting and software development.

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