1. INTRODUCTION

This Asset Management Plan (AMP) describes how we manage our assets. It outlines our approach to asset management, our asset classes, and details the forecast replacement and refurbishment base capital (Capex) and operational (Opex) expenditure for the period 1 July 2017 through to 30 June 2035\(^1\).

This AMP is one of three supporting documents within our 2017 Integrated Transmission Plan (ITP), as illustrated in Figure 1.

Figure 1: The 2017 ITP Narrative and supporting documents

This year’s AMP has been updated to reflect the substantial amount of work that has gone into refreshing and renewing our strategy, planning, and delivery functions. It incorporates our updated approach to grid asset management, reflects our continuous improvements in Information and Communications Technology (ICT) strategy, and changes in managing our business support assets. It was approved by the Board for publication in August 2017.

We trust you find the AMP both informative and useful.

This section covers:
- Strategic context
- Our asset portfolios
- The structure of this document

STRATEGIC CONTEXT

Our approach to asset management and the plans presented in this AMP, are underpinned by the principles described within Transmission Tomorrow and our Corporate Strategy suite. These are described in the 2017 ITP Narrative. The objective of these principles and strategies is to achieve our purpose. Our business operates at the heart of New Zealand, powering our economy and way of life. Our purpose emphasises safety, our drive to find smart solutions, and a long-term perspective.

We connect New Zealanders to their power system, through safe, smart solutions for today and tomorrow.

\(^1\) Our forecast grid enhancement and development capital expenditure is discussed within the 2017 Transmission Planning Report. All data in figures and tables is at 30 June 2017, unless otherwise stated.
We are aware that the world in which we operate is constantly changing, and more so now than ever. As new technologies emerge, business models evolve, and our customers and end use consumers find new and innovative ways to realise the benefits that these bring; we have a vital role to play in enabling and adapting to this new environment.

As such, we are working to make our business more service orientated for our customers and end use consumers. We have a continual focus on reducing costs, and becoming more innovative while sustaining a focus on good asset stewardship and risk management. We are working with care within our communities, working hard to keep the lights on, and being careful on how we spend money. This AMP reflects this context.

**OUR ASSET PORTFOLIOS**

- We have classified our assets into three portfolio categories. These are:
  - Grid Asset Portfolios. These cover our primary and secondary grid assets. They are further categorised into seven portfolios that reflect the different asset characteristics. These are AC Stations (ACS), Transmission Lines (TL), Buildings and Grounds, High Voltage Direct Current (HVDC), Reactive, and Secondary Assets.
  - Information and Communications Technology (ICT) Portfolios. The ICT Portfolios cover our ICT related assets, categorised according to business function, including Asset Management Systems, Transmission Systems, Shared Services, Corporate Services, and Telecommunications, Network and Security Services.
  - Business Support Assets Portfolio. The Business Support Assets Portfolio incorporates our corporate buildings, vehicle fleet and other equipment used for our day to day operations that are not directly related to the grid itself.

**STRUCTURE OF THIS DOCUMENT**

The AMP is structured into four parts. The first provides an overview of our approach to asset management for the three asset portfolio categories: Grid, ICT, and Business Support. It also describes the underlying basis for our asset management decisions, including how we manage risk. It concludes with a summary of the forecast Capex and Opex expenditure.

The remaining three parts detail the portfolio plans for each portfolio.

Figure 2 illustrates the structure of this AMP.
2. PLAN SUMMARY

Since publication of our 2016 AMP we have undertaken a significant amount of development and continuous improvement work. This includes the implementation of our new grid planning processes, decision framework, asset health and criticality modelling, and we have started to incorporate our risk bow-ties into our asset class plans. For ICT, we have moved to a ‘life cycle, benefits driven, leading’ investment approach where our investment planning is based on business capability requirements and outcomes integrated with our view on required life cycle investments. We are also continuing to evolve and develop the management of our business support to ensure they provide capability required. As such, there are many changes to this year’s AMP to reflect the significant progress we have made.

GRID EXPENDITURE

- Our grid asset class programmes include some of our largest expenditure by value, and include such activities as transformer replacements, outdoor to indoor conversions, and tower painting. The application of new grid planning processes has resulted in several key changes to our RCP 2 and RCP 3 expenditure forecasts. We have also continued with our focus on finding innovations leading to savings within our portfolios and driving an overall lower cost of ownership.

- We introduced the portfolio savings programme to help us drive cost savings in our everyday work by development and implementation of innovation. The objective was to reduce the grid Base Capex for RCP 2 by $24 million. The portfolio savings programme was run between August 2015 to 30 June 2017 and resulted in a reduction to the RCP 2 forecast of $26 million. Many of the changes resulted in enduring savings and the forecast presented in this AMP are net of these savings.

- After accounting for the savings across our asset portfolios, we still expect an overall increase in investment requirements over the remainder of RCP 2, and RCP 3. The increase is primarily driven from:
  - The rebalancing of our forecasts across asset classes driven from the refinement of our asset health and criticality modelling determining the need for additional works in some asset classes
  - An update of forecast unit costs of asset replacements based on the actual costs of works completed
  - The required refresh of our assets in such items as substation management and the midlife refurbishment of the Pole 2 of the HVDC
  - The increasing need for painting of towers driven by recoating of previously painted towers
  - The forecast requirements for reconductoring into RCP 3 and RCP 4
  - An increasing Opex forecast from optimising the balance between Capex and Opex, ultimately reducing the need for earlier capital investment in our assets.

- Figure 3 below is a summary of our proposed expenditure for RCP 2 and RCP 3 compared with the figures in the 2016 AMP. Based on our current bottom up Base R & R Capex forecasts we expect to commission assets with a total value of $858 million during RCP 2 and $1.1 billion in RCP 3. However, as outlined in our 2017 ITP Narrative, we are considering both a bottom up and a top down view for RCP 3. An indicative top down, and as yet untested, view of RCP 3 is also presented by the dashed line in Figure 3. We expect our current bottom up estimate for RCP 4 will move closer to the indicative line as we further develop and refine our planning.
There are a number of emerging trends both in our operational environment and in the technology available to us that will influence how we invest in the grid into the future. This includes the impact that electric vehicles will have on the shape of demand for electricity, and as storage solutions become more affordable, the value that our customers and end consumers place on our services will change. From a grid management perspective, the advent of digital substations and sophisticated control solutions, enhancement in our use of health and condition information through big data analytics will change what and how we invest.

GRID EXPENDITURE UNCERTAINTY

Each Asset Class Plan in this AMP specifies the key uncertainties embodied in the expenditure forecast for that asset class. However, the following uncertainties relate to all asset classes and across all asset classes:

- There are still asset data gaps and issues with data quality which are being managed through a dedicated programme of work within our Asset Information Section.
- Resource Planning and deliverability testing will be a key area for us to address in the next year. Such planning will extend to our internal and external workforce to ensure our plans are robust and deliverable. The expenditure plans set out in this AMP have not had deliverability testing applied.
- We are still refining our building block rates to better estimate costs; these are expected to become more accurate as we receive and analyse actual delivery costs.
- We have recently ceased all live line work practices, except for joint testing, which under current technology must be conducted live. We undertook a thorough review of our live line decision-making process, and following this, the amount of work that may be performed live is small and it would be difficult to maintain live line competency across our workforce over the long-term. At the time of writing this plan, we are currently working through the detailed implications eliminating live line work from our practices. We have not yet concluded what any cost implications might be.
**ICT EXPENDITURE**

- Our ICT delivers and supports the infrastructure, server hardware and applications that interface with the grid and support our corporate processes and systems. Following an in-depth review of the required business capability and business outcomes, we expect the underlying ICT expenditure to continue to reduce over time. This is due to the adoption of new business models and technology, such as software as a service and other cloud based services. However, there are also several one-off items that we expect to invest in during RCP 3, which will increase the total expenditure during that time, then stepping down in RCP 4.

- The overall themes for our ICT forecast are:
  - Prioritise business capabilities and outcomes required to support the business in delivery of our objectives and the challenges presented in Transmission Tomorrow.
  - Standardising and integration of systems and data to further streamline our processes and reduce the need for investment in parallel systems.
  - Life cycle refresh of key systems and infrastructure. As cloud based services mature, where appropriate we are looking to implement a structured implementation of software as a service. Key life cycle investment into the TransGO network and our Cook Strait fibre cables are also planned for RCP 3.
  - Continue to enhance key infrastructure security, with a focus on risk based cyber security investments.
  - A focus on reducing our operational expenditure through infrastructure rationalisation, improving capacity planning, and the introduction of open source technologies.
  - Continue to monitor technology trends and adopt where appropriate.
  - Our approach to ICT investments is to utilise emerging trends in the market. Overall, we consider there is significant potential in future years to further enhance our business and our processes to incorporate such things as extending our use of cloud based services, further enhancing our use of big data and analytics, and reviewing and monitoring of advancements such as intelligent systems, industrial digital platforms, and pervasive networking.

Figure 4 shows our forecast ICT investments.
BUSINESS SUPPORT

Business support assets cover non-critical substation buildings, our office buildings, vehicle fleet and office equipment. Overall, we expect our business support expenditure to be consistent across the period with a downward trend as we continue to refine our procurement approach. Following the consolidation of our two leased Wellington offices to a redeveloped site at 22 Boulcott Street, in October this year, we expect the overall level of business support expenditure to level out to a business as usual level. In the medium term, we are looking to utilise technology developments by updating our vehicle fleet to hybrid and electric vehicles, and following a review, the sale of unnecessary non-critical buildings. Our forecast expenditure is shown in Figure 5 below.

Figure 5: Business Support Expenditure

SUMMARY

Our forecasts of asset life cycle investments over the period covered by this plan reflects the significant amount of work we have undertaken. As we progress towards our submission for RCP 3 we will be further refining what we consider to be the right level of investment into our grid, ICT, and business support assets.
3. POWERING NEW ZEALANDERS: TODAY AND INTO THE FUTURE

We operate an essential service to which nearly everyone is connected. As a result, all New Zealanders can enjoy reliable access to energy that is transported to demand centres from the lowest cost sources of electricity. We manage approximately $5 billion of transmission assets, including $674 million of high-voltage direct current (HVDC) assets and $176 million of telecommunications assets. We plan to invest $4.1 billion over the forecast period covered by this AMP.

As a regulated monopoly, we operate in five-year regulatory control periods (RCPs). We are now operating in RCP 2 which is for the period 2015-2020. For RCP 2 we developed a set of service performance measures based on customer and end-consumer feedback about what was important to them. The Commerce Commission made further adjustments to derive the targeted levels of performance we operate under today. The measures are:

- **Grid performance measures.** These assess how reliable the grid is. Grid reliability is measured through the number of unplanned interruptions each year, the average duration of unplanned interruptions each year, and the 90th percentile duration of unplanned interruptions in minutes each year.

- **Asset performance measures.** These measures represent the availability of our inter-island high-voltage direct current (HVDC) system and the availability of selected high-voltage alternating circuits (HVAC).

- **Asset health measures.** These are works delivery measures. They measure the volumetric output for the number of towers painted, grillages commissioned, insulators commissioned, outdoor circuit breakers commissioned, transformers commissioned, and outdoor to indoor conversions commissioned.

The environment in which we operate is changing. In 2016, we published Transmission Tomorrow to provide a perspective on what the emergence of new and innovative technologies, and new business models, might mean for us and the wider electricity industry over the next five to forty years. Transmission Tomorrow identified six strategic priorities. Our six strategic priorities are:

1. Reduce our costs and evolve our services to remain competitive  
2. Play an active role in shaping the industry’s future  
3. Sustain our social licence to operate  
4. Match our infrastructure build to need over time  
5. Improve our asset management  
6. Develop our organisational effectiveness.

These six strategic priorities are reflected through our approach to asset management and our asset class plans. Further information on these strategic priorities and how we have incorporated them into our wider strategic approach across all our business activities is described in our 2017 ITP Narrative.
4. OUR APPROACH TO ASSET CLASS MANAGEMENT

This section provides an overview of our approach to asset management. In July 2014, we became one of the first companies in the New Zealand electricity industry to achieve certification against the international asset management specification PAS 55. In 2015 PAS 55 was withdrawn as a formal BSI specification and replaced with the ISO 55000 international standard for Asset Management. We are currently building into our business the fundamental components of ISO 55000. Our approach to asset management reflects the standard of care and focus required by these international standards.

Below we describe:
- Asset Management Governance
- Grid Asset Class Management
- ICT Asset Management
- Business Support Asset Management
- Environmental Enablers
- Continuous improvement and innovation
- Asset Management Capability

ASSET MANAGEMENT GOVERNANCE

We have a governance structure that ensures appropriate oversight is in place during the development and execution of our asset management activities. Our Asset Management System includes systems and processes to ensure a methodological approach to decision-making, promoting consistent, repeatable and appropriate actions.

We maintain organisational roles, responsibilities and authorities, consistent with implementing our policies, strategies and plans. This includes general management oversight and review through the Asset Management Leadership Team (AMLT). Similarly, advisory groups are available from which the AMLT can seek feedback.

Asset management decisions within Transpower reside with the divisions as described in Table 1.

<table>
<thead>
<tr>
<th>Asset Category</th>
<th>Divisions</th>
<th>Responsibilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grid Asset Management</td>
<td>Grid Development</td>
<td>Responsible for planning the national transmission grid, developing grid upgrade plans, managing the regulatory approval processes, and working with customers to develop their connection points</td>
</tr>
<tr>
<td></td>
<td>Grid Projects</td>
<td>Responsible for building grid enhancements – project management, procurement, supplier, and contract management. General Management Grid Projects is also accountable for our environment, stakeholders and customer management</td>
</tr>
<tr>
<td></td>
<td>Grid Performance</td>
<td>Responsible for maintaining the performance and operation of our grid assets such as substations and transmission lines, and property management related to our assets</td>
</tr>
<tr>
<td>ICT Asset Management</td>
<td>Information Services &amp; Technology</td>
<td>Responsible for maintenance and development of Transpower’s information services and technology</td>
</tr>
<tr>
<td>Business Enabling Assets and support functions</td>
<td>Corporate Services</td>
<td>Responsible for management of the company’s financial performance and position including management of its funding base, the relationships with the Commerce Commission and Electricity Authority, the company’s insurance programme, enterprise wide risk management framework and its property portfolio</td>
</tr>
</tbody>
</table>

Table 1: Asset Management Divisions
GRID ASSET CLASS MANAGEMENT

Our approach to managing grid assets is based on our asset management system, strategic goals, life cycle stages, and planning tools.

GRID ASSET MANAGEMENT SYSTEM

Our grid asset management system provides direction for the main activities of our Grid Business. It recognises the need for clear alignment between our strategic direction (including Transmission Tomorrow and our Corporate Strategy) and our ‘day-to-day’ processes and activities.

Figure 6 illustrates the key elements of this system. It shows the alignment between business drivers, our strategies and plans, the need for feedback and continuous improvement, and our focus on delivering customer value.

Figure 6: Grid Asset Management System Framework
Transmission Tomorrow explores the challenges and opportunities facing the electricity industry over the next five to forty years. It identifies our strategic priorities and how we will advance these. We use these strategic priorities to guide development of the Grid Business Strategy. Our Grid Business Strategic Plan describes our asset management system illustrated above, and five key principles that link Transmission Tomorrow through to our asset class strategies and plans.

Subsequently, for each of our asset classes, we have a set of documents that together describe how we plan and deliver the required asset management activities for each stage of the asset life cycle. These documents are:

- **Asset Class Strategies.** These describe the strategies and objectives specific to the management of individual asset classes throughout their life cycles. This covers planning, delivery, operation, and maintenance.

- **Portfolio Management Plans (PMPs).** These describe the application of the Asset Class Strategy and portfolio planning approach to each of the grid asset classes. In many cases, more than one strategy will apply to a PMP. Our PMPs contain forecast expenditure for 15 years, the first seven of which are more detailed.

- **Programme Management Plans.** These describe how the works plan is to be delivered. More than one PMP applies to each programme management plan, as works are integrated by location, work type, resources, and outage management requirements. The time horizon is 7 years with much of the detail covering the 2 years up to implementation.

These documents form the basis for the asset class plans presented in this AMP. The asset class plans provide a succinct summary of our approach to asset management for each of the asset classes and the asset management activities for each life cycle stage.

**GRID STRATEGIC PRINCIPLES AND GOALS**

Within our Grid Business Strategic Plan, we have developed five key principles we use to deliver our strategic priorities contained within Transmission Tomorrow. The application of these strategic principles establishes specific requirements for our management approach of each asset class. In summary, these principles are:

**Safety**

Safety is our foremost organisational value. We are committed to achieving an injury-free workplace for our employees and service providers, and to minimising public safety risks.

**Strategic Goals:**

- Safety is foremost in all our decision-making
- We lead efforts to improve safety practices in New Zealand, and set a benchmark for our stakeholders
- We minimise the risk our assets and activities pose to our workforce and the public
- Our work environment promotes the health and wellbeing of our workforce
- We extend our leading safety culture to our suppliers and service providers.

**Service Performance**

We will refine our performance measures to ensure they remain relevant to stakeholders, and set targets that support our ability to balance cost and performance.

**Strategic Goals:**

- We have agreed service levels with customers and we mutually understand the implications
- Service performance drives our investment decisions, leading to effective cost-service trade-offs
- We tailor our investments to support differentiated, competitive service offerings
- Refined processes will streamline new connections
- We deliver our workplan and minimise its impact on our stakeholders.

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2 We are progressively updating our older Fleet Strategies with new Asset Class Strategies.
Cost Performance
Delivering a valued transmission service requires that we provide acceptable service levels at an efficient cost. To achieve this, we will challenge ourselves to improve our cost performance through efficiency initiatives and innovation, allowing us to deliver our service targets at lower cost.

Strategic Goals:
- We consistently challenge ourselves to deliver value to New Zealand
- We understand what drives our costs, and continually challenge and review the underlying need
- We minimise life cycle costs while delivering expected service levels
- Our investments match known needs and achieve ‘least-regret’ outcomes
- We increase value by delivering quality outcomes, internally and with our service providers.

Customers & Stakeholders
Our customers, New Zealand’s communities, and the wider environment can be negatively impacted by our assets and activities. We aim to minimise these impacts as far as practicable and to build effective relationships with all our stakeholders.

Strategic Goals:
- As a trusted advisor, we engage with stakeholders to deliver the best national and regional outcomes
- We are respected and trusted by the electricity sector and its regulators
- Minimise the impact on landowners and communities hosting our assets
- Our activities are sustainable and have minimal impact on the environment
- We enable the technology choices of our customers.

Asset Management Capability
We will continue to develop our skills and competencies to ensure we achieve our safety, service, and cost objectives.

Strategic Goals:
- As a learning organisation, we value innovation and try new things to develop and improve our services
- Managing and embedding change is part of our culture of continuous improvement
- Our competency framework identifies capability gaps and ensures our skills-base is sustainable
- Staff and service providers know their roles and how they support our objectives
- We use the right information to fully understand the risks we manage.
GRID LIFE CYCLE STAGES

We have developed a ‘blueprint’ to explain the core functions and processes the Grid Business undertakes to manage the grid. It is based on a value chain approach, which has been used to identify our core asset management activities and reflect our end-to-end processes.

The blueprint is a functional view, with each core grid function including its defining processes, the people involved, and the tools that support them.

Figure 7 below shows a generalised version of the blueprint. It includes the following key components.

- Governance: reflects the oversight provided by our Board and management teams
- Strategic Direction: includes corporate-level and external drivers, including our Transmission Tomorrow strategic priorities
- Value Chain: the six life cycle stages used to manage our grid-related activities
- Core functions: the set of key functions undertaken as part of each value chain step, each of which will include multiple functions
- Asset Feedback and Monitoring: this process provides feedback on our performance and allows us to monitor key outcomes
- Enabling and Support Functions: includes shared services that support our grid functions, including IST and human resources.

Figure 7: Our blueprint of life cycle stages

The core functions that form part of each life cycle stage are described below.

**Strategic Planning**

The role of Strategic Planning is to provide medium and long-term planning and strategic guidance on how best to deliver a transmission system that meets the service requirements of users, is enduring, and cost effective. Strategic Planning’s five main functions are:

- System planning
- Asset management strategy development
- Setting service performance targets
- Identify, evaluate, and progress innovation
- Demand modelling.
Strategic planning establishes our overall management approach for each asset class, the specific objectives, and the performance targets. The objectives for each asset class are specified in accordance with our five grid strategic goals. Our asset class plans apply these objectives to both replacement and repair capital, and operational expenditure, including routine maintenance and inspections.

**Tactical Planning**

Tactical planning manages the application of the strategies to our asset base, ensuring our investment is targeted and prioritised to meet our strategic performance requirements over the medium term. Tactical includes six main functions:

- Asset planning
- Engineering design
- Asset health and criticality modelling
- Cost estimation
- Maintaining standards and specifications
- Developing site service continuity plans

Tactical Planning has the overall role of establishing our asset class plans and the works that are required to deliver an enduring and cost-effective grid. We identify and manage the condition of our assets through specified inspection and testing regimes, assess the options for intervention and plan the required works for each asset portfolio. This process is undertaken through the application of our decision framework, which provides a structured method of assessing the most efficient investment requirement for each asset class accounting for safety, statutory compliance, and deliverability. The decision framework, asset health modelling and criticality modelling are described further below.

**Planned Maintenance**

Planned maintenance keeps assets in an appropriate condition, ensure that they operate as required, and to proactively manage the risk of failure. Maintenance also covers our response to failures and defects as these occur. We classify maintenance within four work types:

- Preventive
- Corrective
- Predictive
- Proactive.

The four work types are summarised below.

**Preventive**

Preventive maintenance is work undertaken on a scheduled basis to ensure the continued safety and integrity of assets and to compile condition information for subsequent analysis and planning. Preventive maintenance is generally our most regular asset intervention, so it is important in terms of providing feedback of information into the overall asset management system. The main activities undertaken are listed below:

- Inspections: checks, patrols, and testing to confirm safety and integrity of assets, assess fitness for service, and identify follow up work.
- Condition assessments: activities performed to monitor asset condition and provide systematic records for analysis.
- Servicing: routine tasks performed on the asset to ensure asset condition is maintained at an acceptable level, such as adjustment and lubrication.

**Corrective**

Corrective maintenance is undertaken to restore an asset to service, make it safe or secure, prevent imminent failure, or address defects. The key distinguishing feature is that the work is initiated in response to unforeseen damage, degradation, or an operational failure. Corrective work is usually identified as a result of a fault or during preventive inspections. Failure to undertake urgent corrective work may result in reduced network reliability. Less urgent repairs are scheduled at the appropriate time when access, resources, and parts are available.
Corrective work activities include:

- Fault restoration: immediate response to a fault, or urgent repairs to equipment that has safety, environmental or operational implications.
- Repairs: unforeseen work necessary to repair damage, prevent failure or rapid degradation of equipment.
- Corrective Inspections: patrols or inspections used to check for public safety risks or conditions not directly related to the fault in the event of failure.

Predictive

Predictive maintenance is scheduled in response to condition-based inspection and monitoring programmes. This includes activities to replace components or repair assets to correct defects, wear and tear to return the asset to a defined standard that keeps it operational. Predictive maintenance also includes any additional targeted condition monitoring (such as thermographic imaging) to validate an existing condition assessment or predict likelihood of failure.

Maintenance projects are a form of predictive maintenance and typically involve condition-based replacement of assets or components or repairs, that are of a scale beyond the scope of routine maintenance. For example, lines projects typically bundle identical work (such as attachment point replacement) throughout a line route.

Proactive

Proactive maintenance is improvement work initiated from formal analysis and investigation by the engineering or reliability teams to reduce risk or provide an efficiency gain. Examples are asset modifications, one-off adjustments to scheduled activities, and condition monitoring programmes to provide more information or validate findings.

Cost estimation

For Capex cost estimation, we use a tool known as the Transpower Enterprise Estimating System (TEES). TEES provides consistent and traceable pricing, automated rate updates and centralised management of foreign exchange risk. This means we can more accurately estimate costs, which will lead to better and more accurate forecasts. For grid Capex costs, we use two forms of estimate:

- Customised estimates: Large single projects require individual, tailored investigation. To provide these estimates we develop project-specific scopes of work.
- Volumetric estimates: For smaller, high-volume projects that are routine and uniform. All volumetric estimates are based on TEES ‘building blocks’ which are cost items built up from individual components. If required, additional tailored scoping and costing cost items can be built into the volumetric estimation. For example, specific factors may be applied for site specific elements such as poor access, project risks, and items known in advance that materially alter outturn costs.

Contingency Planning

We have developed contingency plans for the grid. These cover specific asset types and situations that are envisaged. Generally, they cover such aspects as skilled manpower and emergency spares to enable restoration of services within specified timeframes. The timeframe is dependent on the type of asset involved and the criticality of the service provided. For example:

- For Transmission lines, contingency plans cover skilled manpower and emergency spares to enable restoration of the transmission service within one calendar week, with one emergency tower for every 800 in service and 30 spare poles located strategically throughout the country.
- For Substations, contingency plans cover skilled manpower and we hold spares to cover in-service equipment. We have a one spare emergency mobile 33/22/11kV switchroom, a mobile substation (15MVA 110kV/33-11kV) which can be used at N sites where site make-ready works have been undertaken (provided it is not in use for project or maintenance works). We hold sixteen strategic spare transformers which provide coverage for 98% of our entire present and future three-phase fleet with the aim to restore full security of supply within one calendar month of a major transformer failure. On-site spares are provided at most sites where single-phase transformers are installed.
Service Continuity for N sites, works with customers to ensure they are aware of the level of service provided, who is best to own risks associated with resilience and recovery and develop joint contingency plans to minimise service interruption.

Our risk and review processes also feed into contingency planning. These review processes include our Major Hazards Site Risk Review, Customer Hazard Risk Review, Condition and Reliability Review.

Programming and Scheduling

The role of programming and scheduling is to manage the timing of the works established within the Tactical Planning stage. The primary function of the programming and scheduling stage is to manage and maintain the grid works plans.

In many instances, the overall process of managing programming and scheduling is the same across asset classes and fulfils the function of integrating the work plans from across the asset classes into a comprehensive plan for delivering the required investment. The objective of programme management is to leverage and optimise the volume of related works to achieve efficiencies in time, cost, safety, and quality.

Programming occurs in the medium-term planning horizon once the work needed and general timing for this is confirmed. It ensures the works plan is feasible and as efficient as possible.

Scheduling occurs in a shorter time horizon, at a maximum of two years prior to the delivery year. It involves similar processes to programming, with the focus on refining the planning. Specific activities include:

- Scheduling the work and booking the associated outage/s
- Forecasting and confirming the specific resources required
- Planning for procurement of goods and services which may include placing orders for long lead time equipment.

Project Delivery

The role of project delivery is to construct and commission projects (grouped into programmes) identified within the Strategic and Tactical Planning stages. It involves the following main functions:

- Programme delivery management
- Plan and Deliver projects
- Commission assets
- Review works practices
- Acquire grid assets

Capital and maintenance projects are grouped into 14 programmes of similar or related projects. Most grid programmes are on-going over time, across multiple RCPs. A smaller number of programmes are established to deliver specific grid capability.

There is not always a one-to-one relationship between the scope of a delivery programme and the scope of an asset portfolio (and their respective management plans). For example:

- Multiple asset portfolios are delivered by the Primary Assets Programme, including indoor switchgear, LVAC switchboards, outdoor circuit breakers etc.
- Alternatively, one asset portfolio may be delivered by several programmes e.g. TL Conductor which delivers multiple large scale re-conductoring programmes.

In most cases, the management of project delivery is the same across asset classes. Delivery relies on activities such as procurement, active contract and cost management, internal and external stakeholder management, environmental assessment and property rights and stakeholder relationships.

Two project methodologies are used for delivery depending on the nature and scope of the project or programme. Volumetric projects use our Minor Project Delivery Framework, and larger scale, non-volumetric projects use the Investigation-Delivery Framework.

Our minor project delivery framework consists of four stages, supported by a monitoring and control function, and underpinned by our health and safety policy and practices. This is illustrated in Figure 8.
Together these methodologies have 5 common elements. These are:

1. **Design** – This stage involves the detailed design of the solutions. Project design is tailored to the size and complexity of jobs. All jobs require detailed design and large, complex jobs also include a conceptual design phase. For volumetric works standard designs are used where possible and design work is awarded on a programme rather than a project basis.

2. **Procurement** - Project procurement (for services and materials) largely involves working with our pre-selected panels. Depending on the size of a purchase (assets or services) the works will be either sole sourced or closed tendered to panel members. Panels have been established through competitive open tenders.

3. **Construction and Project Delivery** - Is the construction phase of the projects where we mobilise teams to carry out the works. Volumetric projects and programmes are allocated to Service Providers in a regional “patch” i.e. service area. Non-volumetric work is competitively tendered.
4. Commissioning – Commissioning includes planning, testing, livening, hand over, operational, and maintenance processes. Once all works are complete, our project close-out activities include final capitalisation of the project within our financial systems, providing feedback about actual costs to assist with future cost estimation, updating asset management information systems, archiving of the relevant documentation, the processing of ‘as-built drawings’ and the review of ‘lessons learned’ including a review of health and safety performance.

5. Decommissioning and Disposal – We make decommissioning and disposal decisions when we are replacing assets or removing redundant assets from service. We also dispose of equipment and materials as a result of servicing and repairs. In doing so, we take the interests of the local community (including iwi) and landowners into account. This includes consulting with customers, affected landowners, occupiers, and communities at an early stage of planning projects that involve disposal or removal of assets.

While most of work is delivered through these standard processes, and in themselves do not vary significantly between asset classes, where there are material and specific requirements for an asset class these requirements are described in our asset class plans.

Service Delivery
The role of service delivery is to maintain our assets through the delivery of maintenance services. This includes fault response, conducting routine maintenance requirements, regular inspections and testing of equipment and other field related services. It includes two main functions:

- Maintain Assets
- Manage Service Performance

We deliver our maintenance activities through the efforts of many people in wide-ranging and interdependent roles. Some are direct employees but the majority are external service providers. We have several different long-term service provider arrangements. These outsourced contracts are divided broadly into:

- **Lines**: Covering transmission lines, access ways, and fibre optics on transmission lines
- **Stations**: Covering our substations, including control and protection, revenue metering and communications equipment, and underground cables
- **Others**: Includes submarine cables, high-voltage (HV) cables and facilities (buildings and grounds).

The costs of service delivery are not directly related to a specific asset class and as such are determined at a business function level.

Operate the Grid
The role of grid operations is to manage the grid such that planned work can be carried out within a safe environment and that communication with parties involved is clear and complete. It involves the following main functions:

- Manage real time grid operations
- Outage Planning
- Manage 12-week outage window.

In the same manner that project and service delivery are in many cases similar across asset classes, operating the grid occurs independently of the asset class itself. A key component of grid operations is outage planning. The outage planning requirements for each asset class differs depending on the characteristics of the assets involved. However, where outages are required we co-ordinate with stakeholders prior, during, and post outage windows. We also ensure that to the extent possible work is co-ordinated to minimise the duration of any interruptions. Extensive communications with stakeholders is a key part of managing outages. Where there are specific requirements for an asset class, these are recorded in the asset class plans presented in Section 6, 7, and 8.
GRID PLANNING TOOLS AND FRAMEWORKS

To support good asset decision making it is necessary to have the appropriate tools. There are several key tools that we use to support our asset management decision making. These are:

- The decision framework
- Asset and condition information
- Asset health models
- Criticality and risk frameworks

Each of these is described in the sections below.

The Decision Framework

The decision framework is a transparent, robust and repeatable business process that enables consistent asset planning decisions that balance risk, service levels and expenditure. The process is used to determine and justify grid expenditure including all grid enhancements and developments, asset replacements and refurbishments, maintenance activities, customer projects and investigations.

Figure 10 illustrates the decision framework process.

Figure 10: Asset Planning Decision Framework

There are four key decision steps in the decision framework process. These are described below.
Identify the need
A need is a clearly defined problem and/or opportunity that is to be addressed. Identifying the need includes establishing a need date, and the planning lead time (i.e. the total time required to identify the solution, approve the delivery business case and complete/commission the delivery project). A need can include a group of problems that have a common solution or set of solutions.

Options assessed for each need
Options to address the need are assessed. Where a sole option is prescribed by an Asset Class Strategy, other options are not considered. Needs which are complex, expensive, and imminent, receive more rigor than those which are simple, inexpensive, or more distant in the future. A do-nothing option which represents the status quo, is always considered. An option assessment accounts for:

- all life cycle costs to deliver, maintain, operate, and dispose of the option
- residual risk costs associated with the option, where the need date isn’t solely based on asset age or condition
- benefit including risk mitigation or opportunity value, provided by the option
- maximum net benefit that can be provided by the option and the associated need date
- changes in the net benefit (including any changes in risk cost as illustrated below) which result when the need date is delayed or advanced (typically by +/- 2 years)
- sensitivity analysis where two options have the same net benefit.

The option with the highest net benefit, subject to sensitivity analysis, is selected as the solution.

Prioritise Solutions
Solutions are, in the first instance, prioritised based on need dates. Where solutions are based on a risk assessment, further prioritisation is undertaken based on the magnitude of the net benefits, with the solutions with the highest net benefit being prioritised first. Where available criticality is also utilised in prioritising solutions.

Develop a Programme Management Plan
A programme management plan is developed to ensure solutions can be delivered feasibly, reliably and efficiently. This includes accounting for funding and deliverability constraints. If all solutions cannot be delivered by the need date, they are re-phased based on their priority. The need date is the required commissioning date of the solution.

Asset and Condition Information
Our transformation has resulted in material changes to the way we plan our asset replacements. As we move from strategies that require age-based replacements to those that require consideration of condition and risk based replacements, our asset information requirements have also changed.

Condition information and asset information are a fundamental component of our asset health modelling. The specific method, assessment standard, and frequency for condition assessments differs by asset type, depending on the asset characteristics, risk and criticality of the asset.

Our Asset Information includes asset and condition data in our asset management system (Maximo), operational data, reports, drawings, and geospatial information.
We have reviewed our asset data and redefined the information we need for our capital and maintenance decision making, with the objective of improving our data management framework to meet future business needs and to lift and maintain our asset data quality. As part of this review, we have identified the following improvement opportunities:

- Opportunities to improve and control our data management to enable us to:
  - maintain or improve data quality
  - prioritise our data collection
  - take advantage of efficiencies in the future (such as direct business-to-business data processes and mobility).

- Data Quality improvements including:
  - requirements to significantly improve the asset condition and core asset data in Maximo
  - data model changes to enable improved data management for some assets classes.

We have initiated a significant project over the remainder of RCP 2 to consolidate and improve our asset information framework such that our systems, processes, and data are sustainable, robust and fit-for-purpose. The following diagram explains the key activities and the related outcomes for our developing asset information framework.
**Asset Health Models**

Our Asset Health Framework provides an Asset Health Index (AHI) which reflects an asset’s proximity to the end of its useful life. The end of an asset’s useful life is when it will need replacement or major refurbishment. When combined with other information within the context of the decision framework described above, an AHI can inform the optimal timeframe for various interventions. Our asset health modelling aims to achieve the following objectives:

- Alignment with the Asset Class Strategies
- Integrated with the Asset Planning Decision Framework
- Use our expert knowledge
- Leverage empirical data where quality and correlation are strong
- Leverage industry data where appropriate
- Have the appropriate balance between modelling complexity and uncertainty
- Be systematic and repeatable.

The common inputs into our AHI model are described below.

**Base life** - The base life is the “Normal Expected Life” for an asset type. It represents the age at which significant signs of deterioration have historically been observed. The base life assumes normal conditions, and that no duty and location conditions that will accelerate asset degradation exist. If an asset class strategy requires replacement or refurbishment before failure, then it is likely that a sizeable population of assets for that class, under these normal operating conditions, will be removed from service once base life is reached. Base life is based on our experience of Transpower whilst leveraging industry data and other information such as forensic assessments.

**Known degradation rates** - A known ageing rate is used to determine the future health index. Where information exists, we use the information to chart the degradation rates for specific assets.

**Asset Health Bands**

Our asset health modelling results in each asset within an asset class being described in one eight asset health bands, HI1 to HI8. These are shown in Table 2.

<table>
<thead>
<tr>
<th>AHI Band</th>
<th>Health level</th>
</tr>
</thead>
<tbody>
<tr>
<td>HI1 to HI3</td>
<td>Good</td>
</tr>
<tr>
<td>HI4 to HI5</td>
<td>Fair</td>
</tr>
<tr>
<td>HI6 to HI7</td>
<td>Poor</td>
</tr>
<tr>
<td>HI8</td>
<td>Very Poor</td>
</tr>
</tbody>
</table>

*Table 2: Asset health band definition*

**Asset Criticality**

While the Asset Health provides an indicator of the probability of failure, asset criticality describes the consequence of asset failure. The criticality and risk associated with owning and maintaining an asset is derived using the likelihood and the resulting potential credible consequence of the failure.

We measure criticality across five dimensions, in alignment with our Corporate Risk Assessment Matrix. The dimensions are additive. They are:

1. Service Performance Criticality - describes the impact of asset failure on the conveyance of electricity across our network. It is defined as the average cost of unserved power across a year for the most likely load interrupted by the asset. It also considers the average impact (in dollars) on the wider network when an asset fails.
2. Public Safety Criticality – describes the impact of asset failure which could cause harm to the public. It is based on the most likely consequence and does not anticipate worst case scenarios or high impact low probability (HILP) events. A primary contributor to Public Safety criticality is the location of the asset and its public surroundings. It accounts for harm to members of the public caused by:
   - Crushing and electric shock from transmission lines falling
   - Induced road and railway accidents (lines over infrastructure)
   - Induced electrical explosions of low voltage appliances (lines over household or business).

3. Workplace Safety Criticality – describes the impact of asset failure on our workforce. It is based on the most likely consequences of asset failure and not worst-case scenarios or HILP events. A primary contributor to Workplace Safety criticality is the location of the asset and the probability of workforce presence around it. It considers harm to our workforce from:
   - Explosive asset failures and shrapnel
   - Falling assets
   - Electric shock
   - Arc Flash.

4. Environmental Criticality – describes the most likely environmental consequences of asset failure. The main environmental consequences considered are:
   - Soil contamination
   - Water contamination
   - Air pollution (combustion products and SF₆ gas releases)
   - Noise pollution
   - Vibration.

5. Direct Cost Criticality – describes the financial costs incurred in case of asset failure. This includes the average costs to restore service and the average cost to repair the asset. It excludes all secondary costs related to other dimensions of criticality, and the costs of collateral damage and opportunity costs.

Criticality Bands
Our criticality modelling results in each asset within an asset class being described in one of eight criticality bands, C1 to C8. The criticality bands are based on the risk bands within our corporate risk matrix. These are shown in Table 3.

<table>
<thead>
<tr>
<th>Criticality Band</th>
<th>Criticality level</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1 to C3</td>
<td>Low, $0 to $3 million</td>
</tr>
<tr>
<td>C4 to C5</td>
<td>Mid, $3m to $30 million</td>
</tr>
<tr>
<td>C6 to C7</td>
<td>High, $30m to $300 million</td>
</tr>
<tr>
<td>C8</td>
<td>Extreme, $300 million+</td>
</tr>
</tbody>
</table>

Table 3: Criticality band definition
These bands cover have a broad monetised consequence. As a result, one asset class may fall into a single criticality band. Note the difference between the highest and the lowest monetised value in the band can be a factor of up to 10. As such, we plot criticality to a more granular level when making asset management decisions.
Asset Risk Framework

In addition to criticality, we assess the asset risk associated with each asset type through standardised bow-tie risk analysis and semi-quantitative risk assessment (SQRA). Bow-tie risk analysis and SQRA are key methodologies set out in our corporate risk framework which is consistent with AS/NZS ISO 31000. Our corporate risk framework forms the basis for a consistent approach to our risk analysis.

We have prepared risk bow-ties for 24 asset classes and incorporated the risk assessments into our strategies and plans. The purpose of asset class bow-tie is to inform us about the most likely causes of asset failure, the consequences of that failure, and the controls we apply that will make the most impact on reducing the risk.

Bow-ties inform us about the most likely causes of asset failure, and the most effective mitigations measures to enable us to incorporate such causes and mitigations into our plans for each asset class. We consider the causes from the bow-tie analysis that have the most influence on the potential failure mode, establish monitoring processes that account for those causes, and target expenditure to mitigate the likelihood of occurrence.

This is illustrated in the following example of an asset risk analysis (Figure 11) which shows a bow-tie risk assessment for a failure of a DC systems asset class and the top 4 risks such a failure has on AC network.

Figure 11: Risk Bow-tie for DC Systems failure

The width of the lines show which cause (listed on the left side of the diagram) has the most influence on the risk. In this case degradation/corrosion has the most influence. Controls implemented to reduce the likelihood of this causal pathway include such items as life cycle planning, predictive modelling, data quality improvements, strategic interventions (e.g. staggering battery replacements at a site), procurement specifications and a preventative maintenance programme to regularly test 125V DC systems.

An assurance framework on the controls identified within the bow-tie analysis is in the process of being developed.

Technical Standards and Policies

We maintain a set of controlled documents that are an important part of our asset management process. They cover design standards, service specifications and operating instructions. They refer to codes of practice or industry standards where relevant.
Standards tend to be of a technical or compliance nature and they are required to go through a managed review and approval process. Table 4 describes the types of policies and standards that we use in our asset management processes.

<table>
<thead>
<tr>
<th>Document type</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corporate policy</td>
<td>Represent the core requirement of good governance (such as the Code of Ethics and Conduct Policy) and/or are applicable across the company</td>
</tr>
<tr>
<td>Corporate procedure</td>
<td>Specify procedures applicable across the organisation</td>
</tr>
<tr>
<td>Technical policy</td>
<td>Specify our policy on general commercial and technical issues (eg, asset maintenance or replacement.) They are split into:</td>
</tr>
<tr>
<td>General and technical standard</td>
<td>Specify approved systems, guidelines and processes and define a minimum level of compliance. They are split into:</td>
</tr>
<tr>
<td>Service specifications</td>
<td>Are published as schedules to contracts, incorporating the requirements of appropriate standards. They are split into:</td>
</tr>
<tr>
<td>Service advisory</td>
<td>Interpret, extend or provide supporting information for a standard or service specification</td>
</tr>
<tr>
<td>Standard maintenance procedures</td>
<td>Set out step-by-step procedures for scheduled services on each asset type</td>
</tr>
<tr>
<td>Asset operations instructions</td>
<td>Set out business processes, procedures and policies involving regional operating centres</td>
</tr>
<tr>
<td>Purchase specification</td>
<td>Specify the performance and technical requirements for equipment and materials to be purchased for Transpower use</td>
</tr>
<tr>
<td>Business continuity plan</td>
<td>Plans to ensure Transpower’s preparedness to be able to sustain business critical functions</td>
</tr>
</tbody>
</table>

Table 4: Document and policy types used in our asset management process
Continuous improvement of technical standards and policies

We have commenced an extensive review of our technical controlled documents with a view to ensure alignment with our asset management document suite. This will improve their accessibility and usability, reducing duplication, and ensuring new revisions to the documents are underpinned by risk based justification. We have defined a future state and actions to get there which were derived through consultation with internal and external stakeholders. A plan resulting from this consultation has now been shared with our internal and external stakeholders.

ICT ASSET MANAGEMENT

This section describes our approach to managing ICT assets. Our ICT assets incorporate the software and hardware necessary to operate the grid and support our management functions. Below we describe our:

- ICT strategic goals and asset portfolios
- ICT asset management approach.

ICT STRATEGIC GOALS AND ASSET PORTFOLIOS

We utilise technology in a way that supports our business capability in a sustainable and efficient manner. Due to the rate of technology and business change, it is essential we adapt and respond to changes in our business requirements and efficiently utilise new and emerging technologies. Our approach to achieving this is crystallised in our ICT strategy which establishes five strategic goals:

- Implement business focused solutions
- Ensure reliability and resilience
- Utilise strategic sourcing
- Excellence in information management
- Ensure security.

To deliver these strategic goals we have moved from a more traditional ‘run, grow, transform’ business model to a ‘life cycle, benefits driven, leading’ investment approach. By defining our ICT capability in this manner, we can classify and prioritise initiatives to meet business challenges as they emerge, and face the challenges outlined in Transmission Tomorrow.

At a functional level, our required business capability is defined within five core ICT asset portfolios. These are:

- Asset Management Systems
- Transmission Systems
- Corporate Systems
- Shared Services
- Telecommunications, Network and Security Services.

Together the five portfolios cover the range of services delivered within our ICT space. Asset Management Systems and Transmission Systems provide the core capability for the grid. We have categorised these functions into 12 defined areas, described in Section 7. Corporate Systems, Shared Services and Telecommunication Network and Security Services portfolios provide the underlying business capability to support our operations across the company. The detailed approach and expenditure associated with these portfolios is summarised in Section 7.

ICT ASSET MANAGEMENT APPROACH

The alignment between Transmission Tomorrow, our ICT Strategy down through to our initiatives is illustrated in Figure 12. Our business functional requirements drive the outcomes we are seeking to achieve from this process.
There are three essential steps to our planning process. These are:

- Identifying business outcomes and capability requirements by portfolio.
- Identifying the life cycle needs of existing systems
- Develop the ICT Roadmap.

Each of these steps are discussed below.

**Business outcomes and capability requirements**

We use the outcomes that are sought or planned by the business to define the required ICT capability change outcomes (People, Process, Information, and Technology). To assess the ICT capability required we have developed a capability assessment model for each business area. Capability models provide a structured map of all the key capabilities required to effectively enable the business functions and processes. They utilise the building blocks of the business, abstracted from our organisation structure, to link the business functions and processes to the ICT systems and services. Each ICT system has been linked to one or more business capability that it supports.

The capability assessment is based on three sets of criteria: business importance, functional fit and technical quality. The criteria are defined as:

- **Business Importance** - the contribution to performance goals, objectives, and KPIs
- **Business Functional Fit** – the level of fit to current & anticipated business functions and processes
- **Current Quality** – the technical quality as enabled by current supporting system or systems.
ICT systems life cycle

We have more than 250 ICT systems that support our business processes and capabilities. Each system is mapped to a technology platform and assessed for vendor supportability. For each system, we have developed a life cycle assessment and plan which incorporates the importance of the capabilities supported, the rationalisation and retirement of some systems, and the replacement of some key systems which are at end of life but support essential business capabilities.

The ICT life cycle assessment incorporates existing ICT systems and assets, vendor technology platform supportability, the refresh cycles and level of risk based on the criticality of capabilities supported.

ICT Roadmap and initiatives

Following capability assessment and identification of system life cycle needs, we capture the gaps and opportunities for development, review need for the development, and then refine scope to establish an indicative cost of the initiative. The initiatives are then prioritised. The prioritisation is based on four key criteria:

- The alignment with strategic objectives and goals
- Value for money for Transpower, our customers and stakeholders
- Level of risk associated with the projects that may erode the expected benefits and increase delivery costs. This includes the organisation’s capacity to make the required business change and embed the capability into BAU processes
- Level of urgency to implement the project or capability improvements.

The prioritisation process is iterative as the initiatives are reviewed and confirmed with the owners of the business functions. The final ICT roadmap provides an integrated picture of all the prioritised and accepted initiatives by financial year. The outcome of this process is the basis for the forecast expenditure of ICT portfolios presented in this AMP.

BUSINESS SUPPORT ASSETS

Our business support assets enable us to operate as the business and provide essential capability to deliver our service objectives. Business support expenditure falls into four categories:

- Non-critical substation buildings
- Office buildings and facilities
- Vehicles
- Office equipment.

Our overall objective for our business support assets is to provide the appropriate level of capability at the least cost. Due to the diversity of the asset types our strategic approach to these assets is specific to the asset type and they are managed through different mechanisms and processes. The following summarises each area.

NON-CRITICAL SUBSTATION BUILDINGS

Non-critical substation buildings generally consist of storage buildings and several current and former depots. These buildings were built at our older substations and remain at a significant number. They are generally managed by our regional service managers and may be used by connected customers for feeder access or associated connections equipment. Where possible and appropriate, we tenant the buildings to cover costs. Generally, tenants are responsible for maintenance of land and improvements.
OFFICE BUILDINGS AND FACILITIES
The leased office buildings and facilities are managed by the Corporate Facilities Management team, who have contracts in place with building services providers to maintain these facilities. This team also manages the leases for these offices e.g. rent reviews, renewals etc. The Auckland office, Christchurch office, all the warehouses and training facilities are on sites owned by Transpower, so the maintenance of these sites is included as part of ACS buildings and grounds asset management. The Corporate Facilities Management team hold the Opex budgets for all the offices to ensure a consistent and cost-effective approach to this expenditure.

VEHICLES
The vehicle fleet is managed by an outsource provider, who are overseen by the Corporate Facilities Management team. All the vehicles have GPS fitted to better manage the fleet and improve safety. The provider reports monthly on the charges and life cycle utilisation for each vehicle, which together with the GPS data enables us to make informed strategic decisions about the vehicle fleet.

OFFICE EQUIPMENT
Office equipment is regularly maintained by service providers and generally replaced when it is unsafe or the cost of repair is too expensive. The budget for office equipment is held centrally by the Corporate Facilities Management team to ensure a consistent and cost-effective approach to replacement.

The investment requirements for these areas are described further in Section 7.

CORRIDOR MANAGEMENT
Corridor management involves maintaining our relationships with communities, iwi and landowners, to ensure we can continue to access and maintain our assets is essential for us to effectively manage our network. We call this our social licence to operate. Communities, iwi and landowners can be significantly impacted by transmission projects and our asset management activities, so it is important for us to carefully manage our relationships with them.

We need to be able to gain access to our assets for routine inspection, maintenance, resolving incidents, and responding quickly in emergency situations. We also need our present and future network to be protected from development that might impact on safety or constrain our operations.

Within this context we continue to secure corridors through implementing the National Policy Statement on Electricity Transmission into regional and district planning documents. This programme of work will ultimately result in Council Plans which will provide controls on what can and can’t be developed in transmission corridors, and adjacent subdivisions, in order to control inappropriate under-build. Likewise, appropriate buffers are sought around substations to protect against reverse sensitivity issues and to provide future protection on cable routes where appropriate. We have considered ongoing requirements for corridor management in our maintenance budget allocation.

CONTINUOUS IMPROVEMENT AND INNOVATION
We have a focus on continuous improvement, reducing costs and becoming more innovative while sustaining a focus on good asset stewardship and risk management. This involves both driving innovation and responding to innovations led by others. We have established co-ordinated oversight of our innovation initiatives. Our innovative approach focuses on more than technology. It includes innovations in process, service, and our relationships with customers and key stakeholders. The innovations we embrace and the efficiencies we gain today, will ensure our ability to serve New Zealand for generations to come.

A number of innovations have been applied to our asset classes resulting in significant savings across our portfolios. These are detailed in the individual asset class plans described in Sections 6, 7, and 8.
5. EXPENDITURE OVERVIEW

This section provides an overview of our forecast expenditure directly associated with our asset categories. It incorporates forecast grid R&R Capex, base enhancement and development Capex, grid operational costs, ICT Capex and Opex costs, along with Business support Capex. A description of our Base E&D Capex and Major projects is set out in the TPR.

An overall top down adjustment has been made to our total overall spend. This is discussed further in the ITP Narrative document. The top down adjustment has not at this stage been applied to the forecast expenditure presented in this AMP. As such, the forecasts presented below are our bottom up view on the expenditure requirements under each portfolio and asset class.

GRID ASSET EXPENDITURE

Our grid asset portfolios set out our forecast R&R expenditure for RCP 2, RCP 3, and RCP 4. The asset class programmes include some of our largest expenditure by value, and include such activities as transformer replacements, outdoor to indoor conversions and tower painting.

When assets approach the end of their lives we also take the opportunity to review whether they are at appropriate capacities or capabilities, or whether they are still required. Over the last year, since the development of the 2016 AMP, we have updated several key strategies, refined our decision framework to include updated health models, implemented a new criticality framework, added bow-tie risk analysis, and incorporated additional asset data and feedback. The application of these new factors to our asset fleets has resulted in several changes to our RCP 2 and RCP 3 expenditure predictions.

Below is a summary of our proposed expenditure and a comparison with the forecast in the 2016 AMP. Based on our refined Base R & R Capex forecasts we expect to commission assets with a total value of $858 million during RCP 2 and $1.1 billion in RCP 3.

<table>
<thead>
<tr>
<th></th>
<th>RCP 2</th>
<th>RCP 3</th>
<th>RCP 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC Stations</td>
<td>49</td>
<td>58</td>
<td>69</td>
</tr>
<tr>
<td>Buildings and Grounds</td>
<td>8</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>Transmission Lines</td>
<td>63</td>
<td>68</td>
<td>76</td>
</tr>
<tr>
<td>HVDC</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Reactive Assets</td>
<td>2</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Secondary Assets</td>
<td>18</td>
<td>23</td>
<td>27</td>
</tr>
<tr>
<td>E&amp;D</td>
<td>2</td>
<td>13</td>
<td>16</td>
</tr>
<tr>
<td>Listed Projects</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Portfolio Total</td>
<td>143</td>
<td>173</td>
<td>199</td>
</tr>
</tbody>
</table>

Table 5: Grid R&R Expenditure
The overall impact for RCP 2 for grid Base Capex including listed projects is an increase of $4 million, from what we forecasted in the 2016 AMP. While the expenditure in RCP 2 has increased, it is anticipated that this will lead to savings in expenditure in later periods, relative to what otherwise would have been incurred. The material changes in the RCP 2 Capex expenditure are:

- An additional $11 million for Power Transformers. A new strategy and health model has resulted in our decision to extend the operating life of a number of our transformers through bushing replacements rather than replacing the transformer.
- An additional $14 million for Substations Management Systems due to update and refinement of portfolio costs, incorporating new information from actual projects completed.
- An increase of $7 million for Tower Painting due to some movement in building block rates compared to those used for the 2016 AMP.
- An additional $20 million of E&D predominantly due to the addition of the North Taranaki Transmission Capacity project.
- Reductions in Disconnectors ($-4m), Grillages ($-6m), Buildings and Grounds ($-7m), Insulators ($-5m), Protection ($-5m) due to the implementation of strategy revisions, and/or new condition assessment data and refinements to health modelling, which has deferred capital spend.

**RCP 3 CAPITAL EXPENDITURE SUMMARY**

The overall change in RCP 3 expenditure from the 2016 AMP is an increase of $169m or 13%. This increase is due to the initial application of our new planning framework and tools, and a thorough review of our plans. As we continue to mature our processes we are likely to see further changes in forecast expenditure. For 2017, approximately 60% of the expenditure across all our asset classes has been planned using our new framework.

The material changes between the 2016 AMP and the 2017 AMP are:

- $41 million less in the Outdoor to Indoor conversions due to a review of needs for this portfolio.
- An additional $13 million as additional condition data has led to a predicted increase in expenditure in some substations assets such as structures and buswork.
- An increase of $18 million on the HVDC due to the Pole 2 mid-life refurbishment programme to achieve an asset life of 50 years.
- An increase of $22 million in the Reactive Assets as several capacitor bank replacements that were deferred from RCP 2 will meet the replacement criteria in RCP 3.
An increase of $10 million in the Buildings and Grounds portfolio as improvements in our asset management planning and condition data has resulted in further work on fencing, metalizing, cable trench lids, and prevention of water ingress through roofs and substrate materials.

An additional $33 million for Tower Painting as more towers reach the optimal intervention point for painting.

A reduction of $17 million for grillages as the new strategy results in less grillages being required.

An additional $63 million for the conductor portfolio; RCP 3 represents the start of a large increase in the volume of reconductoring needed on the network due to condition, which will be managed through a combination of base and major capital projects depending on the size and complexity.

An overall increase of $48 million over the protection and battery asset classes. This is predominantly due to the need to replace feeder protection schemes (not previously included); an increase in cost to meet black start requirements; a higher number of forecast charger replacements in RCP 3; and an increase in the number of meters to be replaced due to the cyclical replacement programme.

An increase of $36m for Substation Management Systems (SMS) as additional planning has taken place and costs have been updated based on the actual delivery cost projects completed to date.

OPERATIONAL EXPENDITURE RCP 2 AND RCP 3

Total forecast grid operating expenditure has increased by approximately $22 million for the balance of RCP 2 and is forecast to increase in RCP 3 by approximately $26 million. This increase in expenditure across RCP 2 and RCP 3 is due to the following material factors:

- New condition data for our substations assets has resulted in an increase in maintenance project work, predictive maintenance, and corrective maintenance that was previously not identified.

- Additional maintenance work for transmission lines to accelerate the mitigation measures for under-clearance violations and Earth Potential Rise (EPR). This increase has been offset to some degree by lower expenditure on maintenance projects. In addition, there is a significant program of conductor assessment, joint testing and on-going repairs that support the capital replacement program.

- Higher HVDC preventive maintenance (PM) costs, although this has been offset by lower preventative maintenance costs in the other portfolios due to our PM Optimisation project, which was completed this year and has been incorporated into our budgeting.

- Implementation of new decision framework has, in some cases, resulted a deferral of Capex but an increase in operational expenditure as this is deemed the best whole of life cost outcome.

- Remediation of asbestos work as we implement asbestos management plans for each site.

![Grid Maintenance Operating Expenditure](image)

Figure 14: Grid Opex expenditure
LISTED PROJECTS

We are on track to have three submissions for listed projects in by June 2018. These cover CPK-WIL B, OTB-HAY A and BPE-WIL A lines. The BRK-SFD B line which was previously included as a listed project for RCP 2 has been delayed while we review the long-term system need for that section of the Grid and possible solutions that may not require the reconductoring of this line.

The listed projects for RCP 3 have been identified and we are going through a review of the scope and timing of the reconductoring to ensure projects are correctly categorised as either Base Capex or Listed projects for the RCP 3 submission. This reconductoring is also being considered by our Auckland Strategy team, where lines of interest include OTA-WKM A & B, ALB-HEN A, and BOB-OTA A. So far this wider review and categorisation has identified 3 projects nationally, of which BOB-OTA is likely to be listed; this is included in the table below. However, there is still a reasonable degree of uncertainty regarding all three projects. For RCP 4 the listed projects are based off the condition data and health modelling presently available. More work will be done to confirm the scope and timing of these projects. Based off our modelling we are expecting an increase in the volume of listed projects in RCP 4 from RCP 2 and RCP 3.

Table 6 shows our forecast of listed projects as at June 2017.

<table>
<thead>
<tr>
<th></th>
<th>RCP 2</th>
<th></th>
<th>RCP 3</th>
<th></th>
<th>RCP 4</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>BPE-WIL A</td>
<td></td>
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<tr>
<td>Reconductoring</td>
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<tr>
<td>(WIL-JFD</td>
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<tr>
<td>Section)</td>
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<td>Bunnythorpe–</td>
<td></td>
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<td></td>
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<td>8</td>
</tr>
<tr>
<td>Wilton A</td>
<td></td>
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</tr>
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<td>reconductoring</td>
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<td></td>
</tr>
<tr>
<td>(BPE–JFD</td>
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<td></td>
</tr>
<tr>
<td>CPK-WIL B</td>
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<td></td>
</tr>
<tr>
<td>Reconductor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>15</td>
</tr>
<tr>
<td>OTB-HAY A</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reconductor</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>BRK-SFD B</td>
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</tr>
<tr>
<td>Conductor</td>
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<td></td>
<td></td>
<td>16</td>
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<tr>
<td>RCP 4</td>
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<td></td>
</tr>
<tr>
<td>Reconductoring</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Listed Project</td>
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</tr>
<tr>
<td>Total</td>
<td>15</td>
<td>34</td>
<td>58</td>
<td>78</td>
<td>61</td>
<td>51</td>
</tr>
</tbody>
</table>

Table 6: Listed Project forecast
**INDICATIVE RCP 4 AND RCP 5 EXPENDITURE**

This AMP 2017 also includes indicative spend for RCP 4 and an indication of RCP 5. Relative to RCP 3, RCP 4 shows an overall reduction in capital expenditure of $352 million. Whilst these periods require further review and refinement – and require further asset data (including condition data) to provide a more reliable forecast based on our newly introduced processes and frameworks, we note the following:

- The steady growth of the Tower Painting programme is forecast to continue into RCP 4 with approximately 750 Towers per year forecast to be painted during this period. In RCP 4 the proportion of recoat towers starts to increase as towers painted during the beginning of the tower painting programme start to become due for recoat painting. This growth in the Tower Painting programme is presently forecast to plateau at about 1,000 Towers per year in RCP 6.

- With respect to conductors, we are expecting an increasing spend over the next few RCPs as the existing assets approach their end of life. Such programme of work will necessitate a significant amount of advanced planning, especially where reconductoring needs to take place is in areas of under-build.

- At this stage, it is expected that during RCP 4 eight to ten transformers will require replacement. It is likely that expenditure on Transformers will increase again in RCP 5 as the units refurbished will require replacement.

- We will continue with our savings programmes, looking to further implement identified efficiencies throughout the business and the application of innovations into the field.

**ICT EXPENDITURE**

Our ICT delivers and supports the infrastructure, server hardware and applications that interface with the grid and support our corporate processes and systems. This section provides an overview of our expenditure forecasts for the ICT Portfolios. Each Portfolio covers the business requirements, life cycle needs and the forecast investment path for the planning period. Following an in-depth review of the required business capability and business outcomes, we expect the underlying ICT to continue to decline over time as we move to improve our processes and adopt new technology and business models through use of approaches such as software as a service and other cloud based services. However, there are also several one-off items that we expect to invest in during RCP 3 which will increase the expected expenditure during that time, then stepping down in RCP 4. This view will be refined as we extend our business planning further over the next year. Table 7 below shows the ICT capital expenditure by Portfolio.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Transmission Systems</td>
<td>16</td>
<td>4</td>
<td>4</td>
<td>6</td>
<td>5</td>
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<td>2</td>
<td>5</td>
<td>5</td>
<td>14</td>
<td>11</td>
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<tr>
<td>Corporate Systems</td>
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<td>5</td>
<td>1</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Shared Services</td>
<td>6</td>
<td>6</td>
<td>4</td>
<td>12</td>
<td>5</td>
</tr>
<tr>
<td>Telecommunications, Network and Security Services</td>
<td>5</td>
<td>20</td>
<td>11</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>12</td>
<td>35</td>
<td>27</td>
<td>3</td>
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<td>9</td>
<td>9</td>
<td>9</td>
<td>8</td>
<td>9</td>
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<tr>
<td><strong>Portfolio Total</strong></td>
<td>32</td>
<td>40</td>
<td>26</td>
<td>38</td>
<td>31</td>
</tr>
</tbody>
</table>

Table 7: ICT capital expenditure by Portfolio
RCP 2 CAPITAL EXPENDITURE

The material drivers for our forecast expenditure for the remainder of RCP 2 are:

- Transmission systems: investment is targeted at standardising and integrating operational data, enabling more sophisticated situational awareness and decision support, and streamlining processes and tools.
- Asset management systems: during the remainder of RCP 2 we plan to continue to mature, consolidate and integrate our systems to provide a coherent delivery pipeline from strategy through to operations, supported by improved feedback from asset condition and risk.
- Corporate systems: our focus is to maintain our existing systems through life cycle refresh, and look to leverage investment opportunities through increased use of cloud based services.
- ICT shared services: the primary areas of focus is life cycle refreshes of key systems and enhancing our infrastructure security. Where it makes sense, we are moving systems to the cloud as part of their life cycle refresh.
- Telecommunications, Network and Security Services: continue to focus on life cycle refresh of existing systems and to proceed with a risk based approach to cyber security investment in alignment with our ICT Strategy. We will also look to determine the range of feasible options for TransGO replacement to provide the level of functionality and security required to run the national grid.

RCP 3 AND RCP 4 CAPITAL EXPENDITURE

We continue to improve the processes with which we manage our ICT expenditure and have aligned our investments with improvements to business capabilities and outcomes. During the period, our investment focus has shifted from building new capability to ensuring continued support and maintenance of our existing systems. The main exception to this is the continuing investment in developing our asset management capability.

While the overall trend is downward, we expect expenditure to increase through to the middle of RCP 3, due to the ‘lumpy’ nature of certain large projects and their timing during the period. This includes the renewal of our TransGO communications network, and life cycle replacement of our undersea fibre cables. We expect that we will see a reduction for the life cycle refresh of our systems throughout RCP 3, as we consider the potential efficiencies from adopting everything as a Service (XaaS) and cloud-based services for non-critical functions.

We expect the downward trend to continue from the end of RCP 3 into RCP 4 despite major refresh pressures. This reflects the cost reduction efforts which will continue.

Over the long-term, it is difficult to predict with certainty what technologies we will commission or exactly what techniques that will be used to deliver them. Maintaining agility has the advantage of allowing us to consider emerging, cost-effective technologies and to adopt them if they are sufficiently mature. Reflecting this we will continue to refine our forecasts over the period.

OPERATIONAL EXPENDITURE

ICT Opex includes telecommunications and equipment leases, outsourced support and maintenance fees, and software licences. Since our 2016 AMP we have implemented changes to our network support model through insourcing roles where appropriate, renegotiating key contracts and rationalising how our operating centres function. This has driven our Opex profile down for the 2017 forecast. As a result, we expect to incur a total of $195 million ICT Opex during RCP 2, which is $14 million below the 2016 forecast or a 7% reduction. Both our 2016 and 2017 forecasts are also well below our RCP 2 allowance. The reduction reflects savings in the following areas:

- Network lease costs: expenditure has and will continue to reduce as we realise the benefits of successful contract renegotiation and scope rationalisation.
- Data-centre costs: have reduced from the RCP 2 allowance due to infrastructure rationalisation.
- Licencing: we continue to focus on improving our capacity planning, licensing management and introduction of open source technologies in appropriate areas.

Despite upward cost pressures we continue to identify and implement cost reduction measures. The benefits of this process will flow into RCP 3. Overall, we expect that RCP 3 expenditures will be broadly constant from the end of RCP 2.
UNCERTAINTIES AND RISKS

We plan to continuously monitor and evaluate the acceleration of ICT technology development which will drive changes to our forecast expenditure. Hence, while the forecast expenditure is based on the best information we have today, expenditure beyond 5 years is relatively uncertain and will likely change as we adopt newer emerging technologies.

BUSINESS SUPPORT EXPENDITURE

Business support assets cover non-critical substation buildings, our office buildings, vehicle fleet and office equipment. Overall, we expect our business support expenditure to be consistent across the period with a downward trend as we continue to refine our procurement approach. Following the building move in October this year, we expect the overall level of business support expenditure to stabilise. Table 8 shows the expenditure.

Table 8: Business Support Expenditure

The material drivers for the expenditure are:

- We continue to review our holdings of non-critical buildings. We have earmarked a final tranche of buildings for sale, that collectively have an estimated value of $6 million.
- We have committed to changing 30% of our vehicle fleet over to hybrid or electric by 2019. As technology progresses, efficiencies and distance of these vehicles improve, we would expect this to reflect into our forecast expenditure.
- Following the building move in October 2017, the expenditure associated with office furniture will reduce to a normalised level.

The details for each of the categories under the business support portfolio are described further in Section 8.
6. GRID ASSET PORTFOLIOS

This section describes our management approach, plans, risks, and expenditure forecasts for each grid asset portfolio. We have categorised our grid assets into six portfolios:

- **AC Substations** pg 37
- **Buildings and Grounds** pg 104
- **Transmission Lines** pg 115
- **HVDC** pg 150
- **Reactive Assets** pg 160
- **Secondary Assets** pg 171

Each grid asset portfolio contains one or more asset class plan. These are discussed in the following sections.
Our AC Substations asset portfolio covers all our primary substation assets. It consists of the following asset classes:

- Power Transformers
- Indoor Switchgear
- Outdoor Circuit Breakers
- Outdoor Instrument Transformers
- Power Cables
- Outdoor Disconnectors and Earth Switches
- Low Voltage Alternating Current (LVAC) Distribution Systems
- Structures and Buswork
- Other Substation Equipment

It also incorporates one programme of works:

- Outdoor 33 kV Switchyards: Outdoor to Indoor Conversions (ODID)

A substation contains a set of equipment, including power transformers, that enables energy transfer between voltage levels. A substation without transformers and operating only at a single voltage level is called a switching station. Our substations have power system equipment that operates at 220, 110, 66, 33, and 11 kV.

Our AC Substations asset portfolio comprises all the primary assets within the substation boundary. It includes the structures on which primary equipment is installed, the high voltage electrical conductors and cables connecting the primary equipment within the substation, and the LVAC supply system for the substation itself.

Our AC Substations asset portfolio does not include our Secondary Assets, Communications, and Building and Grounds.

Our AC Substation portfolio asset base is atypical in terms of the boundary between the grid and our customers’ assets. For example, we own a large number of local supply transformers. This means that there is a relatively large number of 11 kV to 33 kV assets on the grid, which would more typically be owned by distributors. This is gradually changing as we continue a programme of divestment, transferring sub-transmission assets to local distributors.

Our AC Substation assets are older than our international peers. We do not believe having older assets is, in-itself, an issue. However, our assets have a finite life, which many of them will be reaching in the next 15 years. This necessitates setting robust investment and maintenance expenditure plans to ensure customer expectations are met, irrespective of future trends in electricity demand.
Common Terms
Within the AC Stations portfolio there are some common terms used. These are:

- **HV AC**: High voltage alternating current.
- **HV DC**: High voltage direct current.
- **Station**: A general term to cover substations, power stations and switching stations. Often ‘station’ and ‘substation’ terms are used interchangeably.
- **Substation**: A building, structure or enclosure incorporating equipment used principally for the control of the transmission of electricity.
- **Switchyard**: An area enclosed by a security fence, containing normally live conductors and/or other exposed materials.

Key Initiatives
In RCP 2 and RCP 3, we will continue to develop our optimisation processes to further improve the targeting of expenditure to ensure we lower the life cycle cost of these assets. This involves:

- Developing Asset Health models for most of the asset classes within the portfolio,
- Improving asset Condition Assessment information and the collection process,
- Trading-off between Capex and Opex to find the optimum Totex expenditure.

Expenditure Summary

Capital Expenditure
The main programme and spend for each asset class are shown below.

<table>
<thead>
<tr>
<th>Asset class</th>
<th>Main Capex programme</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Transformers</td>
<td>Transformer replacements</td>
</tr>
<tr>
<td>Indoor Switchgear</td>
<td>Indoor switchgear replacements</td>
</tr>
<tr>
<td>Outdoor Circuit Breakers</td>
<td>Circuit breaker replacement, preventive replacement of SF₆ leak-prone or legacy type circuit breakers</td>
</tr>
<tr>
<td>Outdoor Instrument Transformers</td>
<td>Instrument transformer replacements</td>
</tr>
<tr>
<td>Power Cables</td>
<td>Power cables replacements</td>
</tr>
<tr>
<td>Outdoor Disconnectors and Earth</td>
<td>Disconnectors and earth switches replacements</td>
</tr>
<tr>
<td>Switches</td>
<td></td>
</tr>
<tr>
<td>Low Voltage Alternating Current</td>
<td>LVAC switchboard replacements</td>
</tr>
<tr>
<td>(LVAC) Distribution Systems</td>
<td></td>
</tr>
<tr>
<td>Structures and Buswork</td>
<td>Painting and other life extension interventions</td>
</tr>
<tr>
<td>Other Substation Equipment</td>
<td>OJDB replacements</td>
</tr>
<tr>
<td>Outdoor 33 kV Switchyards: Outdoor</td>
<td>33kV outdoor bus and equipment converted to indoor 33kV switchgear</td>
</tr>
<tr>
<td>Indoor Conversions (ODID)</td>
<td></td>
</tr>
</tbody>
</table>

Table 9: Substation Programmes
The summary of the expenditure is provided in Table 10.

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<thead>
<tr>
<th></th>
<th>RCP 2</th>
<th>RCP 3</th>
<th>RCP 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Transformers</td>
<td>6.8</td>
<td>7.6</td>
<td>21.7</td>
</tr>
<tr>
<td>Indoor Switchgear</td>
<td>0.8</td>
<td>5.9</td>
<td>10.8</td>
</tr>
<tr>
<td>Outdoor Circuit Breakers</td>
<td>2.8</td>
<td>4.4</td>
<td>5.6</td>
</tr>
<tr>
<td>Outdoor Instrument Transformers</td>
<td>4.3</td>
<td>5.7</td>
<td>4.4</td>
</tr>
<tr>
<td>Power Cables</td>
<td>0.0</td>
<td>0.3</td>
<td>0.1</td>
</tr>
<tr>
<td>Outdoor Disconnectors and Earth Switches</td>
<td>0.0</td>
<td>0.1</td>
<td>0.5</td>
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<tr>
<td>LVAC Distribution Systems</td>
<td>0.1</td>
<td>1.6</td>
<td>1.5</td>
</tr>
<tr>
<td>Structures and Buswork</td>
<td>6.6</td>
<td>12.8</td>
<td>4.9</td>
</tr>
<tr>
<td>Other Substation Equipment</td>
<td>1.7</td>
<td>1.2</td>
<td>-1.1</td>
</tr>
<tr>
<td>Outdoor 33 kV Switchyards: ODID</td>
<td>25.6</td>
<td>18.3</td>
<td>20.6</td>
</tr>
<tr>
<td>Portfolio Total</td>
<td>48.7</td>
<td>57.8</td>
<td>68.9</td>
</tr>
</tbody>
</table>

Table 10: Substation capital expenditure

**Operational Expenditure**

Maintenance at AC Stations incorporates a wide range of assets, including power transformers, indoor and outdoor switchgear, reactive equipment, and protection equipment. Our specific approaches vary between asset types. It generally includes the following activities:

- **Inspections**: inspection of station assets aims to ensure that facilities and equipment are in a safe and serviceable condition, and that any abnormalities that represent a risk to grid reliability, safety of personnel, or the security of the site are identified and rectified.
- **Condition assessments**: these provide a standard assessment of the condition and expected remaining life of the assets.
- **Diagnostic testing**: this involves measuring electrical and mechanical parameters such as insulation, mechanism timing checks, and clearances.
- **Servicing**: this involves periodic servicing, aligned with inspections and condition assessments, to maintain asset condition.
- **Corrective maintenance**: this is work initiated as a result of faults, identified defects, or condition assessments. The work also includes responding to remote monitoring (SCADA) alarms.

We have developed the frequencies for our inspections, condition assessments, and servicing for AC Stations over a number of years, in line with common industry practice.
A summary of the Opex expenditure is included in Table 11.

<table>
<thead>
<tr>
<th>Portfolio Total</th>
<th>RCP 2</th>
<th>RCP 3</th>
<th>RCP 4</th>
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<tr>
<td>2016</td>
<td>45.5</td>
<td>40.8</td>
<td>36.4</td>
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<tr>
<td>2017</td>
<td>43.8</td>
<td>43.5</td>
<td>43.0</td>
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<tr>
<td>2018</td>
<td>42.8</td>
<td>41.5</td>
<td>44.2</td>
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<tr>
<td>2019</td>
<td>39.5</td>
<td>45.5</td>
<td>40.8</td>
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<tr>
<td>2020</td>
<td>36.4</td>
<td>43.8</td>
<td>43.5</td>
</tr>
<tr>
<td>2021</td>
<td>41.5</td>
<td>44.2</td>
<td>40.8</td>
</tr>
<tr>
<td>2022</td>
<td>43.5</td>
<td>43.0</td>
<td>36.4</td>
</tr>
<tr>
<td>2023</td>
<td>42.8</td>
<td>41.5</td>
<td>43.8</td>
</tr>
<tr>
<td>2024</td>
<td>41.5</td>
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<tr>
<td>2025</td>
<td>44.2</td>
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<tr>
<td>2026</td>
<td>43.0</td>
<td>42.8</td>
<td>43.5</td>
</tr>
<tr>
<td>2027</td>
<td>41.5</td>
<td>44.2</td>
<td>43.5</td>
</tr>
<tr>
<td>2028</td>
<td>43.8</td>
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<td>43.5</td>
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<td>2029</td>
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</tr>
<tr>
<td>2030</td>
<td>43.5</td>
<td>43.0</td>
<td>43.5</td>
</tr>
</tbody>
</table>

Table 11: Forecast Operational Expenditure

**Risks and Uncertainties**

The material risks and uncertainties associated with this portfolio are:

- We are continuing to work on improving our asset health modelling maturity, condition assessments and information quality. As these develop further it may lead to a change in the plan.
- As the accuracy of the cost estimation continues to improve, this may lead to an updated forecast expenditure.
- Deliverability of the Capex and maintenance Opex plans is dependent on internal and external resource availability and expertise.

**Asset Class Plans**

The following sections describe in more detail our asset management approach for each of the asset classes. These asset class plans describe the strategy, asset characteristics, management approach and expenditure profile for each asset class. The expenditure covers the capital requirements, along with any specific maintenance projects to be undertaken.
ASSET CLASS PLAN – POWER TRANSFORMERS

This asset class plan describes our life cycle management approach for power transformers. It covers the following asset types:

- Supply transformers which connect generators, distribution networks and major users to our transmission network
- Interconnecting transformers which interconnect between our backbone transmission network (220 kV) and our regional transmission and sub-transmission networks (110 kV or 66 kV)
- Other transformers which include traction transformers (supplying KiwiRail), local service transformers (supplying our own substations), earthing transformers, regulator transformers and oil immersed reactors.

Power transformers enable the transfer of power between voltage levels. The performance of power transformers is critical to maintaining reliability of supply to customers.

We have a mix of single phase transformers (where we use a bank of three single phase transformers) and three phase transformers.

Table 12 provides a breakdown of our power transformer population by voltage level.

<table>
<thead>
<tr>
<th>Type</th>
<th>220kV</th>
<th>110kV</th>
<th>66kV &amp; below</th>
<th>Other</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply (three-phase)</td>
<td>68</td>
<td>95</td>
<td>16</td>
<td></td>
<td>179</td>
</tr>
<tr>
<td>Supply (single-phase)</td>
<td>13</td>
<td>62</td>
<td>2</td>
<td></td>
<td>77</td>
</tr>
<tr>
<td>Interconnecting (three-phase)</td>
<td>34</td>
<td>1</td>
<td></td>
<td></td>
<td>35</td>
</tr>
<tr>
<td>Interconnecting (single-phase)</td>
<td>20</td>
<td>1</td>
<td></td>
<td></td>
<td>21</td>
</tr>
<tr>
<td>Spare (three-phase)</td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Spare (single-phase)</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>Railway traction (two-phase units)</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>Regulator</td>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Reactor</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Local service</td>
<td>7</td>
<td>1</td>
<td>174</td>
<td>10</td>
<td>192</td>
</tr>
<tr>
<td>Earthing</td>
<td>2</td>
<td>115</td>
<td>2</td>
<td></td>
<td>119</td>
</tr>
<tr>
<td>Other (not commissioned/classified)</td>
<td>10</td>
<td>7</td>
<td></td>
<td></td>
<td>17</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>157</strong></td>
<td><strong>164</strong></td>
<td><strong>321</strong></td>
<td><strong>19</strong></td>
<td><strong>661</strong></td>
</tr>
</tbody>
</table>

Table 12: Power Transformer population
### Asset Characteristics

Most transformers installed since the early 1970s are three phase. Prior to then, banks of single phase units were used. Transformers are designed to operate continuously up to their rated capacity, or at a higher rating for short periods of time. Key performance characteristics are described in Table 13.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Consequences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated capacity</td>
<td>Appropriate capacity for power transformers must be economically justified considering the load forecast out into the future.</td>
</tr>
<tr>
<td>Availability (N-1 configuration)</td>
<td>Outage of one transformer transfers load to other transformers so that supply is not interrupted. Resilience is reduced, and can cause increased losses.</td>
</tr>
<tr>
<td>Availability (N configuration)</td>
<td>Outage immediately interrupts supply. Interruption can be prolonged.</td>
</tr>
<tr>
<td>Overload capacity</td>
<td>Ability to operate a transformer in the short term above continuous steady state rating to avoid load management following the outage of a parallel transformer</td>
</tr>
<tr>
<td>Integrity</td>
<td>Transformers are oil-filled and can leak (environmental harm) or explode (safety and environmental harm).</td>
</tr>
<tr>
<td>Power quality (Voltage)</td>
<td>Many older single-phase transformers only have off-load tap selectors which can create voltage constraints and require short outages for temporary changes to off-load tap settings.</td>
</tr>
</tbody>
</table>

Table 13: Key transformer performance characteristics

### Age Profile

There has been an ongoing investment in power transformers as the grid has been developed and the need for additional capacity has emerged. This has resulted in a population age profile that is relatively spread out. This is illustrated in Figure 16, which shows the age profile of our power transformers by type.
Asset Health
Recently we have implemented an asset health model based on CBRM for our power transformers. The key inputs for the power transformer asset health model are:

- Major component base lives
- Observed condition information i.e. external condition assessment data
- Measured condition information
- Location and duty factors
- Systematic reliability factors based on expert knowledge and experience

The asset health model for our power transformers does not currently cover local service and earthing transformers. In 2016, we undertook a nationwide survey of external condition of major substation equipment to refresh our baseline understanding of condition. We have reviewed end-to-end processes for condition assessment. The identified issues for power transformers are:

Corrosion and oil leaks
Maintenance projects are planned to address a significant number of corrosion and oil leak problems. Transformer manufacturers discontinued the use of lead based paints in the late 1980’s, and introduced protective coating systems that have inferior performance. This has led to significant corrosion occurring on relatively young transformers. We have changed our procurement specification for new power transformers with the aim of ensuring a much longer life of the protective coating for new units. However, continuing attention will be required to young and ‘mid-life’ transformers with poor quality coating systems.

Aged and poor condition Resin Bonded Paper (RBP) bushings
We are experiencing an increase in the rates of failures of RBP bushings, both in service and under routine testing conditions. A bushing replacement programme is now underway to mitigate this failure risk by replacing RBP bushings on power transformers to extend their useful life when the transformer bank is in otherwise healthy condition.

Figure 17 illustrates the asset health of our power transformers.

Figure 17: Power Transformer Asset health

Developed by EA Technology, the Condition Based, Risk Management (CBRM) has been used by UK Electricity Distribution Network Operators for over 10 years. CBRM is a commercial software platform for asset health and probability of failure.
Asset Criticality
Criticality for our power transformers is based on our criticality framework. Figure 18 illustrates the population of our power transformers in each criticality category.

Figure 18: Power Transformer Criticality

Asset Performance
Figure 19 shows the unplanned outages for our power transformers and the causes.

Figure 19: Power transformers unplanned outages

Approximately 60% of outages are attributed to minor equipment malfunctions or failure which does not cause damage or prolonged outages.
Asset Life Cycle Stages

Our asset management approach is to actively manage our power transformers to ensure they achieve a high level of reliability and operate safely at least life cycle cost.

Strategic Planning

The following strategic objectives have been set for power transformers:

Safety
- No injuries or fatalities resulting from explosive failure of power transformers
- No injuries or fatalities resulting from working on power transformers

Service Performance
- The 10-year rolling average major failure rate to be less than 0.3% each year
- The unplanned outage rate to be less than 7% each year
- Restore security of supply within one calendar month of a major failure occurring

Cost Performance
- Optimise life cycle cost including lifetime cost of energy losses
- Optimise lifetime maintenance cost through timely interventions

Customers and Stakeholders
- No significant damage to external environment from transformer leaks, failures, or fire
- Acoustic noise emissions from power transformers comply with territorial authority requirements

Development Initiatives
- We have deployed a relocatable online dissolved gas monitoring system for use on power transformers that show abnormal gassing trends. We anticipate the results from this unit will assist us to define our strategy for online power transformer monitoring generally.

Tactical Planning

Our planning approach for power transformers is based on an economic evaluation of options to establish the least life cycle cost, accounting for the failure probabilities and consequences.

Condition Assessments

The internal condition of power transformers cannot be directly observed and this presents a challenge in quantifying their failure risk. There are many transformer tests used for condition assessments such as Dissolved Gas Analysis (DGA), furans and Degree of Polymerisation tests. These tests help us understand how power transformers age and can indicate if there are any systemic issues. However, they only provide inferences about actual transformer condition, and standard techniques are unable to identify many factors that contribute to transformer failure.

In some cases, testing may indicate the need for more intensive monitoring using on-line DGA monitors. Our experience is that these online monitors are helpful, but are often more useful in identifying the cause of failure, rather than preventing failures.

Additionally, as power transformers are bespoke, it is difficult to build and maintain knowledge or draw inferences about condition and risk from the performance of other transformers. Due to these limitations, we do not rely entirely on condition assessments as the only basis for forecasting the probability of failure. We also consider performance data on transformers of different designs, but made by the same manufacturer.

Table 14 outlines our condition monitoring tests and inspections.
<table>
<thead>
<tr>
<th>Frequency</th>
<th>Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two Monthly:</td>
<td>An in-service visual and audible noise level 1 inspection during routine station inspections.</td>
</tr>
<tr>
<td>Yearly:</td>
<td>An in-service level 2 inspection is carried out, which is more comprehensive than the level 1 inspection and includes operational checks.</td>
</tr>
<tr>
<td></td>
<td>A thermo-graphic survey is carried out during a survey of the station.</td>
</tr>
<tr>
<td></td>
<td>Oil screen tests.</td>
</tr>
<tr>
<td></td>
<td>Dissolved gas analysis of oil samples.</td>
</tr>
<tr>
<td>Two yearly:</td>
<td>Refresh of condition scoring for observed condition (based on ground level inspection), for all assets with a most recent observed condition score of 50 or less.</td>
</tr>
<tr>
<td></td>
<td>Tests of inhibitor levels in oil samples.</td>
</tr>
<tr>
<td>Four yearly:</td>
<td>An out-of-service diagnostic inspection of the transformer and all its components.</td>
</tr>
<tr>
<td></td>
<td>Out-of-service diagnostic tests, including winding insulation resistance and polarisation index, and tests of bushing insulation.</td>
</tr>
<tr>
<td></td>
<td>Tests of levels of furans in oil samples.</td>
</tr>
<tr>
<td></td>
<td>A high-level condition assessment.</td>
</tr>
<tr>
<td>Two, four or six yearly:</td>
<td>Major service of on-load tap changer (interval depends on make, type and operating duty).</td>
</tr>
</tbody>
</table>

Table 14: Condition-monitoring tests and inspections

We are observing increased deterioration and failures in our older bushings. We replace all defective bushings with a new standard composite bushing, unless there is an identical and serviceable spare available.

The older on-load tap changers require more frequent maintenance compared with modern units. Major services of older units are required at 5,000 or less operations, compared with modern units that need to be serviced at 50,000 operations or more.

We are also having to replace the oil in a number of power transformers. These transformers are units manufactured or overhauled in the 1990’s, when the oil refinery process included corrosive sulphur additives that have been found to damage the core parts of the transformers. This is an issue affecting utilities world-wide. We are mitigating it by replacing the oil, starting with the most critical units that have been found to contain corrosive sulphur in their oil.

Decision Framework

The work programme for power transformers is determined by applying the four steps of the Decision Framework.

Need identification

Asset health and criticality are used to determined needs and associated need dates.

Options Assessment

The investment decision for power transformers is based on an economic evaluation of options to establish the least life cycle costs, accounting for failure probabilities and consequences, including the site-specific potential for damage to other assets in the event of a power transformer fire.

Significant maintenance interventions such as corrosion or oil leak repairs do not generally require detailed options assessment.

Prioritise solutions

The selection and prioritisation of solutions for power transformers is based on a ranking that delivers the highest ratio of overall monetised risk reduction benefit to expenditure.

Develop an Programme Management Plan

The selected solution is considered in conjunction with other scheduled programmes of work to achieve synergies with other planned work such as outdoor to indoor conversions or customer upgrade requirements.
Cost estimation

High level building blocks for power transformer replacement projects have been created based on past project costs. These are used as an input to the economic options analysis model when assessing replacements. For business cases, a customised, bottom-up cost estimate for each project is completed, as costs can vary significantly depending on site-specific factors. The customised estimate is then compared via a top down review to the end costs of similar projects.

Maintenance and refurbishment project costs are based on building blocks using historic costs only.

Contingency planning

We maintain contingency response resources including sufficient field staff and emergency spares to enable rapid restoration following a failure. The spares are condition-monitored, maintained, and are ready for immediate installation and service.

Key aspects of our approach to contingency planning and managing spare transformers include:

- Strategic spares will be kept in a state of readiness, and will be subject to regular close inspection and preventive maintenance
- Developing site specific contingency plans based on a cost benefit analysis of the risk reduction achieved
- Ensuring a mobile substation can be deployed at N security sites in a timely manner.

Programming and scheduling

Power transformer replacements and upgrades are individually scoped and priced works. As such, they are scheduled according to need and resource availability, while accounting for other work at the same location, such as major customer upgrades, using common resources.

Project Delivery

The five aspects of project delivery are design, procurement, programme and project delivery, commissioning, and decommissioning and disposal.

Design

Our transformers are bespoke, as each unit was designed and built to meet site specific operational, and customer requirements. New power transformers are specified based on standard designs and footprints wherever practical, and use standard components such as tap changers and bushings. Where we can, we use standardised specifications to limit diversity and reduce design errors.

Procurement

We apply a quality systems approach in the procurement of our power transformers. To mitigate risks of latent design or manufacturing errors, we:

- Have in-house technical and commercial expertise
- Maintain a panel of pre-qualified suppliers
- Perform qualified inspections during key manufacturing stages
- Oversee factory testing
- Use standardised specifications for transformer bushings and tap changers

Programme and Project Delivery

Our Programme and Project delivery is undertaken in accordance with our programme management framework. The delivery timeframes for power transformers account for detailed design, procurement, outage planning and co-ordination with other major works at the site. This is typically two to three years in duration.

Commissioning

We use pre-commissioning testing to ensure all essential functions and characteristics have been checked and tested (as far as is reasonably practicable) before system livening.
Decommissioning and Disposal
Predominantly our decommissioned power transformers are scrapped. The oil is sold to a licensed oil dealer for regeneration and re-use. The metals such as steel and copper is sold to be smelted and re-used. Some decommissioned transformers are retained as spares for specific sites where there are concerns about the condition of the existing units and they are not adequately covered by general spares.

Service Delivery
We undertake preventive, corrective, predictive and proactive maintenance activities as specified in our maintenance standards for power transformers.

Operate the Grid
We plan and manage outages in a way that creates a safe environment for employees while minimising the disruption for customers.

Forecast Expenditure
Our forecast expenditure for power transformers is described below.

Capital Expenditure
RCP 2, 2018 to 2020
The number of power transformers forecast to be replaced over RCP 2 remains the same as presented in the 2016 AMP. However, the total Capex forecast has increased by $10.5 million (12%) due to commencement of the transformer bushing replacement programme, which is expected to defer approximately 32 transformer replacements over the RCP 3 period. There are also additional minor works incorporated into the forecast such as enabling works for installation of strategic spares, enabling faster fault response, and firewall installations which have arisen out of planning work over the last year.

RCP 3, 2020 to 2025
The change in management approach from complete transformer replacement to first considering investment options, which cost effectively extends the life of a transformer and mitigates transformer performance risk, has resulted in an overall reduction in the RCP 3 and RCP 4 Capex forecast. The forecast provides for a continuation of the bushing replacement programme, replacement of 16 transformers, retrofitting firewalls at four sites, along with minor works enabling the deployment of strategic spares and mobile substation connections.

RCP 4, 2025 to 2030
The transformer replacements during RCP 2 and 3, along with the bushing replacement programme, results in a further reduction in the forecast for RCP 4. At this stage, it is expected that during RCP 4 eight to ten transformers will require replacement. It is likely that expenditure on transformers will increase again in RCP 5 as the units refurbished will require replacement.

Operating Expenditure
While our RCP 2 programme of work had very little allocated budget for power transformer maintenance projects, a review of our approach to managing power transformers has shown that it is efficient and cost-effective for increasing the maintenance projects to be undertaken. This includes covering:
- Those bushing replacements that cannot be capitalised
- Corrosion and oil leak repairs
- Refurbishments
- Various other investigations, enabling works, component replacements and monitoring works.
As an additional maintenance programme of work, we have to replace the oil of a number of power transformers. These transformers are units manufactured or overhauled in the 1990’s, when the oil refinery process included corrosive sulphur additives that have been found to damage the core parts of the transformers. This is an issue affecting utilities world-wide. We are mitigating it by replacing the oil, starting with the most critical units that have been found to contain corrosive sulphur in their oil.

**Key risks and uncertainties**

The forecast assumes that two transformers which are planned to be upgraded through customer works will be able to be redeployed at another site. Should the customer change their proposed approach, the forecast will be updated to reflect this. The forecast is also dependent upon the market costs of transformers remaining constant, and the availability of resources to deliver the proposed programme of works.

**Summary, 2018 to 2030**

<table>
<thead>
<tr>
<th></th>
<th>RCP 2</th>
<th></th>
<th></th>
<th></th>
<th>RCP 3</th>
<th></th>
<th></th>
<th></th>
<th>RCP 4</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Power</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transformers</td>
<td>6.8</td>
<td>7.6</td>
<td>21.7</td>
<td>46.0</td>
<td>17.5</td>
<td>25.0</td>
<td>20.6</td>
<td>16.3</td>
<td>8.7</td>
<td>20.4</td>
<td>12.7</td>
<td>8.2</td>
<td>7.2</td>
</tr>
</tbody>
</table>

Table 15: Power Transformers Forecast R&R capital expenditure

**Long-term forecast**

It is expected that expenditure during RCP 5 will be closer to the RCP 3 level, as many units which had bushing replacement completed will start to require replacement. For example, the internal condition of several 1960s transformers are expected to have degraded to the point where replacement is required. It is also expected that the current levels of operational expenditure will continue.
ASSET CLASS PLAN – INDOOR SWITCHGEAR

This asset class plan describes our life cycle management approach for indoor switchgear. Indoor switchgear is used to control, protect, and isolate electrical equipment on electric power systems.

Each indoor switchgear panel consists of a circuit breaker, disconnectors, instrument transformers, and bus-work. However, in terms of expressing the condition, population, and diversity, circuit breakers are used as a proxy for the whole panel. Each switchgear panel is assumed to have one circuit breaker.

There are two types of indoor switchgear: medium voltage (MV), and high voltage (HV).

**MV indoor switchgear**

The two main MV switchboard systems are:

- Air insulated: Used for most metal-clad switchgear purchased since the early 1980s and still being purchased for 11 kV switchboards
- SF6 insulated: Used since 2000 and is current technology.

Table 16 provides a breakdown of our MV indoor switchgear circuit breakers, by type and voltage.

<table>
<thead>
<tr>
<th>Type</th>
<th>11 kV</th>
<th>22 kV</th>
<th>33 kV</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vacuum</td>
<td>260</td>
<td>14</td>
<td>395</td>
<td>669</td>
</tr>
<tr>
<td>SF6</td>
<td>4</td>
<td>26</td>
<td>109</td>
<td>139</td>
</tr>
<tr>
<td>Bulk oil</td>
<td>71</td>
<td>0</td>
<td>12</td>
<td>83</td>
</tr>
<tr>
<td>Air blast</td>
<td>12</td>
<td>0</td>
<td>0</td>
<td>12</td>
</tr>
<tr>
<td>Minimum oil</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>356</strong></td>
<td><strong>40</strong></td>
<td><strong>516</strong></td>
<td><strong>985</strong></td>
</tr>
</tbody>
</table>

Table 16: MV indoor switchgear circuit breaker population

**HV indoor switchgear**

Our HV indoor switchgear is SF6 insulated. Table 17 provides a breakdown of our HV indoor switchgear circuit breakers.

<table>
<thead>
<tr>
<th>Type</th>
<th>220 kV</th>
<th>110 kV</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>SF6</td>
<td>64</td>
<td>9</td>
<td>73</td>
</tr>
</tbody>
</table>

Table 17: HV indoor switchgear circuit breaker asset class population

**Asset Characteristics**

Compared with outdoor switchgear, indoor switchgear delivers superior safety performance, reduced maintenance requirements, reduced substation footprint, and protects the electric power system from vandalism, pests, and corrosion.

Our MV switchgear is of widely varying designs and technology. The older switchboards have withdrawable circuit breakers, and generally use air-insulated buswork. In contrast, our recent installations of 33 kV indoor switchboards are ‘fixed pattern’ types, where the circuit breaker is non-withdrawable, and the busbar chambers are SF6 insulated.

HV indoor switchgear is characterised by high safety and reliability performance, as all the HV parts are enclosed within a sealed metal compartment.
Age Profile

Figure 20 shows the age profile of our Indoor Switchgear.

Figure 20: Indoor Switchgear Age Profile

Asset Health

The standard life expectancy for our HV indoor switchgear is 40 years. The standard life expectancy for MV indoor circuit breakers by type is shown in Table 18.

<table>
<thead>
<tr>
<th></th>
<th>Vacuum</th>
<th>Bulk oil</th>
<th>Minimum oil</th>
<th>SF₆</th>
</tr>
</thead>
<tbody>
<tr>
<td>Life Expectancy</td>
<td>35</td>
<td>50</td>
<td>35</td>
<td>35</td>
</tr>
</tbody>
</table>

Table 18: MV Indoor Circuit Breakers Life Expectancy

A small number of our older MV switchboards use bulk oil circuit breakers. These are relatively high maintenance types and have an increased risk of causing explosive failure, compared with modern circuit breakers. These bulk oil circuit breaker type switchboards are all prioritised for replacement.

Our MV and HV indoor switchgear is generally in good condition, based on historic performance and monitoring using standard industry techniques. However, there are some specific issues of concern with some of our GIS indoor switchgear. These are in relation to:

- Performance and maintenance of the hydraulic drives for the circuit breakers
- Failures of disconnector and earth switch motor drives
- Lack of adequate gas monitoring equipment in each gas compartment
- Condition of the outdoor portions of the GIS supporting the line terminations.

Asset Criticality

We are currently developing criticality for indoor switchgear based on our standard criticality framework.
Asset Performance

The performance of our indoor switchgear is essential to ensuring safety and maintaining reliability of supply to customers. There have been no recorded safety incidents. However, HV circuits breakers represent a potential environmental hazard because of the large volumes of SF$_6$ gas in these installations. To mitigate this, we have gas monitoring and handling procedures and equipment in place.

Most of the historic major failures of our MV indoor switchgear have been caused by internal flashovers, typically triggered by external events (such as lightning surges), or rodent intrusion. Some switchboard failures have been triggered by the failure of a voltage transformer that was an integral part of the switchgear.

In several cases, the lack of physical segregation in these installations compromised the reliability of supply from the complete switchboard following the failure.

Less serious failures have occurred in cable termination compartments of MV indoor switchgear, when defective cable terminations have failed (although these are strictly not faults caused by the switchgear itself).

The performance of our HV switchgear has been good, apart from the Rangipo 220 kV GIS, where work has been required over many years to address SF$_6$ gas leaks.

Figure 21 shows the failures of our indoor switchgear by year and component cause.

Figure 21: Indoor Switchgear failures

Asset Life Cycle Stages

Our asset management approach is to actively manage indoor switchgear to ensure a high level of reliability, mitigate safety and environmental hazards, and avoid major failures at least life cycle cost.

Strategic Planning

The following strategic objectives have been established for our indoor switchgear:

Safety

- Zero harm or incidents resulting from explosive failure, arc flashes, or fire
- Zero instances of indoor circuit breakers failing to trip
- Zero fatalities and injuries while maintaining, repairing, installing, or decommissioning indoor switchgear, including the handling of contaminated oil and SF$_6$
- Physical clearances for safe egress around indoor switchgear to meet international standards.

Service Performance

- Unplanned outage rate to be less than 1% each year
- Restore security of supply within one calendar month of a major failure occurring
- Zero failures attributable to vermin.
Cost Performance
- Minimise life cycle cost by standardising designs for compact, modular, segregated switchgear
- Achieve efficiency through divesting non-core transmission and distribution network investment.

Customers and Stakeholders
- Limit SF₆ emissions to less than 1% of total inventory each year.

Development Initiatives
- We review industry practices and materials employed to ensure modern, cost effective solutions are being used. This includes having an awareness of emerging technologies, including CO₂, vacuum, and intelligent circuit breakers. We have developed an improved approach to SF₆ switchgear leak monitoring and top-ups.

Tactical Planning
Our planning approach for indoor switchgear is based on a combination of performance and safety based drivers. The drivers for asset replacement include:
- Legacy technology, such as bulk oil circuit breakers, with a relatively high maintenance requirement and increased potential for explosive failures
- Local or international experience with a model of switchgear that indicates a high risk of major failure
- Condition assessment inspections, tests, and service history show insulation or other major component deterioration beyond specified limits, and where reconditioning or component replacement is not a viable option
- Maintenance and physical access clearances do not comply with applicable safety standards
- No physical segregation, leading to the potential for widespread damage and outages in the event of a major failure
- The current or fault rating is inadequate for the required service duty, and cannot be economically uprated
- A systemic defect has been identified which cannot be economically addressed by refurbishment
- Spares or replacement components can no longer be purchased or the cost is uneconomical
- Maintenance, reconditioning, or repair costs become uneconomical

Most of our older population of MV switchgear is not ‘arc-fault contained’. We are retrofitting arc-fault containment to some models of indoor switchgear to minimise the risk of harm, limit damage to equipment, and help maintain reliability of supply to customers.

Condition Assessments
Regular condition assessment of our indoor switchgear is undertaken. Our programme of routine condition monitoring inspections, tests, and servicing is shown in Table 19. We aim to carry out regular inspections and tests with frequencies based on criticality, risk exposure, age, and type.

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 Monthly:</td>
<td>An in-service visual and audible noise level 1 inspection during routine station inspection</td>
</tr>
<tr>
<td>Yearly:</td>
<td>An in-service level 2 inspection is carried out from ground level, but is more comprehensive than the level 1 inspection. A thermo-graphic survey is carried out during a survey of the station. <strong>MV Switchgear</strong> A non-invasive survey for indications of partial discharge.</td>
</tr>
<tr>
<td>Two yearly</td>
<td>Refresh of condition scoring for observed condition (based on ground level inspection), for all assets with a most recent observed condition score of 50 or less.</td>
</tr>
</tbody>
</table>
## Frequency Activities

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Activities</th>
</tr>
</thead>
</table>
| Four yearly | MV Switchgear  
Insulation testing of all switchboards over 30 years old.                |
|           | MV Switchgear – air break and oil                                           |
|           | Out-of-service comprehensive diagnostic testing, functional checks and servicing. This includes insulation and contact resistance testing, minimum operating voltage, power factor and partial discharge tests.  |
|           | Condition assessment, including numeric scoring, during the out of service inspection. |
| Eight yearly | HV Switchgear  
Out-of-service comprehensive diagnostic testing, and functional checks including busbar diagnostic inspection and service.  |
|           | MV Switchgear – SF₆, and vacuum                                           |
|           | Out-of-service comprehensive diagnostic testing, functional checks and servicing. This includes insulation and contact resistance testing, minimum operating voltage, power factor and partial discharge tests.  |
|           | Condition assessment, including numeric scoring, during the out of service inspection. |

Table 19: Condition-monitoring tests and inspections

### Decision Framework

The work programme for indoor switchgear is determined by applying the four steps of the Decision Framework.

**Need identification**

Needs and need dates are identified based on a combination of performance, condition, and industry experience.

**Options Assessment**

The options considered for MV indoor switchgear is:
- Retrofitting arc-fault containment (where technically feasible)
- Retrofitting arc flash protection
- Retrofitting with new circuit breakers, if the existing equipment will support this
- Full replacement.

We use economic analysis to determine the most cost-effective approach.

Options for HV indoor switchgear include refurbishment and replacement. We use economic analysis and advice from the original manufacturer to determine the most effective approach.

**Prioritise solutions**

Solutions are prioritised based on need dates.

**Develop an Programme Management Plan**

We integrate indoor switchgear replacements with other works such as other replacement works or upgrades at the same site, and supply point upgrades undertaken by customers to achieve efficiencies and minimise outages.

**Cost estimation**

Cost estimation for indoor switchgear projects are customised on an individual basis. However, a small number of building blocks are used for site specific factors such as relocation of existing underground services, consent costs and environmental costs.

**Contingency planning**

We maintain and review spares holding to ensure an adequate level of contingency response in the event of failure or damage. We retain provision of a mobile 33/22/11 kV switchboard that can be deployed at short notice in the event of a major failure of a MV switchboard.
Programming and scheduling
Indoor switchgear replacements and upgrades are individually scoped and priced works. As such, they are scheduled according to need and resource availability accounting for other work at the same location using common resources.

Project Delivery
The five aspects of project delivery are design, procurement, programme and project management, commissioning, and decommissioning and disposal.

Design
We use a set of design standards for all new indoor switchgear. Specifically, for all new indoor switchgear projects, we deploy switchgear designs that include arc fault detection, arc-fault containment and venting, and physical segregation between bus sections serving significant loads.

Procurement
Our procurement plans involve:
- Procuring indoor switchgear from a limited number of approved manufacturers to reduce diversity, resulting in lower costs, risk, and increased reliability
- Seeking to obtain extended warranty periods for indoor supply contracts
- Staying in regular contact with the original equipment manufacturer so that we receive adequate notice of declining availability of spare parts. This will provide us with an opportunity to purchase additional spares before they are no longer available.

Programme and Project Delivery
Our Programme and Project delivery is undertaken in accordance with our programme management framework.

The delivery timeframes for MV switchboard replacement, which usually require building a new switch room building, account for detailed design, procurement, outage planning, and co-ordination with other major works at the site. This is typically 2 to 3 years in duration.

Commissioning
Our commission plan outlines commissioning planning, testing, livening, hand over, operational, and maintenance processes.

Once all works are complete, our project close-out activities include final capitalisation of the project within financial systems, feedback about actual costs to assist with future cost estimation, updating asset management information systems, archiving of the relevant documentation, and the review of ‘lessons learned’ including a review of health and safety performance.

Decommissioning and Disposal
We maintain and follow an appropriate decommissioning process that includes safe work site management and responsible scrap disposal.

Service Delivery
We undertake preventative, corrective, predictive, and proactive maintenance activities as specified according to our maintenance standards for indoor switchgear.

Operate the Grid
We plan outages to provide a safe environment for employees and service providers to undertake the work, while minimising the disruption for customers.
Forecast Expenditure

Our forecast expenditure for indoor switchgear is described below.

Capital Expenditure

RCP 2, 2018 to 2020
Expenditure has increased from the RCP 2 budget after revising the priorities and substituting some projects for higher priority (and higher cost) projects. We are currently forecast to be $7.8 million overspent from the original RCP 2 plan of $33.1 million.

The original plan covered four indoor switchboard replacements at three sites together with 10 arc-venting (safety) retro fits. The current forecast encompasses four switchboard replacements at four sites but has substituted the Kaiapoi switchboard replacement with the more expensive Penrose replacement (following identification of asbestos containing dust at the Penrose site). An additional safety improvement project has also been added to the plan.

RCP 3, 2020 to 2025
The number of boards requiring replacement in RCP 3 remains reasonably steady with eight planned. There is only one remaining board requiring a safety improvement, which is planned for RCP 3.

The unit costs are based on TEES building blocks for components of the switchboard replacement aggregated into a total replacement cost. The costs are also expected to remain reasonably steady throughout these periods.

RCP 4, 2025 to 2030
The planned replacements will continue to follow the same steady trend with seven replacements planned for RCP 4.

Operating Expenditure

Maintenance project expenditure of $6.1 million was planned for RCP 2 mainly focusing on works at Rangipo and Clyde. A reassessment of the work required at Clyde has enabled us to reduce this forecast to $2.9 million for the period.

Key risks and uncertainties
The key risks in delivering the forecasted expenditure and replacement volumes are ensuring the budget estimates for the projects are accurate and that resource continues to be available. The previous estimates using the building blocks for indoor switchgear have been accurate and therefore we expect the future cost estimates to be accurate. Some smoothing of projects has been done to attempt to produce a steady stream of work to ensure the resource is available when required.

Summary, 2018 to 2030

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<th>RCP 2</th>
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Table 20: Forecast capital expenditure

Long-term

As described above, the planned replacements will continue to follow the same steady trend with eight planned replacements in RCP 5.
ASSET CLASS PLAN – OUTDOOR CIRCUIT BREAKERS

This asset class plan describes our life cycle management approach of outdoor circuit breakers. Circuit breakers are essential to the safe operation of the grid. They are used to rapidly disconnect faulty electrical equipment from the grid. Correct operation is vitally important for limiting safety risk and ensuring reliability of supply. In addition, they are used to control the flow of power around the network. Table 21 provides a breakdown of our outdoor circuit breakers population by type and voltage.

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<tr>
<th>Type</th>
<th>11kV</th>
<th>22-33kV</th>
<th>50-66 kV</th>
<th>110 kV</th>
<th>220 kV</th>
<th>Other</th>
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<td>529</td>
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Table 21: Outdoor circuit population

The number of outdoor 33 kV circuit breakers is progressively reducing as we:
- convert our outdoor 33 kV switchyards to indoor switchgear
- divest our assets
- decommission some points of supply.

Asset Characteristics

We classify circuit breakers by the interrupter medium they use to extinguish the arc that occurs when the current is interrupted. Progressively we have changed the standard type of breaker from the older bulk oil through to the SF₆ and Vacuum Breakers that are in use today. Generally, our outdoor circuit breakers are in good condition. However, as they age increasing volumes will need replacement.

Age Profile

Our outdoor circuit breakers have been installed progressively, with periods of grid development in the 1930s and the 1950s to 1980s. There has also been ongoing replacement and upgrading of assets throughout this time, driven by asset condition and depending on the life expectancy of various circuit breaker types. In the early 1990s we adopted a strategy to progressively replace a range of 110 kV and 220 kV circuit breakers that we found had systemic problems. These circuit breakers were replaced with new SF₆ technology.

Figure 22 shows the age profile of our outdoor circuit breakers.

---

4 11kV category includes load break switches and ring main units
Our normal life expectancy for SF₆ circuit breakers is 35 years, 45 years for bulk oil circuit breakers, and 40 years for others. Recently we have implemented an asset health model based on CBRM, for our outdoor circuit breakers. Our asset health modelling approach for outdoor circuit breakers uses the normal life expectancy for each type of outdoor circuit breaker, adjusted for factors such as condition, operation count and expected operating count, maintenance costs, and corrosion zone.

Figure 23 illustrates the asset health of our outdoor circuit breakers.
Asset Criticality

Criticality for our outdoor circuit breakers is based on our standard criticality framework. Figure 24 illustrates the proportion of our outdoor circuit breakers in each criticality category.

![Figure 24: Outdoor Circuit Breaker Criticality](image)

Asset Performance

The most common cause of minor failures of outdoor circuit breakers is SF₆ leaks. These leaks occur because of the design and materials used in the original manufacture leading to corrosion occurring in the New Zealand environment. The historic performance of our circuit breakers shows a rate of unplanned outages that is higher than international benchmarks, particularly for 110 kV circuit breakers.

However, the observed major failure rate over the past 20 years is less than 0.5% which is considerably less than our international peers. Our low rate of major failures is attributed to the circuit breaker replacement programme that commenced in the early 1990s.

Figure 25 illustrates unplanned outages by cause.

![Figure 25: Outdoor Circuit Breaker Unplanned Outages](image)
Asset Life Cycle Stages

Our asset management approach is to actively manage our outdoor circuit breakers to ensure a high level of reliability, at least life cycle cost.

Strategic Planning

The following strategic objectives have been set for our outdoor circuit breakers:

Safety

- Zero instances of circuit breakers failing to trip
- Zero fatalities or injuries while maintaining, repairing or installing circuit breakers, including the handling of contaminated oil and SF₆
- Minimise risk of injuries from explosions by phasing out porcelain in favour of composite insulator materials of new circuit breakers.

Service Performance

- Ten year rolling average for major failures remains less than 0.5% per annum over RCP 2
- Reduce unplanned outage rates of outdoor circuit breakers to less than the following by the end of RCP 2:
  - 1.5% each year at 220 kV
  - 1% each year at 110 kV
  - 0.5% each year at 66 kV

Cost Performance

- Minimise life cycle cost, including:
  - Improved procurement processes, considering maintenance costs as well as capital costs
  - Extended warranties in place for new circuit breakers
  - Increased use of disconnecting circuit breakers
- Optimised maintenance schedules, reflecting technology changes
- Further reduce model diversity to help reduce maintenance costs.

Customers and Stakeholders

- Limit SF₆ emissions to less than 1% of total inventory for each year.
- Minimise oil spills to the external environment.
- Minimise the future requirements for SF₆ by exploring alternative circuit breaker designs (such as CO2 and vacuum).
- Minimise risk of damage to third-party property from circuit breaker explosions.

Development Initiatives

We have commenced detailed forensic investigations on the main models of our aged SF₆ outdoor circuit breakers, to ascertain whether their normal expected life can be extended from beyond 35 years. To date forensic investigations have been completed on seven models. From these investigations, four models have had their expected life extended from 35 to 50 years. We are currently working through the results from the remaining three investigations. It is likely that two models will have their life extended from 35 to 45 years and one model’s life expectancy to remain at 35 years.

We are monitoring new and emerging technologies, including our approach to circuit breaker leaks and top ups.
Tactical planning

We have an ongoing programme to replace aged, deteriorated, and unreliable circuit breakers, in accordance with the strategy. Our main activities for outdoor circuit breakers are:

- Replacing and repairing leak-prone SF₆ circuit breakers
- Continuing to replace legacy circuit breakers that use bulk oil and minimum oil interrupters with our preferred circuit break type (SF₆)
- Replacing circuit breakers that exceed their forecast life expectancy
- Undertaking forensic investigations of samples of ageing populations
- Replacing circuit breakers that have reached maximum operation limits
- When circuit breaker replacements are required, using where practicable live tank disconnecting circuit breakers, to reduce the number of disconnector and earth switches.

Condition Assessments

A nationwide assessment of external condition of our outdoor circuit breakers was undertaken in 2016. Our routine condition monitoring tests and inspections is shown in Table 22.

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two Monthly</td>
<td>An in-service level 1 inspection involving visual and audible noise observations during routine station inspection.</td>
</tr>
<tr>
<td>Yearly</td>
<td>An in-service level 2 inspection is carried out, which is more comprehensive than the level 1 inspection and includes operational checks.</td>
</tr>
<tr>
<td></td>
<td>External inspection and certification of pressure vessels in circuit breakers with pneumatic and hydraulic mechanisms.</td>
</tr>
<tr>
<td></td>
<td>A thermo-graphic survey is carried out during a survey of the station.</td>
</tr>
<tr>
<td>Four yearly</td>
<td>An out-of-service diagnostic inspection and condition assessment of bulk oil circuit breakers, including the external insulation, support structure, HV connections, mechanism boxes and low voltage wiring.</td>
</tr>
<tr>
<td></td>
<td>The scope includes electrical test measurements of minimum operating voltage, contact resistance, insulation resistance, and timing.</td>
</tr>
<tr>
<td></td>
<td>Internal inspection and certification of air receivers of circuit breakers with pneumatic mechanisms.</td>
</tr>
<tr>
<td></td>
<td>External condition assessment, including numeric scoring, for all outdoor circuit breakers.</td>
</tr>
<tr>
<td>Eight yearly</td>
<td>An out-of-service diagnostic inspection and condition assessment of SF₆ circuit breakers, including the external insulation, support structure, HV connections, mechanism boxes and low voltage wiring.</td>
</tr>
<tr>
<td></td>
<td>The scope includes electrical test measurements of minimum operating voltage, contact resistance, insulation resistance, and timing.</td>
</tr>
</tbody>
</table>

Table 22: Condition-monitoring tests and inspections
Decision Framework
The work programme for outdoor circuit breakers is determined by applying the four steps of the Decision Framework.

Need identification
Our model of asset health and probability of failure is assisting in identifying and prioritising the need for interventions. Replacement needs and need dates are usually driven by condition assessment, type of circuit breaker, age, condition, performance and maintenance history, safety, and corrosion zone.
While we continue to test and refine the CBRM model, we will sense check its outputs against our existing understanding of asset condition and previously developed replacement plans.

Options Assessment
Replacement is usually the only option for outdoor circuit breakers. Replacements are either:
- Like-for-like. This is replacing with a modern equivalent model installed on same pad.
- A slight change to like-to-like. This is replacing with a modern equivalent model, with pad modification and new secondary cables.
- Replacement with another model of circuit breaker. This option is chosen when the original is installed in a configuration that doesn’t meet current electrical clearances.
In some cases, leak prone SF₆ circuit breakers can have the leaking poles replaced, rather than replacing the unit.

Prioritise solutions
Solutions are prioritised based on need date. Our standard criticality framework is used to further refine intervention timing.

Develop a Programme Management Plan
In developing the programme management plan, we may bring forward or defer replacement works to integrate them with other works such as power transformer upgrades, site reconfigurations, or work in the same bay the circuit breaker is located. If the preferred option is replacement, any deferral will require assessment of the risks and costs of maintaining service until the later replacement date.

Cost estimation
We have defined building block unit rates for outdoor circuit breaker replacements. Our experience during RCP 2 is that site specific factors should be carefully averaged out in the calculation of the building block rates. As such, building block estimates are frequently reviewed using trend information on past project actuals. Also, large site-specific scope changes, such as bay reconfiguring when replacing outdoor circuit breakers, are not included in the building block rates. A customised estimation approach is used in these instances.

Contingency planning
We maintain contingency response resources, including sufficient field staff and emergency spares, to enable rapid restoration following a failure.

Programming and scheduling
Works associated with outdoor circuit breakers are integrated into a wider programme schedule that accounts for other works at the same location using common resources.
**Project Delivery**

The five aspects of project delivery are design, procurement, programme and project management, commissioning, and decommissioning and disposal.

**Design**

Our design process for outdoor circuit breakers is based on standard installation designs, and a standard procurement specification. We specify SF₆ circuit breakers as our standard interrupter technology for operating voltages above 33 kV. Vacuum circuit breakers are specified for application at 33 kV and below. For special applications, we specify disconnecting circuit breakers, or compact switchgear assemblies. These devices have a built-in disconnector and earth switch function.

Our technical specification for procurement includes requirements for our environmental conditions such as seismic strength and corrosion protection. We specify non-ceramic post insulators or bushings for all outdoor circuit breakers, to mitigate risks in the event of an explosive failure. Our specification also requires that SF₆ circuit breakers can be safely topped-up live.

**Procurement**

Lifetime performance of an outdoor circuit breaker is dependent on the quality in the original product design and manufacture. We apply a quality systems approach in our procurement process including careful selection of vendors, procuring from the minimum number of vendors, and specification of quality requirements in the design and manufacturing process. Procurement lead time for outdoor circuit breakers is approximately 8-12 months.

**Programme and Project Delivery**

Our programme and project delivery is undertaken in accordance with our programme management framework. As a volumetric programme, the delivery timeframes for outdoor circuit breakers is 24 months. This enables the design and procurement to be completed within the first 12 months, with the final year allocated for construction. This ensures clear visibility and allows resource planning for the service providers.

**Commissioning**

Our commissioning plan outlines planning, testing, livening, hand over, operational, and maintenance processes.

Once all works are complete, our project close-out activities include final capitalisation of the project within financial systems, feedback about actual costs to assist with future cost estimation, updating asset management information systems, processing as-built drawings, archiving the relevant documentation, and reviewing "lessons learned", including a review of health and safety performance.

**Decommissioning and Disposal**

We follow an appropriate decommissioning process that includes safe work site management and responsible scrap disposal. The disposal stage of the life cycle involves decommissioning outdoor circuit breakers and the associated air compressors, where applicable. In decommissioning SF₆ circuit breakers, we recover SF₆ to avoid emissions into the atmosphere. Disposal of porcelain and oil from bulk oil outdoor circuit breakers are subject to hazardous waste requirements.

**Service Delivery**

We undertake preventive, corrective, predictive, and proactive maintenance activities as specified in our maintenance standards for outdoor circuit breakers. Minor maintenance and refurbishment works occur typically at the time of scheduled servicing which is four yearly for bulk oil breakers or twelve yearly for newer assets. Where necessary, outages will be taken to accommodate corrective and preventative maintenance.

**Operate the Grid**

We plan outages to provide a safe environment for employees and service providers to undertake the work, while minimising disruptions to customers and end users.
Forecast Expenditure

Our forecast expenditure for outdoor circuit breakers is described below.

Capital Expenditure

RCP 2, 2018 to 2020
The RCP 2 plan was reviewed and amended in 2015. There has been significant overspend on the circuit break asset class due to replacements being treated as like for like. It was discovered in many instances that, on the 110kV, 66kV and 33kV circuit breaker replacements, there was insufficient clearance to install a new circuit breaker and meet clearance standards. Extensive work was required to find a solution and in some instances a Disconnecting Circuit Breaker was installed, increasing costs further.

This will be accounted for in future by carrying out an investigation to design a pipeline of replacements up front to meet the clearances. The first one of these investigations is being carried out in the 2017/2018 financial year to scope and price the remaining RCP 2 projects.

RCP 3, 2020 to 2025
An increasing number of circuit breakers are reaching the end of their life in RCP 3, and therefore we need to replace increasing volumes from 2020.

Forensic investigations are planned to determine the health of aging outdoor circuit breakers and whether their lives can be extended. Depending on the investigation outcomes, some of these replacements may be delayed a further 5-15 years, which could significantly reduce the forecast expenditure.

The unit costs for outdoor circuit breakers are based on TEEs building blocks for volumetric replacements. We have found that most of the 110kV, 66kV and 33kV outdoor circuit breaker replacements cannot be replaced like-for-like. Accordingly, the approach to planning for the replacement of these outdoor circuit breakers is currently under review.

RCP 4 and 5, 2025 to 2035
The proportion of outdoor circuit breakers that are reaching end of life continues to increase into RCP 4 and 5. Therefore the numbers of replacements planned continues to increase.

Operating Expenditure
In addition to the on-going routine maintenance, it is planned to carry out regular forensic assessments as described above.

Key risks and uncertainties
The implementation of CBRM has the potential to significantly change the current forecast. Additionally, the outcome of the forensic investigation into the 110kV, 66kV and 33kV circuit breaker replacements has the potential to significantly change the forecast for future replacements. The forensic investigations also have the potential to defer a significant number of replacements.

Summary, 2018 to 2030

<table>
<thead>
<tr>
<th>Outdoor Circuit Breakers</th>
<th>RCP 2</th>
<th>RCP 3</th>
<th>RCP 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>2.8</td>
<td>3.8</td>
<td>5.3</td>
</tr>
<tr>
<td>2017</td>
<td>4.4</td>
<td>5.1</td>
<td>5.2</td>
</tr>
<tr>
<td>2018</td>
<td>5.6</td>
<td>4.3</td>
<td>5.3</td>
</tr>
<tr>
<td>2019</td>
<td>2.4</td>
<td>1.4</td>
<td>3.8</td>
</tr>
<tr>
<td>2020</td>
<td>4.5</td>
<td>4.9</td>
<td>5.1</td>
</tr>
<tr>
<td>2021</td>
<td>1.9</td>
<td>4.3</td>
<td>4.3</td>
</tr>
<tr>
<td>2022</td>
<td>3.2</td>
<td>3.2</td>
<td>4.3</td>
</tr>
<tr>
<td>2023</td>
<td>1.4</td>
<td>3.8</td>
<td>5.2</td>
</tr>
<tr>
<td>2024</td>
<td>4.9</td>
<td>5.1</td>
<td>5.3</td>
</tr>
<tr>
<td>2025</td>
<td>4.3</td>
<td>4.3</td>
<td>5.3</td>
</tr>
<tr>
<td>2026</td>
<td>3.8</td>
<td>3.8</td>
<td>5.3</td>
</tr>
<tr>
<td>2027</td>
<td>5.1</td>
<td>5.1</td>
<td>5.3</td>
</tr>
<tr>
<td>2028</td>
<td>4.3</td>
<td>4.3</td>
<td>5.3</td>
</tr>
<tr>
<td>2029</td>
<td>5.2</td>
<td>5.2</td>
<td>5.3</td>
</tr>
<tr>
<td>2030</td>
<td>5.3</td>
<td>5.3</td>
<td>5.3</td>
</tr>
</tbody>
</table>

Table 23: Outdoor circuit breaker Forecast R&R capital
ASSET CLASS PLAN – OUTDOOR INSTRUMENT TRANSFORMERS

This asset class plan describes our life cycle management approach for outdoor instrument transformers. Instrument transformers are essential to the protection and monitoring of the grid. Their purpose is to convert high voltages and currents to lower levels that can be safely measured by power system protection and instrumentation equipment. Table 24 provides a breakdown of our outdoor instrument transformers population by type and voltage level.

<table>
<thead>
<tr>
<th>Type</th>
<th>N/A</th>
<th>11-33 kV</th>
<th>50-66 kV</th>
<th>110 kV</th>
<th>220 kV</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacitor Voltage Transformer (CVT)</td>
<td></td>
<td></td>
<td></td>
<td>102</td>
<td>860</td>
<td>962</td>
</tr>
<tr>
<td>Current Transformer (CT)</td>
<td>273</td>
<td>217</td>
<td>1,307</td>
<td>1,605</td>
<td>3,402</td>
<td></td>
</tr>
<tr>
<td>Neutral Current Transformer (NCT)</td>
<td>274</td>
<td></td>
<td></td>
<td></td>
<td>274</td>
<td></td>
</tr>
<tr>
<td>Voltage Transformer (VT)</td>
<td>273</td>
<td>111</td>
<td>520</td>
<td>7</td>
<td>923</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>274</td>
<td>547</td>
<td>328</td>
<td>1,929</td>
<td>2,472</td>
<td>5,546</td>
</tr>
</tbody>
</table>

Table 24: Outdoor instrument transformer population

Asset Characteristics

Almost all our outdoor instrument transformers are oil-filled with porcelain insulation. Experience has shown oil filled outdoor instrument transformers with porcelain insulators can be subject to explosive failures, which can result in shards of porcelain travelling considerable distances. The safety and asset damage risks associated with explosive failure can be substantially mitigated by using non-porcelain insulators. Composite insulator types have been introduced recently, and some resin encapsulated types are in service at lower voltages.

Outdoor oil-filled instrument transformers can be difficult to closely monitor. They are sealed units, and cannot be inspected internally. Routine oil sampling is generally prohibited because of the risk of disturbing the hermetic sealing and pressure control bellows, leading to increased likelihood of failure. Additionally, due to network impacts, outdoor instrument transformers are only removed from service for testing on an infrequent basis.

Our outdoor instrument transformers are predominantly single-phase units. However, there is a small population of 11 kV and 33 kV and metering units where all three phases are in one enclosure.

Age Profile

Figure 26 shows the age profile of our outdoor instrument transformers.

![Age Profile of Outdoor Instrument Transformers](image)

Figure 26: Age Profile of our Outdoor Instrument Transformers
**Asset Health**

Our instrument transformer asset health model incorporates an expected life assumption of 45 years, with adjustments made to reduce the forecast remaining life based on observed and measured condition assessment data. Figure 27 illustrates the asset health of our outdoor instrument transformers.

![Figure 27: Outdoor Instrument Transformer Asset Health](image)

**Asset Criticality**

Criticality for our outdoor instrument transformers is based on our criticality framework. Figure 28 shows the proportion of our outdoor instrument transformers in each criticality category.

![Figure 28: Outdoor instrument transformer criticality](image)
Asset Performance

Our outdoor instrument transformers are highly reliable. Most of our outdoor instrument transformer failures have been minor, involving primary connections, secondary wiring, or fuse holders. Major failures are rare but can result in explosions. Explosive failures create serious safety risks, and typically cause prolonged outages. They may also result in significant damage to other equipment.

We had major failures in 2003 and 2006, each involving 110 kV VTs; although these failures did not result in explosions. Investigation of both failures led to the identification of poor batches of VTs that were subsequently completely replaced. On 15 Dec 2016, there was an explosive failure of a 110 kV VT at Oamaru. An investigation is currently underway as to the cause of the failure.

Our rate of major failures is currently less than 0.01 per 100 outdoor instrument transformer years, assessed on a 10-year rolling average basis. Figure 29 shows the failures of our outdoor instrument transformers by year and component cause.

![Figure 29: Instrument Transformer failures](image)

Asset Life Cycle Stages

Our experience, and that of our international peers, is that well-designed and well-built outdoor instrument transformers can have a useful life of at least 45 years in benign environments. There is potential for extending the planned maximum lifetime for some specific models based on internal examination of samples from that population. Therefore, our strategy for outdoor instrument transformers is to replace based on condition, subject to a maximum life expectancy of 45 years, except where specific evidence obtained from expert dismantling of samples of a specific model justifies life extension of that model.

Strategic Planning

The following strategic objectives have been set for outdoor instrument transformers:

**Safety**
- Zero fatalities and injuries while maintaining, repairing, or installing outdoor instrument transformers
- Minimise risk of injuries from explosions of outdoor instrument transformers

**Service Performance**
- 10-year rolling average for major failures remains less than 0.05% each year
- 10-year rolling average rate of forced outages to be less than 5 events per annum

**Cost Performance**
- Minimise life cycle cost

**New Zealand Communities**
- Minimise risk of damage to third party property from outdoor instrument transformer explosions
Development Initiatives
We have commenced detailed forensic investigations of samples of larger populations of instrument transformers (where there is a minimum of 100 of a model in the field), to ascertain whether the normal expected life can be extended beyond 45 years. Should the findings from the investigation provide positive feedback, we will extend the life of that model up to a maximum of 10 years.

We are also trialling the use of non-conventional instrument transformers. We currently have a set of 110 kV optical instrument transformers and, subject to their reliability and accuracy, and the economics of implementing the associated new technology, non-conventional instrument transformers may be introduced progressively across the grid.

Tactical Planning
Our planning approach for our outdoor instrument transformers is to replace based on condition, as informed by the asset health model, subject to a maximum age of 45 years.

Condition Assessments
In 2016, we completed a one-off nationwide external condition assessment of instrument transformers, based on ground level inspections and a standardised photographic scoring guide.

We also undertake regular condition monitoring of our outdoor instrument transformers as shown in Table 25.

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monthly:</td>
<td>An in-service level 1 inspection involving visual and audible noise observations during routine station inspection</td>
</tr>
<tr>
<td>Yearly:</td>
<td>An in-service level 2 inspection is carried out, which is more comprehensive than the level 1 inspection and includes operational checks. A thermo-graphic survey is carried out during a survey of the station.</td>
</tr>
<tr>
<td>Four yearly:</td>
<td>An out-of-service diagnostic inspection of the instrument transformer, including its external insulation, housing, support structure, HV connections, terminal boxes and low voltage wiring. The scope includes numeric condition assessment scoring of external condition. Out-of-service diagnostic tests, including insulation resistance test and power factor test on all instrument transformers and capacitance tests on capacitor voltage transformers. Note The interval from original commissioning (as new) to first diagnostic testing, and the interval for the subsequent two diagnostic tests is 8 years. When the asset reaches an age of 24 years the diagnostic testing interval reverts to four years.</td>
</tr>
<tr>
<td>Eight yearly:</td>
<td>Calibration testing of instrument transformers that are primary inputs to revenue metering installations</td>
</tr>
</tbody>
</table>

Table 25: Condition-monitoring tests and inspections

Decision Framework
The work programme for outdoor instrument transformers are determined by applying the four steps of the Decision Framework.

Need identification
Asset health and criticality are used to determine needs and associated need dates.

Options Assessment
The only option considered for outdoor instrument transformers is replacement.

Prioritise solutions
Solutions are prioritised based on need date.
Develop a Programme Management Plan

We focus on identifying specific outdoor instrument transformers that require replacement. Our needs and need dates may be adjusted to allow for bundling and alignment with other works. For example, we may defer the replacement of our outdoor 33 kV instrument transformers to align with our outdoor to indoor 33 kV conversion work programme.

Cost estimation

We have defined building block unit rates for each outdoor instrument transformer type (CT, VT, CVT, and NCT) at each voltage level.

Actual delivery costs have often exceeded building blocks estimates due to factors that are site-specific and which are not adequately accounted for in the building block scope. These include:

- A need to strengthen or extend foundations for some assets to meet our current seismic specification
- Environmental costs (soil sampling and disposal of contaminated fill) associated with foundation earthworks can vary significantly from region to region depending on local council requirements
- Remote site locations
- Special site-specific design requirements that can be unique for each site.

To mitigate these factors, we are investigating the potential to move to more customised cost estimation prior to development of the Delivery Business Case.

Contingency planning

We maintain contingency response resources including sufficient field staff and emergency spares to enable rapid restoration following a failure. The spares are condition-monitored, maintained, and are ready for immediate installation and service.

Programming and scheduling

Outdoor instrument transformer replacement works are integrated into a wider programme schedule that accounts for other works at the same locations using common resources.

Project Delivery

The five aspects of project delivery are design, procurement, programme and project delivery, commissioning and decommissioning and disposal.

Design

Our design standards specify key activities to be considered during the design process. Factors considered in this process include our safety, service performance, and cost performance objectives and our legal obligations.

Our design process for outdoor instrument transformers is based on standard installation designs and a standard procurement specification.

Our technical specification includes requirements for our environmental conditions such as seismic strength and corrosion protection. Subject to technical compliance and availability, we specify non-porcelain insulators for all outdoor instrument transformers, to mitigate risks in the event of an explosive failure.

Procurement

Lifetime performance of an outdoor instrument transformer is dependent on the quality in the original product design and manufacture. We apply a quality systems approach in our procurement process including careful selection of vendors, procuring from the minimum number of vendors, and specification of quality requirements in the design and manufacturing process. Procurement lead time for new outdoor instrument transformers is approximately 8-12 months.
Programme and Project Delivery
Our Programme and Project delivery is undertaken in accordance with our programme management framework. Our volumetric programme for outdoor instrument transformers is based on a delivery timeframe of twenty-four months. This enables the design and procurement to be completed within the first twelve months with the final year allocated for construction. This ensures clear visibility and enables efficient resource planning for our service providers.

Commissioning
Our commissioning plan outlines commissioning planning, testing, livening, hand over, operational, and maintenance processes.
Once all works are complete, our project close-out activities include final capitalisation of the project within our financial systems, feedback about actual costs to assist with future cost estimation, updating asset management information systems, archiving of the relevant documentation, the processing of ‘as-built drawings’ and the review of ‘lessons learned’ including a review of health and safety performance.

Decommissioning and Disposal
We undertake diagnostic testing of selected outdoor instrument transformers prior to disposal as valuable information for supporting asset management decisions can be obtained. Testing can support inferences about the internal condition of the remaining population and the relative priorities for replacement.
Disposal of porcelain and oil from outdoor instrument transformers is subject to hazardous waste management requirements.

Service Delivery
We undertake preventive, corrective, predictive, and proactive maintenance activities as specified in our maintenance standards for instrument transformers. Minor maintenance works occur typically at the time of scheduled servicing which is four yearly or eight yearly for newer assets.

Operate the Grid
There are no specific outage planning strategies for outdoor instrument transformers.

Forecast Expenditure
Our forecast expenditure for outdoor instrument transformers is described below.

Capital Expenditure
RCP 2, 2018 to 2020
Expenditure in the initial years of RCP 2 has been higher than forecast. Significant cost overruns have occurred at sites that are very remote or where we have needed to address environmental issues (such as removing contaminated soil), or where the existing design scope is more complex than assumed by the TEEs building blocks (where substantial work is needed for new or extended foundations, reconfiguring bus work, and seismic strengthening). Current planning and forecasting is carried out well in advance before detailed project designs are completed and confirmed.
Due to recently revised asset class strategy, asset health modelling, and application of the decision framework, we have substituted all planned instrument transformer replacements for the final two years of RCP 2, based on updated priorities. This has reduced the forecast spend slightly however we remain forecasted to be $2.0 million over the RCP 2 allowance.

RCP 3, 2020 to 2025
An increasing number of outdoor instrument transformers are reaching end of life and therefore we have forecasted an increasing volume of replacements from 2020. Forensic investigations are being undertaken to determine whether an extension of life can be applied. Depending on the forensic investigation outcomes, some of these replacements may be pushed out a further 5-15 years which could significantly reduce the forecast expenditure in the RCP 3 and RCP 4 periods.
The unit costs for outdoor instrument transformers are based on TEEs building blocks. We have found over the period of RCP 2 that costs have over-run by an average of approximately 20%. This increase has been factored into the forecast expenditure.

**RCP 4, 2025 to 2030**

The proportion of outdoor instrument transformers that is reaching its end of life continues to increase into RCP 4 and therefore the numbers of replacements planned continues to increase.

**Operating Expenditure**

In addition to the on-going maintenance, the forensic assessments, as described above, will be treated as maintenance expenditure.

**Key risks and uncertainties**

The key risks in delivering the forecasted expenditure and volumes are ensuring the budget estimates for the projects are accurate, and that resource continues to be available to deliver the replacements. The building blocks are continuously reviewed and some smoothing of project replacements has been done to produce a steady stream of work, ensuring resource is available when required.

**Summary, 2018 to 2030**

<table>
<thead>
<tr>
<th>Instrument Transformers</th>
<th>RCP 2</th>
<th>RCP 3</th>
<th>RCP 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>4.3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2017</td>
<td>5.7</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2018</td>
<td>4.4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2019</td>
<td>2.5</td>
<td>2.2</td>
<td>2.9</td>
</tr>
<tr>
<td>2020</td>
<td>1.3</td>
<td>0.6</td>
<td>0.8</td>
</tr>
<tr>
<td>2021</td>
<td>1.3</td>
<td>1.5</td>
<td>1.0</td>
</tr>
<tr>
<td>2022</td>
<td>2.9</td>
<td>0.6</td>
<td>1.3</td>
</tr>
<tr>
<td>2023</td>
<td>1.5</td>
<td>1.0</td>
<td>3.0</td>
</tr>
<tr>
<td>2024</td>
<td>1.0</td>
<td>1.9</td>
<td>3.0</td>
</tr>
<tr>
<td>2025</td>
<td>3.0</td>
<td>1.9</td>
<td>3.0</td>
</tr>
<tr>
<td>2026</td>
<td>1.9</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>2027</td>
<td>3.0</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>2028</td>
<td>3.0</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>2029</td>
<td>3.0</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>2030</td>
<td>3.0</td>
<td>3.0</td>
<td></td>
</tr>
</tbody>
</table>

Table 26: Outdoor Instrument Transformer Forecast R&R capital

**Long-term forecast**

It is expected that the proportion of outdoor instrument transformers reaching end of life continues to slightly increase into RCP 5 and therefore the numbers of replacements planned continues to increase. Again, the forecast might change depending on the outcome from the forensic investigations that will be carried out.
ASSET CLASS PLAN – POWER CABLES

This asset class plan describes the life cycle management approach of our high voltage (HV) and medium voltage (MV) cables and their accessories, such as terminations and joints.

It excludes the capital costs associated with projects undertaken as part of other work programmes, such as outdoor to indoor conversions; power transformer and indoor switchgear replacement projects; HVDC submarine cables; and low voltage power cables (operating voltage below 1,000 volts). These are all covered in other asset class plans.

Our HV cables have an operating voltage from 66,000 V to 220,000 V and our MV cables have an operating voltage between 11,000 V and 33,000 V. These voltage classes are consistent with those used in international standards such as IEC\(^5\) and IEEE\(^6\) which we reference for design purposes and the procurement of electrical equipment (there are no equivalent NZ standards). HV cables are used mainly in public places outside substations in lengths greater than 500 metres, although there are some shorter cables inside substations. MV cables are used in short lengths (less than 500 metres), inside substations, mainly to connect power transformers and indoor switchgear.

Most of our grid relies on overhead transmission lines. However, HV power cables are becoming an increasingly important element of the system. Our HV cables provide transmission services in urban areas where the use of overhead lines is undesirable. Our HV cables consist of either oil-filled (OF) paper insulation or XLPE insulation. A small number of HV OF paper insulated cables were installed up until the mid-1980s. Since then we have used XLPE insulation for all new HV cables.

Our MV cables consist of either paper-insulated lead-sheathed cables (PILCs) insulation or cross-linked polyethylene (XLPE) insulation. We installed most of our MV PILC cables with porcelain outdoor pothead terminations up until the mid-1980s. Since then, we have used XLPE insulation with heat shrink or cold shrink terminations or plug-in cable connectors for almost all new and replacement cables.

For both HV and MV cables, the conductor type is either aluminium or copper. Table 27 provides a breakdown of our power cable population by type and voltage level.

<table>
<thead>
<tr>
<th>Cable Class</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>HV cable circuits &lt; 1km</td>
<td>53</td>
</tr>
<tr>
<td>HV cable circuits &gt; 1km</td>
<td>13</td>
</tr>
<tr>
<td>MV cable circuits &lt; 1km</td>
<td>660</td>
</tr>
<tr>
<td>Other</td>
<td>3</td>
</tr>
</tbody>
</table>

Table 27: Power Cable population

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\(^5\) International Electrotechnical Commission  
\(^6\) Institute of Electrical and Electronics Engineers
Asset Characteristics

A general characteristic of power cables is that fault rates are significantly lower when compared to overhead lines. However, when there is a fault, repairs take a long time to complete. The greatest risks arising from a cable installation are the hazards created by a cable being damaged because of third party excavations.

Age Profile

Figure 30 shows the age profile of our HV and MV power cables.

![Figure 30: Power Cable Age Profile](image)

Asset Health

The life expectancy for power cables is typically 50 to 60 years. In estimating the remaining life of our MV and HV cables and cable accessories, we assess condition and performance, together with relevant information on power cable failures internationally.

XLPE type cables, which make up 95% of our MV cables, are generally in good condition. Most of our legacy MV PILC cables are in fair to good condition. However, some MV cables have issues relating to moisture ingress and poor workmanship, which have led to sheath/termination failures. Most are being replaced as part of other projects. We are also taking steps to ensure cable termination installers are adequately trained and qualified.

A type issue has been identified with some of our 33 kV heat-shrink cable terminations failing at less than 10 years of age. We have a programme in place to replace these. A type issue has also been identified with a particular design of plug-in 33 kV cable terminations, warranting near term replacement. An annual testing regime has been established to monitor terminations of this design.

Our HV XLPE cables are in good condition, most having been installed since 2010.

We still have 11 legacy oil-filled paper-insulated HV cable circuits in service in Bream Bay, Wilton, New Plymouth, and Rangipo. Condition assessments on the Bream Bay cables showed cracks in the oversheaths and a minor leak in the oil tank, all of which were repaired. The insulation of the New Plymouth cables is also showing signs of deterioration. We are planning to replace the Bream Bay cables by the end of 2020. We expect to decommission and permanently remove the New Plymouth cables by around the same time (in conjunction with decommissioning all Transpower’s assets on the old power station site).
Asset Criticality
We are currently developing criticality for power cables based on our standard criticality framework.

Asset Performance
Power cables are highly reliable, mainly because the conductors are insulated from the surrounding environment and hence are shielded from pollution, direct lightning strikes, animals, etc. For cables installed outside controlled areas (substations), the main risks arise from damage caused by third parties during excavations. We have registered our power cable assets located in public areas with “beforeUdig” so that contractors can ascertain their location prior to excavation.

We have had an average of two to three MV cable failures a year. The main causes have been poor workmanship on cable joints and terminations, faulty cables and terminations.

Asset Life Cycle Stages
Our asset management approach for our power cables enables them to operate safely and reliably, at least life cycle cost.

Strategic Planning
The following strategic objectives have been established for our power cables:

Safety
- No injuries or fatalities resulting from installation or maintenance of cables
- No fatalities caused by incidents of members of public hitting cables while digging
- No fatalities caused by cable failures
- No injuries caused by earth potential rise (EPR) or transfer of potential on cable screens

Service Performance
- Fewer than 5 cable faults per year on MV cables
- Recovery from major failure of a single MV cable is achieved within one week. Recovery from major failure of an HV cable may take several weeks due to the longer time needed to find and expose the fault location and the probable need to obtain cable jointers from overseas to repair the damaged cable.
- Zero cable faults on HV cables

Cost Performance
- Design, construct, and maintain cables to minimise life cycle costs, while meeting required levels of performance

Customers and Stakeholders
- No significant oil spills into the environment
- Magnetic fields caused by cables are within limits specified by the Resource Management (National Environmental Standards for Electricity Transmission Activities) Regulations 2009 (SR 2009/397)
- Maintain effective relationships with stakeholders affected by cable works
- Asset management approach is effectively coordinated with other owners of infrastructure where our cables are installed

Development Initiatives
We are not undertaking any specific development initiatives activities in relation to our power cables. However, we periodically review our cable maintenance and testing practices in accordance with international practice and available technologies.

Tactical Planning
Our planning approach for power cables is to replace on condition and the potential risk consequence of failure. In the period since RCP 2 planning was undertaken, several additional needs have been identified.
We have projects underway to replace certain types of MV (33 kV) cable terminations which have an unacceptable failure rate due to a combination of poor design and poor installation practice. Some have failed within ten years of service and others have indications of failure. These types of terminations are being monitored/tested annually to prioritise their replacement and minimise the risk of failure. Our experience is that it is more cost effective to pro-actively replace a defective termination than to allow it to run to failure, because of the costs of collateral damage to other equipment that can occur if the termination fails.

Our tactical plans for cables are determined based on condition and performance of the cables together with information on failures of power cables internationally. We prioritise replacements based on the likelihood and consequence of failure, where the latter incorporates factors such as load served, and level of redundancy.

**Condition Assessments**

We undertake regular patrols of the cable routes in public places, to mitigate the risk of damage caused during excavations by third parties. In the case of the HV Oil filled cables we undertake a specific programme of condition assessment. It is difficult to predict precisely when a cable will reach the end of its life. Table 28 summarises the key maintenance activities we carry out on our power cables.

<table>
<thead>
<tr>
<th>Application</th>
<th>Inspection &amp; Testing Activities</th>
<th>Frequency</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>All power cables</td>
<td>Visual inspection and service</td>
<td>MV Cables: 4 yearly</td>
<td>Detect deterioration of visible parts of the cables and their components</td>
</tr>
<tr>
<td></td>
<td></td>
<td>HV Cables: Annually</td>
<td>and mounting infrastructure</td>
</tr>
<tr>
<td>HV cables outside substations</td>
<td>Cable route patrol</td>
<td>Weekly</td>
<td>Detect third-party activities that could damage cable assets</td>
</tr>
<tr>
<td>All power cables installed in tunnels</td>
<td>Cable tunnel inspections</td>
<td>Annually</td>
<td>Detect damage and deterioration to the tunnel structure and infrastructure</td>
</tr>
<tr>
<td>All power cables</td>
<td>Over-sheath integrity testing</td>
<td>MV cables: 4 yearly</td>
<td>Detect damage to the cable outer sheath that is designed to keep water out</td>
</tr>
<tr>
<td></td>
<td></td>
<td>HV cables: 2 yearly</td>
<td></td>
</tr>
<tr>
<td>HV oil- filled cables</td>
<td>Cable oil testing</td>
<td>Annually</td>
<td>Measure condition of oil and detect gases generated by deteriorating paper insulation</td>
</tr>
<tr>
<td>All power cables</td>
<td>Primary insulation testing and partial discharge testing</td>
<td>As needed, e.g. towards end of life, after a major insulation failure/repair, reason to suspect failing cable insulation or terminations</td>
<td>Measure the quality of the primary insulation</td>
</tr>
</tbody>
</table>

Table 28: Condition-monitoring tests and inspections

The inspections above are used to generate work orders and maintenance projects with the aim of reducing the rate of deterioration of the power cables and their accessories and infrastructure.

**Decision Framework**

The investment programme for power cables is determined by applying the four steps of the Decision Framework.

**Need identification**

Condition and criticality are used to determine needs and associated need dates.
Options Assessment
Options considered are either refurbishment or, more often, replacements. Refurbishment options for power cables are limited as it usually is impractical to restore degraded cable insulation. We are considering mid-life replacement of components of some of our HV oil-filled cable systems. The preferred solution is ascertained based on reliability and life cycle cost. Cables of all types are replaced with a modern equivalent cable (XLPE-insulated).

Prioritise solutions
Solutions are prioritised based on need date.

Develop a Programme Management Plan
We focus on identifying specific power cables that require refurbishment or replacement. Needs and need dates may be adjusted to allow for bundling and alignment with other works.

Cost estimation
MV power cables refurbishments and replacements are not considered to be volumetric works, as they are not repetitive with similar scope or quantity.
We use a customised cost estimating approach for all power cables as designs are bespoke.

Contingency planning
We maintain contingency response resources including sufficient field staff and emergency spares to enable rapid restoration following a failure. Spare cables, cable joints and cable terminations are maintained in a benign environment and are ready for immediate installation and service. Some spare components have limited shelf-life and must be replaced every 5-10 years.
We manage cable failure by:
- Using local service providers to repair MV cable failures and overseas specialists (if local expertise is unavailable) to repair HV cable failures
- Developing and maintaining a plan for repairs or replacement following failures of major cable circuits within two weeks within our substation boundaries and one month if outside
- Considering bypass arrangements, which involve temporary bays with associated switchgear, national spare transformers, transmission lines and protection.

Programming and scheduling
Power cable refurbishments, replacements, and upgrades are individually scoped and priced works. As such, they are scheduled according to need and resource availability, while accounting for other work at the same location, such as outdoor to indoor switchgear conversions, major customer upgrades, etc, using common resources.

Project Delivery
The five aspects of project delivery are design, procurement, programme and project management, commissioning, and decommissioning and disposal.

Design
Our design process aims to ensure safety, optimize the use of materials, standardise cable designs as much as possible, and ensure the cables are appropriately resilient to high loading and seismic events.
Cable installation designs and equipment are being standardised, where practicable, regarding:
- Cable sizing for specific range of current rating
- Cable termination or joint kits
- Installation methods for cable termination
- Development of a line/cable hybrid design
Procurement
We combine the procurement of similar cables across different projects to reduce per unit costs of power cables. This strategy is more useful for MV cables as the range of conductor sizes (cross-sectional area) used is smaller and the turnover of cable stock is greater. New HV cable projects occur, on average, only once every two years and a much greater range of conductor size is needed.

Programme and Project Delivery
Our Programme and Project delivery is undertaken in accordance with our programme management framework.

Commissioning
Our commissioning plan outlines commissioning planning, testing, livening, hand over, operational, and maintenance processes.

Once all works are complete, our project close-out activities include final capitalisation of the project within our financial systems, feedback about actual costs to assist with future cost estimation, updating asset management information systems, archiving of the relevant documentation, and the review of ‘lessons learned’ including a review of health and safety performance.

Decommissioning and Disposal
Our decommissioned power cables are sold as scrap

Service Delivery
We undertake preventive, corrective, predictive, and proactive maintenance activities as specified in our service specifications and standard maintenance procedures for power cables. Regular maintenance activities occur on a monthly, annual, two-yearly or four-yearly cycle. Refurbishment works (maintenance or capital projects) are carried out on an as-required basis, usually during the second half of the asset’s life.

Operate the Grid
We plan and manage outages in a way that creates a safe environment for employees while minimising disruption for customers and end-users.

Forecast Expenditure
Our forecast expenditure for power cables is described below.

Capital Expenditure

RCP 2, 2018 to 2020
Progress against the RCP 2 budget has been to plan except for the following:
- The purchase of an oil treatment plant to refurbish and repair the legacy HV oil-filled cables has been deferred until FY2019 while the strategy for the 30+ year old cables is developed
- 33 kV PILC cables at Tokaanu were found to be in poor condition and were replaced in FY2016.

RCP 3, 2020 to 2025
As power cable projects are mainly based on condition and risk and are not under the volumetric replacement category, there is no specific trend in costs for power cables. It is also difficult to determine trends for costs of cable projects as each cable project is bespoke and difficult to carry out a comparison. Accordingly, an estimation of the costs of cable replacement has been made based on “currently known”, however, this is subject to change.

Provision has been made to replace some PILC cables and to refurbish some of the HV oil-filled cables with a total forecast expenditure of $1.9 million in RCP 3.
RCP 4, 2025 to 2030
Provision has been made to replace some PILC cables and to refurbish some of the HV oil-filled cables with a total forecast expenditure of $0.7 million in RCP 4 based on predicted condition.

Operating Expenditure
In addition to the on-going maintenance of power cables, a replacement programme of 33 kV cable terminations is planned from FY2017 to FY2019. This is a result of recent failures of a certain type of cable termination. This programme may need to be extended beyond 2019 if more terminations show symptoms of pending failure.

Key risks and uncertainties
The key risks in delivering the forecasted expenditure and volumes are ensuring the budget estimates for the projects are accurate and that resource continues to be available to deliver the work. No building blocks have been developed because cable replacements occur infrequently and the designs are bespoke.

Summary, 2018 to 2030

<table>
<thead>
<tr>
<th></th>
<th>RCP 2</th>
<th>RCP 3</th>
<th>RCP 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>0.0</td>
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<td>0.0</td>
</tr>
<tr>
<td>2017</td>
<td>0.3</td>
<td>0.3</td>
<td>0.0</td>
</tr>
<tr>
<td>2018</td>
<td>0.1</td>
<td>0.1</td>
<td>0.0</td>
</tr>
<tr>
<td>2019</td>
<td>4.6</td>
<td>4.6</td>
<td>0.0</td>
</tr>
<tr>
<td>2020</td>
<td>3.1</td>
<td>3.1</td>
<td>0.0</td>
</tr>
<tr>
<td>2021</td>
<td>0.4</td>
<td>0.4</td>
<td>0.0</td>
</tr>
<tr>
<td>2022</td>
<td>0.6</td>
<td>0.6</td>
<td>0.0</td>
</tr>
<tr>
<td>2023</td>
<td>0.2</td>
<td>0.2</td>
<td>0.0</td>
</tr>
<tr>
<td>2024</td>
<td>0.5</td>
<td>0.5</td>
<td>0.0</td>
</tr>
<tr>
<td>2025</td>
<td>0.3</td>
<td>0.3</td>
<td>0.7</td>
</tr>
<tr>
<td>2026</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>2027</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>2028</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>2029</td>
<td>0.0</td>
<td>0.0</td>
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</tr>
<tr>
<td>2030</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Table 29: Forecast capital expenditure

Long-term forecast
The costs into RCP 5 increase significantly as several of the legacy HV oil-filled cables and MV PILC are reaching end of life. The costs in RCP 5 are currently forecasted at $14.2 million.
Expenditure between now and FY2035 will be somewhat “lumpy”, mainly due to work associated with the legacy HV oil-filled cables.
Beyond 2035 there is likely to be increasing expenditure on replacement of MV PILC cables as more of them reach the 50-60-year age range and are therefore more likely to be in poorer condition or fail in service.
ASSET CLASS PLAN – OUTDOOR DISCONNECTORS AND EARTH SWITCHES

This asset class plan describes our life cycle management approach for outdoor disconnectors and earth switches. Outdoor disconnectors and earth switches are essential safety components of our substations. Disconnectors are mechanical devices used to isolate primary equipment, such as power transformers, circuit breakers and transmission lines, from other high voltage equipment for maintenance or operational purposes. Earth switches, when closed, provide an electrical connection between normally live equipment and earth, ensuring isolated equipment is safe to work on, protecting employees or service providers from accidental livening of the equipment and risks arising from induced voltages from adjacent equipment. Table 30 provides a breakdown of our outdoor disconnectors and earth switches population by voltage level.

<table>
<thead>
<tr>
<th>System Voltage HV Class</th>
<th>33 kV and below</th>
<th>50-66 kV</th>
<th>110 kV</th>
<th>220 kV</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disconnectors</td>
<td>639</td>
<td>231</td>
<td>1101</td>
<td>1468</td>
<td>3439</td>
</tr>
<tr>
<td>Earthing Switches</td>
<td>181</td>
<td>60</td>
<td>363</td>
<td>651</td>
<td>1255</td>
</tr>
</tbody>
</table>

Table 30: population by type and voltage

Asset Characteristics

Our outdoor disconnectors and earth switches are robust and well suited for our environment. The bow-tie analysis indicates the predominant failure causes for our outdoor disconnectors and earth switches are mal-alignment and degradation/corrosion. As such, the three key preventive controls that are critical to reducing the likelihood of a failure event are condition monitoring, the competency of the workforce, and the maintenance programme.

Age Profile

Figure 31 shows the age profile of our outdoor disconnectors and earth switches.

![Figure 31: Age profile of disconnectors and earth switches](image)

Asset Health

The standard life of outdoor disconnectors and earth switches is 55 years. However, our experience indicates that providing they are correctly aligned and maintained, disconnectors and earth switches can deliver good operational performance, with low maintenance costs, over a significantly longer lifetime. Overall, our outdoor disconnectors and earth switches are in good condition.
Asset Criticality
We are currently developing criticality for our outdoor disconnectors and earth switches based on our standard criticality framework.

Asset Performance
The main cause of unplanned outages of our outdoor disconnectors is mal-alignment of the mechanism. Mal-alignment can lead to hot spots developing that may require an unplanned outage for remedial work to be carried out. Some models are more vulnerable to mal-alignment than others. Significant improvements can be achieved by lifting the competency of the workforce in maintaining the disconnectors and achieving satisfactory alignment. Figure 32 shows the unplanned outages for our outdoor disconnectors and earth switches, and the causes.

Figure 32: Outdoor disconnectors and earth switches unplanned outages

Asset Life Cycle Stages
Our asset management approach for outdoor disconnectors and earth switches is to maintain them and extend the normal expected life to 90 years. When it becomes uneconomic to maintain outdoor disconnectors and earth switches, they are replaced.

Strategic Planning
The following strategic objectives have been set for our disconnectors and earth switches:

Safety
- Zero fatalities and injuries while maintaining, repairing, or installing
- Appropriately rated disconnectors and earth switches are provided to enable the safe operation of grid assets

Service Performance
- Reduce the number of disconnector and earth switch unplanned outages to 50% of the 2011 level by 2024.

Cost Performance
- Apply life cycle cost analysis to the decisions between replacement and on-going maintenance of disconnectors
- Consider maintenance as well as capital costs during procurement, and seek extended warranties for new equipment
- Reduce model diversity by replacement of small populations, to reduce on-going maintenance and support costs

Development Initiatives
We have ascertained we can extend the life of a large proportion of our outdoor disconnectors and earth switches from 55 years to 90+ years through improved maintenance. We embarked on a programme to increase the workforce skill levels to maintain outdoor disconnectors and earth switches. This has resulted in significant deferral of capital expenditure.
**Tactical Planning**

Our planning approach for outdoor disconnectors and earth switches is to extend the life and improve reliability through maintenance. We will replace small populations of other types of disconnectors when significant performance problems arise, and maintenance and engineering support becomes impractical or uneconomic.

Where feasible, we will eliminate air-break disconnectors (particularly at system voltages of 110 kV and 66 kV), by using disconnecting circuit breakers or compact switchgear assemblies. Economic opportunities to eliminate these disconnectors will normally be co-ordinated with the replacement of existing circuit breakers.

Corrosion is a key factor in equipment failure and reduced life expectancy. Therefore, we have a corrosion protection programme in place to mitigate the effects of corrosion.

**Condition Assessment**

Our condition monitoring and assessment approach is described in Table 31.

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 Monthly:</td>
<td>An in-service visual and audible noise level 1 inspection during routine station inspection</td>
</tr>
</tbody>
</table>
| Yearly:     | An in-service level 2 inspection is carried out from ground level, but is more comprehensive than the level 1 inspection.  
              | A thermo-graphic survey is carried out during a survey of the station.       |
| Four yearly:| An out-of-service diagnostic inspection and servicing of the disconnector and earth switch, including the primary connections, main and arcing contacts, support insulators, base frame, support stand and foundations, operating mechanism (including manual and motor drive mechanism, drive linkages and gearboxes), and secondary wiring. The scope of work includes condition-based replacement of minor components such as flexible braids and transition plates. Functional tests are carried out to confirm correct operation and alignment, and a contact resistance test is carried out prior to return to service.  
              | A high-level condition assessment is carried out to provide numeric scores for planning major interventions. |

Table 31: Condition and Inspection frequency

**Decision Framework**

The work programme for outdoor disconnectors and earth switches is determined by applying the four steps of the Decision Framework.

**Need identification**

Performance history, condition, and the availability of maintenance solutions and engineering support is used to determine needs and associated need dates.

**Options Assessment**

The preferred option is to maintain the outdoor disconnectors and earth switches. Assets are replaced if significant performance problems arise, and maintenance and engineering support becomes impractical or uneconomic.

**Prioritise solutions**

Solutions are prioritised based on need dates.

**Develop a Programme Management Plan**

Needs and need dates may be adjusted to allow for bundling and alignment with other works.
Cost estimation
We use a customised cost estimating approach for significant maintenance projects (such as for special treatment of corrosion).

The replacement of outdoor disconnectors and earth switches is volumetric work because it is repetitive with similar scope. TEES building blocks form the basis for all volumetric replacement works.

Contingency planning
We maintain contingency response resources including sufficient field staff and emergency spares to enable rapid restoration following a failure.

RCP 2 Incentives
There are no specific asset health output measures that apply to our outdoor disconnectors and earth switches.

Programming and scheduling
As a volumetric programme, replacement and maintenance of outdoor disconnectors and earth switches are integrated into a wider programme schedule that accounts for other works at the same locations using common resources.

Project Delivery
The five aspects of project delivery are design, procurement, programme and project management, commissioning, and decommissioning and disposal.

Design
Our design process for outdoor disconnectors and earth switches is based on standard installation designs and a standard procurement specification. Our technical specification for procurement includes requirements for our environmental conditions such as seismic strength and corrosion protection.

Procurement
Lifetime performance of outdoor disconnectors and earth switches is dependent on the quality of the original product design and manufacture. We apply a quality systems approach in our procurement process including careful selection of vendors, procuring from the minimum number of vendors, and specification of quality requirements in the design and manufacturing process. Procurement lead time for new outdoor disconnector and earth switches is approximately 8-12 months.

Programme and Project Delivery
Outdoor disconnectors and earth switches replacement works are integrated into a wider programme schedule that accounts for other works at the same locations using common resources.

Commissioning
Disconnectors and earth switches are installed and commissioned in accordance with manufacturer’s recommendations, including ensuring correct alignment and smooth operation. Contact resistance is measured and recorded.

 Decommissioning and Disposal
At some sites, existing outdoor disconnectors may become available for recovery and re-use. In these cases, subject to condition assessment, these disconnectors will be salvaged, and retained for use in other locations.

Service Delivery
We undertake preventative, corrective, predictive, and proactive maintenance activities as specified in our maintenance standards.

Operate the Grid
There are no specific outage planning requirements for outdoor disconnectors and earth switches.

 Operate the Grid
There are no specific outage planning requirements for outdoor disconnectors and earth switches.
Forecast Expenditure

Our forecast expenditure for outdoor disconnectors and earth switches is described below.

Capital Expenditure

RCP 2, 2018 to 2020

The RCP 2 plan involved replacement of 173 disconnectors and earth switches at a cost of $12.1 million. This was based on asset age as condition information was not available on which to make an assessment. A review of our approach during 2016 has shown there is no significant increase in expenditure or decline in performance due to aging. As such, we believe we can continue to maintain and support these assets in the immediate future.

We have identified 25 disconnectors and earth switches for replacement during RCP 2. These are assets that are either in poor condition and cannot be cost effectively repaired, or are under-rated. The revised cost for the replacement programme during RCP 2 is currently $4 million. This is a saving of $8.2 million.

RCP 3, 2020 to 2025

The forecast into RCP 3 is focussed on bringing our outdoor disconnectors and earth switches up to standard through maintenance supported by additional maintenance staff training.

Capex replacements will be carried out only if the disconnector cannot be refurbished. The forecast currently is at five replacements per year in RCP 3. These numbers are high level estimates and will be planned based on future condition information.

RCP 4, 2025 to 2030

The forecast into RCP 4 is focussed on completing the first round of the maintenance programme. Capex replacements will be carried out only if the outdoor disconnector and earth switches cannot be refurbished. The forecast is currently at seven replacements per year in RCP 4 based on the current condition of the asset class. These numbers are high level estimates and will be planned based on future condition information.

Operating Expenditure

We expect the 2016 condition assessment review to also identify the need for significant maintenance expenditure to address issues and improve the condition of many outdoor disconnectors and earth switches before the end of RCP 2. No provision was made for maintenance project expenditure in the original plan for RCP 2. We will need to initiate maintenance projects focussing on extending the life of concrete poles, corrosion control of steel assemblies and targeted standard maintenance procedure documentation and asset spares availability. The expected cost of this work is approximately $2.7 million during the remainder of RCP 2.

Operating expenditure will initially be high going into RCP 3 to bring the asset class back up to standard and will decrease going into RCP 4 where it is expected the work is covered in on-going business-as-usual maintenance.

Key risks and uncertainties

The costs for refurbishment are currently high-level estimates. The condition of our outdoor disconnectors and earth switches is unknown until further scoping is carried out. An investigation is underway to determine the extent of work required and how the documentation and training will be carried out to meet the requirements. The outcome of this investigation will affect the current estimates.

Summary, 2018 to 2030

<table>
<thead>
<tr>
<th></th>
<th>RCP 2</th>
<th>RCP 3</th>
<th>RCP 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disconnectors &amp; E/S</td>
<td>0.0</td>
<td>0.1</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Table 32: Forecast capital expenditure
ASSET CLASS PLAN – LVAC DISTRIBUTION SYSTEMS

This asset class plan describes our life cycle management approach for LVAC distribution systems. It covers the following assets:

- LVAC Main switchboards
- Alternating Current Junction (distribution) Boxes (ACJBs)
- LVAC distribution boards
- Standby generators

LVAC distribution systems provide a critical function for the operation of the grid. They take supply from the grid through one or more local service transformers and distribute low voltage electricity to secondary assets through an AC to DC conversion. This DC supply is backed up by dedicated batteries that would take over in case of a LVAC outage.

LVAC distribution systems also supply building low voltage AC, such as lighting and power points, as well as AC supply to outdoor ancillary equipment.

Table 33 shows the approximate population of our LVAC distribution system assets.

<table>
<thead>
<tr>
<th>Type</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main LVAC Switchboards</td>
<td>195</td>
</tr>
<tr>
<td>ACJBs</td>
<td>40</td>
</tr>
<tr>
<td>LVAC Distribution Boards</td>
<td>507</td>
</tr>
<tr>
<td>Standby Generators</td>
<td>17</td>
</tr>
</tbody>
</table>

Table 33: LVAC Distribution systems population

Asset Characteristics

The design and installation of our LVAC distribution systems vary widely, with a diverse range of manufacturers, models, ratings, and configurations. Many LVAC distribution systems date back to the original site development, while others have been replaced when significant site redevelopments have occurred.

Age Profile

Figure 33 shows the age profile of our LVAC distribution system assets.
Asset Health
LVAC switchboards are installed either indoors or, sometimes, outdoors in weather-proof enclosures. The primary factors for replacement are obsolescence of components, safety compliance with electrical regulations, and the ability of existing LVAC installations to accommodate site developments.

A small number of LVAC switchboards have internal panels made of asbestos containing material (ACM). The presence of ACM is recorded through condition assessment data collection as these panels require specific hazard identification.

All our LVAC distribution systems that are either past their life expectancy, have safety risks, or have obsolete components will be replaced over the remainder of RCP 2 and into RCP 3, as it is no longer economic to repair them.

Overall, our LVAC distribution system assets are in good condition; however, a small number of them have been identified with safety risks that need remediation.

Asset Criticality
The consequence of the failure of a component of the LVAC distribution system is usually limited as several mitigations are in place. These include:

- DC batteries typically provide between four to eight hours back up to control and relay equipment
- There is usually redundancy in the incoming supply
- In most cases, there is the ability to connect an emergency generator.

A complete loss of the LVAC main switchboard, through an external fire for instance, can have significant consequence due to the time requires to reinstate a complete board replacement. We are determining how criticality will be applied to this asset class.

Asset Performance
Our LVAC distribution system assets have low incidence of operational failures.

Asset Life Cycle Stages
Our asset management approach for LVAC distribution assets ensures they operate safely and reliably, at least life cycle cost. To reduce risk of harm or failure we replace assets that do not meet safety requirements or are in poor condition.

Strategic Planning
The following strategic objectives have been identified for our LVAC Distribution systems:

Safety
- Zero fatalities or injuries while maintaining or operating LVAC distribution equipment or standby generators

Service Performance
- Maintain acceptable reliability of LVAC supply to essential operational equipment
- Zero failures of standby generators to start and carry load when required

Cost Performance
- Minimise life cycle cost

Customers and Stakeholders
- Zero spills of fuel to the environment

Development Initiatives
We have recently standardised our design and installation for new or replacement LVAC distribution systems. Development initiatives within the standard design includes standardised mobile generation and active corrosion control measures for some sites to extend operational life and reduce faults.
**Tactical Planning**

Our planning approach for LVAC distribution assets is to replace based on safety hazards, condition, risk, and obsolescence. The primary driver for planned replacements is ensuring electrical safety and availability of local service supplies. A modest number of sites also have equipment that is no longer commercially available or economically viable to maintain or expand.

A very small number of local service assets may also contain asbestos components and these will have minimal work undertaken on them until they can be safely decommissioned.

**Condition Assessments**

Our programme of routine condition monitoring inspections, tests and servicing is shown in Table 34.

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 Monthly</td>
<td>In-service <strong>level 1</strong> inspection involving visual and audible noise observations during routine station inspection</td>
</tr>
<tr>
<td>Yearly</td>
<td>In-service <strong>level 2</strong> inspection is carried out, which is more comprehensive than the level 1 inspection and includes operational checks. A thermo-graphic survey is carried out during a survey of the station.</td>
</tr>
<tr>
<td>Two yearly</td>
<td>Refresh of condition scoring for observed condition for all assets with a most recent observed condition score of 50 or less</td>
</tr>
<tr>
<td>Four yearly</td>
<td>Diagnostic inspection and electrical testing of LVAC switchboards and LV cables. Condition assessment, including numeric scoring of internal and external condition, during the diagnostic inspection.</td>
</tr>
</tbody>
</table>

Table 34: Condition-monitoring tests and inspections of LVAC Distribution equipment

**Decision Framework**

The work programme for LVAC distribution systems is determined by applying the four steps of the Decision Framework.

**Need identification**

The inputs to determining replacement needs are safety including electrical hazards and fire risk, condition, obsolescence of components, or degraded protection. Need date prioritisation considers the criticality of the site equipment, safety, and reliability.

**Options Assessment**

Replacements are like-for-like with a modern equivalent that meets the latest standards. In some cases a strategic assessment is undertaken to ensure that the site requirements have not changed to a point that would not permit a direct replacement.

**Prioritise solutions**

Solutions are typically prioritised based on need date.

**Develop a Programme Management Plan**

Our needs and need dates may be adjusted to allow for bundling and alignment with other works.

**Cost estimation**

We use a customised estimation approach for our LVAC distribution system assets, as there are significant variations between sites.
Contingency planning
We maintain contingency response plans including sufficient field staff to enable rapid restoration following a failure. The spares are condition monitored, maintained, and are ready for immediate installation and service. The supplier of the new standard LVAC main switchboard also has suitable spares for immediate dispatch.

Programming and scheduling
Replacements and upgrades are individually scoped and priced works. As such, they are scheduled according to need and resource availability, while accounting for other work at the same location, such as major customer upgrades, using common resources.

Project Delivery
The five aspects of project delivery are design, procurement, programme and project management, commissioning, and decommissioning and disposal.

Design
Design of the LVAC distribution system is to be such that it achieves an appropriate level of operational safety and reliability for the equipment that it supports. Designs incorporate the requirements of the appropriate regulations and standards.

Procurement
We have engaged a preferred supplier of replacement LVAC switchboards to help manage costs, minimise spares holdings, and standardise installation where practicable. We currently are identifying the needs associated with procurement of standby generators.

Programme and Project Delivery
Our Programme and Project delivery is undertaken in accordance with our programme management framework. The delivery timeframes for LVAC distribution systems account for detailed design, procurement, outage planning and coordination with other major works at the site. This is typically 2 years in duration.

Commissioning
Our commissioning plan outlines commissioning planning, testing, livening, hand over, operational, and maintenance processes.

Decommissioning and Disposal
Generally, most large switchboards will be decommissioned and sold for scrap. In some instances where a site has similar switchboards, parts in good condition may be retained on site with remaining switchboards until full replacements have occurred.

Suspected asbestos containing materials such as low voltage distribution gearplates and busbar supports will be removed and disposed of in accordance with statutory requirements and our Asbestos Management Plan. Generators will be decommissioned and sold for scrap. Fuel handling equipment and stationary storage vessels will be decommissioned and removed in accordance with statutory requirements.

Service Delivery
We undertake preventive, corrective, predictive, and proactive maintenance activities as specified in our maintenance standards for local service distribution equipment. Minor maintenance and refurbishment works occur according to condition based assessments.

Operate the Grid
We plan and manage outages in a way that ensures a safe environment for employees while minimising the disruption for customers.
Forecast Expenditure

Our forecast expenditure for LVAC is described below.

Capital Expenditure

RCP 2, 2018 to 2020
The initial RCP 2 capital plan was to carry out replacement of 24 low voltage main switchboards at a planned cost of $5.2 million. The works priority has been revised to 23 sites at a planned spend of $5.5 million. On average the number of replacements is consistent each year during the remainder of RCP 2 and into RCP 3.

The overall increase in average cost per site against the initial RCP 2 budget plan is partly due to the increased procurement cost associated with a new standard design (higher capital cost but generally lower life cycle cost.) Additionally, there has been a higher one-off cost associated with upgrades being undertaken at more complex brownfield sites, which are not typical of most remaining sites.

RCP 3, 2020 to 2025
Forecast capital expenditure for this portfolio is expected to decline over the next 10 years once the age of equipment across the asset class is reduced to a point where replacements will occur at a more baseline rate.

RCP 4, 2025 to 2030
It is expected that the replacement rates will continue to occur at a rate similar to those forecasted for the end of RCP 3.

Operating Expenditure

There is no Operating Expenditure (other than routine maintenance) planned.

Key risks and uncertainties

Several risks to achieving the forecast expenditure have been identified which continue to require management during design and delivery. The key risks include ensuring adequate scoping of site so specific risks are identified early and that procurement costs are not increased without adequate justification.

To reduce some of the risks identified to date, we are delivering the first group of planned replacements through a volumetric style procurement strategy. The main intent is to engage a single engineering consultant to promote improved design consistency and improve information related to delivery costs. These costs can be fed back into the planning process to improve confidence in medium and long-delivery cost planning. Further measures to reducing risk of exceeding planned expenditure will likely come through a revised set of design rules for carrying out design and execution of this type of work.

Summary, 2018 to 2030

<table>
<thead>
<tr>
<th></th>
<th>RCP 2</th>
<th>RCP 3</th>
<th>RCP 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>LVAC 2016</td>
<td>0.1</td>
<td>1.6</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>2017</td>
<td>1.5</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>2018</td>
<td>0.4</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>2019</td>
<td>1.9</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>2020</td>
<td>3.1</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>2021</td>
<td>1.1</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>2022</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>2023</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>2024</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>2025</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>2026</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>2027</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>2028</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>2029</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>2030</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Table 35: Forecast capital expenditure

Long-term forecast

Not considering special projects, it is likely that the overall health of the asset class will be improved to a point where routine maintenance and a small number of capital replacements will occur annually to maintain an appropriate level of safety and reliability. It is expected that this will amount to between 2-3 sites per year.
ASSET CLASS PLAN – STRUCTURES AND BUSWORK

This asset class plan describes our life cycle management approach for substation supporting structures and buswork. It covers the following assets:

- Outdoor buswork and tie lines in substations. These comprise lattice structures\(^7\), A-frame structures\(^8\), supporting posts and poles, and associated high-voltage conductors, primary clamps and accessories, and insulators
- Concrete support posts or poles for disconnectors and earth switches
- Earthwires and earthwire hardware that are suspended from the structures that support lightning protection assets.

Supporting structures and buswork provides critical connection within substations between individual components of the grid. It carries large amounts of electricity as it takes electricity from incoming feeders and distributes to where the load is needed. Earthwires provide safety and protection.

Table 36 provides a breakdown of our structures and buswork population.

<table>
<thead>
<tr>
<th>Type</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outdoor bus sections and tie lines asset include associated conductors, insulators and hardware (BS, CON, INS)</td>
<td>1570</td>
</tr>
<tr>
<td>Bus support posts (non-concrete posts)</td>
<td>1635</td>
</tr>
<tr>
<td>Concrete support posts for DS/ES and BS</td>
<td>12787</td>
</tr>
<tr>
<td>Substation structures and girders-incl. Bus tie structures (STRS, TWR)</td>
<td>2755</td>
</tr>
<tr>
<td>Girders (GDR)</td>
<td>2684</td>
</tr>
<tr>
<td>Earthwires &amp; earthwire hardware (EW/EWHW)</td>
<td>1290</td>
</tr>
<tr>
<td>Poles for conductor and DS/ES support</td>
<td>453</td>
</tr>
</tbody>
</table>

Table 36: Asset Class population

Asset Characteristics

We have a diverse design range of supporting structures and buswork.

A bus system generally consists of bus conductors, insulator and insulator hardware and attachments, and support structures.

There are two bus types, a rigid bus\(^9\) and strung bus\(^10\):

- Rigid bus bar sections are generally welded to supports or secured with bolted clamps depending on installation. The diameter of the rigid busbar varies to achieve different electrical rating requirements.
- Strung busworks are generally suspended from larger support structures such as lattice gantries, A-frame gantries or poles (wooden or concrete). Stranded copper or aluminium are typically used for strung buses.

There are wide ranges of insulators types used for busworks, including cap-and-pin insulators, porcelain disc insulators, glass disc insulators, solid core porcelain post insulators, and composite insulators. Different insulator hardware and attachments have been adopted in substations over the years.

\(^7\) Also referred to as lattice gantries  
\(^8\) Also referred to as A-frame gantries  
\(^9\) Also referred to as solid bus or supported bus  
\(^10\) Also referred to as tension bus, or flexible bus, or suspended bus
Galvanized steel lattice gantries (of various design) and reinforced concrete posts are predominantly used as support structures for busworks. Aluminum lattice structures, A-frame structures, wooden poles, reinforced concrete poles, and steel support posts (I beams, channels, rectangular hollow sections, columns etc) are also common in substations.

The bus system design in a substation could be substantially different to another depending on the combination of different types of each component used.

**Age Profile**

This asset class comprises very diverse assets, each having a specific age profile. Table 37 show the age profile of substation structures and girders, which are the asset types driving out the majority of the expenditure.

<table>
<thead>
<tr>
<th>Row Labels</th>
<th>Count of Device Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>1940s</td>
<td>114</td>
</tr>
<tr>
<td>1950s</td>
<td>332</td>
</tr>
<tr>
<td>1960s</td>
<td>897</td>
</tr>
<tr>
<td>1970s</td>
<td>1273</td>
</tr>
<tr>
<td>1980s</td>
<td>1012</td>
</tr>
<tr>
<td>1990s</td>
<td>581</td>
</tr>
<tr>
<td>2000s</td>
<td>437</td>
</tr>
<tr>
<td>2010s</td>
<td>70</td>
</tr>
<tr>
<td>No info</td>
<td>544</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>5260</strong></td>
</tr>
</tbody>
</table>

Table 37: Asset class age profile

**Asset Health**

We undertook a condition assessment of our supporting structures and buswork during 2016. Table 38 describes the condition scoring for our supporting structures and buswork.

<table>
<thead>
<tr>
<th>Condition Score</th>
<th>Description of Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-20</td>
<td>Poor condition requiring urgent condition – remaining life is less than four years</td>
</tr>
<tr>
<td>21-50</td>
<td>Remaining life is greater than four but less than seven years</td>
</tr>
<tr>
<td>51-80</td>
<td>Remaining life is greater than seven but less than ten years</td>
</tr>
<tr>
<td>81-100</td>
<td>As new condition – remaining life is greater than ten years</td>
</tr>
</tbody>
</table>

Table 38: Condition score and description
Figure 34: provides an overview of the condition results.

The data received from this condition assessment will be used to support the development of an asset health model for our supporting structures and buswork that is scheduled for 2017.

Asset Criticality
We are determining how criticality will be applied to structures and buswork.

Asset Life Cycle Stages
Our asset management approach for outdoor support structures and buswork is to refurbish accounting for condition, safety risks and standards, and performance risk.

Strategic Planning
Our strategic planning approach for outdoor buswork support structures is to maintain them in perpetuity.

Tactical Planning
Our planning approach for supporting structures and buswork is to refurbish existing buswork in perpetuity and where required to install new supporting structures and buswork to enable system growth.

Condition Assessments
We undertake regular condition assessments of our supporting structures and buswork. Table 39 shows the routine condition monitoring tests and inspections undertaken.

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monthly:</td>
<td>An in-service visual and audible noise level 1 inspection during routine station inspection</td>
</tr>
<tr>
<td>Yearly:</td>
<td>An in-service level 2 inspection is carried out from ground level, but is more comprehensive than the level 1 inspection. A thermo-graphic survey is carried out during a survey of the station.</td>
</tr>
</tbody>
</table>
Frequency Activities

Four yearly: An out-of-service diagnostic inspection of the structure, buswork and all of its components, typically during planned outages of individual bays. The scope also includes the identification and replacement of non-conforming types of bus and earthwire hardware.

A high-level condition assessment to provide numeric scores for asset health models and planning major interventions such as refurbishment, repair or replacement.

Table 39: Condition-monitoring tests and inspections

Decision Framework

The work programme for structures and buswork is determined by applying the four steps of the Decision Framework.

Need identification

A condition-based approach, along with assessing the risks to service performance and public safety, is used to identify need and need dates. The long-term future requirements, based on load forecasting, planned network developments, and customer intentions is also incorporated into the decision process for intervention. Need dates are determined based on ascertaining the optimum point to undertake interventions that will minimise life cycle cost.

Options Assessment

The preferred option is to maintain in perpetuity. Refurbishment solution options for supporting structures includes protective coating of galvanised surfaces, recoating of previously painted surfaces, repairs to mitigate the effects of corrosion, piece-wise in-situ replacement of structure assemblies, and staged refurbishment including addition or bypass of structure bays.

New buswork and structures are constructed for new locations and where capacity increases are required.

Prioritise solutions

Solutions are prioritised based on need date.

Develop a Programme Management Plan

We focus on identifying specific supporting structures and buswork that require refurbishment. Our needs and need dates may be adjusted to allow for bundling and alignment with other works.

Cost estimation

We use a customised cost estimating approach for supporting structures and buswork, based on the costs of recent similar projects.

Contingency planning

We maintain contingency response resources including sufficient field staff and emergency spares to enable rapid restoration following a failure. The spares are condition-monitored, maintained, and are ready for immediate installation and service.

Programming and scheduling

Supporting structures and buswork refurbishments and upgrades are individually scoped and priced works. As such, they are scheduled according to need and resource availability, while accounting for other work at the same location.

Project Delivery

The five aspects of project delivery are design, procurement, programme and project management, commissioning, and decommissioning and disposal.

Design

We have put a suitable standardised gantry and busbar design in place that is used for new and replacement gantries and busbars. The standardised design is also used as far as practicable for busbar refurbishments.
Procurement
New installation or refurbishment works involve the procurement of standard off-the-shelf hardware and componentry items, which are mostly stored and available from our warehouses. Sometimes, specific hardware is produced, with minimal lead-time.

Programme and Project Delivery
Our Programme and Project delivery is undertaken in accordance with our programme management framework. The delivery timeframes account for detailed design, procurement, outage planning and co-ordination with other major works at the site.

Commissioning
Our commission plan outlines commissioning planning, testing, livening, hand over, operational, and maintenance processes.

Decommissioning and Disposal
We maintain and follow an appropriate decommissioning process that includes safe work site management and responsible scrap disposal.

Service Delivery
We undertake preventive, corrective, predictive, and proactive maintenance activities as specified in our maintenance standards for supporting structures and buswork.

Operate the Grid
There are no specific outage planning strategies for supporting structures and buswork.

Forecast Expenditure
Our forecast expenditure for structures and buswork is described below.

Capital Expenditure
RCP 2 – 2015 to 2020
The total forecast capital expenditure over RCP 2 is 9% below the RCP 2 allowance. The decrease is primarily driven by the cancellation of the Maraetai structure refurbishment project and Henderson bus re-insulation project due to neither being required; and removal of Kinleith 110 kV structures and buswork replacement project from this portfolio and rolling it up to Kinleith redevelopment project. The total Capex forecast has increased slightly compared to the 2016 AMP.

RCP 3 - 2020 to 2025
A significant number of substation structures, the associated insulators and hardware will reach 50 years of age or more by the end of RCP 3. The economic life of structures is 55 years. Many structures have shown significant corrosion on steelwork and bolts. Additionally, the protective galvanising surface has worn off many of the structures due to aging. To mitigate the risk of failure of the aging asset and to slow down the degradation of structures, we are considering the application of protective coating on substation structures, and replacing aging insulators and hardware.

For the sites where applying protective coating isn’t practical, other strategies for managing condition and thus the risk of the structures may be required, such as replacement of the entire gantry or replacing major components (girder or support structure) of the gantry.

RCP 4 and RCP 5 2025 to 2035
Due to the large number of aging assets in this asset class, it is anticipated progressive condition management of substation structures is required over RCP 4 and RCP 5. The expenditure is to be managed in a way that there is no significant variation between RCP 3, 4, and 5 as the probability of major intervention is low.
Operating Expenditure

While our RCP 2 submission had no allocated budget for structures and buswork maintenance projects, with information obtained from the one-off condition assessment in 2016, a large number of structures have steelwork and bolts which are heavily corroded and require replacement.

Corrosion issues have also been observed on structure footings, concrete posts supporting buswork and disconnectors/earth switches, and hardware fittings. At some sites, significant concrete spalling, cracking on the concrete post, and corroding of the top anchor studs have been observed. Concrete posts at some sites may have asbestos containing material. Allowances have been made for work on concrete posts.

Additionally, during the one-off condition assessment in 2016, a number of insulators have been identified as having a high risk of catastrophic failure due to their type and design. Replacing those insulators is required and is to be undertaken as maintenance projects in a progressive manner.

Key risks and uncertainties

Outage availability and practicality of applying protective coatings and environment conditions are the two main risks for substation gantry protective coating application works.

Outage availability at certain sites may require site-specific approaches for managing substation structures. For example, if required outages are not available for carrying out work on gantries, it might be more economical to build at a temporary bypass bay, or build a new bay in a new location and decommission the old bay, or replace the bay at the same location. These options require significant capital investment and require longer planning and build time.

It is unknown at this stage the number of concrete posts that may have asbestos containing material. This is an additional risk on future expenditure.

The lack of information includes costing, constructability, intervention methods, and optimum intervention timing increases uncertainty for the long-term forecast. We are actively working on various areas such as asset data, condition information, and understanding problems and potential solutions.

Summary, 2018 to 2030

<table>
<thead>
<tr>
<th></th>
<th>RCP 2</th>
<th>RCP 3</th>
<th>RCP 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structures &amp;</td>
<td>6.6</td>
<td>12.8</td>
<td>4.9</td>
</tr>
<tr>
<td>Buswork</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 40: Forecast capital expenditure

Long-term forecast

It is expected that expenditure during RCP 5 will be less than RCP 3 and 4, as many of the aging asset that requires more attention will be refurbished or replaced. The protective coating for substation structures will continue in RCP 3 however with less cost as less effort is anticipated for surfaced preparation. Maintenance projects for refurbishing gantry structure and repairing support structures still required but with less effort.
This asset class plan describes our life cycle management approach for other station equipment. This asset class plan covers a wide range of assets, including:

- Earth grids
- Lighting (Outdoor) fittings and cables supplying them
- Cable trenches/ducts (excl. lids)
- Oil containment
- Lightning protection stand-alone poles
- Outdoor firefighting hydrants
- Outdoor bushing washing systems
- Surge arresters
- Outdoor junction boxes (ODJB’s)
- Neutral earthing resistors (NER’s)
- Roof and wall bushings
- Centralised air compressor systems
- Cranes lift gear and platforms

Other substation equipment is used to support the operation of primary and secondary equipment at substation sites. Table 41 provides a breakdown of the population of our other substation equipment by type. In many instances, the assets are necessary requirements at each site.

<table>
<thead>
<tr>
<th>Type</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earth Grids</td>
<td>At all sites</td>
</tr>
<tr>
<td>Lighting (Outdoor) fittings and cables supplying them</td>
<td>At all sites</td>
</tr>
<tr>
<td>Cable trenches/ducts (excl. lids)</td>
<td>At most sites</td>
</tr>
<tr>
<td>Oil containment</td>
<td>At most sites</td>
</tr>
<tr>
<td>Lightning protection stand-alone poles</td>
<td>At most sites</td>
</tr>
<tr>
<td>Outdoor firefighting hydrants</td>
<td>At several sites</td>
</tr>
<tr>
<td>Outdoor bushing washing systems</td>
<td>At several sites</td>
</tr>
<tr>
<td>Surge arresters</td>
<td>2274</td>
</tr>
<tr>
<td>Outdoor junction boxes (ODJB’s)</td>
<td>Over 1500</td>
</tr>
<tr>
<td>Neutral earthing resistors (NER’s)</td>
<td>148</td>
</tr>
<tr>
<td>Roof and wall bushings</td>
<td>94</td>
</tr>
<tr>
<td>Centralised air compressor systems</td>
<td>31</td>
</tr>
<tr>
<td>Cranes lift gear and platforms</td>
<td>29</td>
</tr>
</tbody>
</table>

Table 41: Asset class population
Asset Characteristics

Other substation equipment provides safety and environmental protection, and vital equipment for the reliable operation of the substation. Due to the range and type of assets in this asset class there is no known age profile.

Asset Health

The assets in this asset class are generally in good condition. Due to the diverse types of the assets in this asset class, a range of condition assessment techniques is undertaken. Many of the asset types are managed under a reactive maintenance approach.

A small number of specific asset type issues have been identified. For example, reliability issues have been identified with gap type surge arresters. As such, a programme of work has been instigated to replace them with composite insulation surge arresters.

Asset health, based on external condition assessment, is available for Outdoor Junction Boxes (ODJB’s) and earth grids. A small number of ODJB’s installed pre-1990’s have internal panels made of asbestos-containing-material (ACM). These panels require specific hazard identification.

Safety risks, the presence of ACM, and other mechanical damage, are recorded through on-going condition assessment data collection. Safety-related defects are managed as corrective maintenance actions.

Asset Criticality

We are determining how criticality will be applied to other substation equipment.

Asset Performance

There is no individual performance data recorded for these assets.

Asset Life Cycle Stages

Our asset management approach for other substation equipment assets is to ensure they operate safely and reliably, at least life cycle cost.

Strategic Planning

Our strategic planning approach is to replace or refurbish assets in poor condition, to reduce risk of failure.

Tactical Planning

Our tactical planning approach for these assets is based on asset condition. Those with the most urgent need are scheduled first, with the exact timing of the works co-ordinated with other activities at the same site.

Condition Assessments

In addition to the condition assessment of ODJB’s and earth grids undertaken during 2016, we also obtain condition information for these assets from:

- The annual substation condition reports, which describes the condition of all the assets in the substation.
- The asset feedback register, which records assets that are in poor condition.

For earth grids, specialist tests are carried out every five and 10 years to determine whether they remain safe in terms of protection against electrocution during system faults.
Decision Framework
The work programme for other substation equipment is determined by applying the four steps of the Decision Framework.

Need identification
The need for refurbishment or replacement is determined from the condition reports and during field work at the sites. Need dates are prioritised by condition.

Options Assessment
The options considered for these assets is refurbishment or replacement. In many instances, dependent on the asset the only option is to replace.

Prioritise solutions
Solutions are prioritised on need date.

Develop a Programme Management Plan
Replacements are typically carried out as part of a larger project that replaces or upgrades the associated equipment.

Cost estimation
We have defined building block unit rates for NER, ODJB and surge arrester replacement estimates as they are volumetric works which are repetitive with similar scope. Costs for other projects are based on historical replacement costs.

Contingency planning
We maintain contingency response resources including sufficient field staff and emergency spares to enable rapid restoration following a failure. The spares are condition-monitored, maintained, and are ready for immediate installation and service.

Programming and scheduling
New or replacement installations are usually minor works and are integrated into a wider programme schedule that accounts for other works at the same locations using common resources.

Project Delivery
The five aspects of project delivery are design, procurement, programme and project management, commissioning, and decommissioning and disposal.

Design
We have developed standard designs for ODJB’s and oil interception systems, which are used on all new and replacement installations.

Procurement, Programme and Project Delivery, Commissioning, Decommissioning and Disposal
Installations of new or replacement of other substation equipment assets are usually minor works, and there is no specific approach for procurement, programme and project management, commissioning, and decommissioning and disposal.

Service Delivery
We undertake preventative, corrective, predictive, and proactive maintenance activities as specified in our maintenance standards. Minor maintenance and refurbishment works occur according to an annual cycle.

Operate the Grid
We plan and manage outages in a way that creates a safe environment for employees while minimising the disruption for customers.
**Forecast Expenditure**

Our forecast expenditure for other substation equipment is described below.

**Capital Expenditure**

**RCP 2, 2018 to 2020**

The other substation equipment asset class has had changes made that has seen several asset types removed and established as separate classes or within other classes e.g. structures and buswork, and LVAC systems. While these assets are still shown in the RCP 2 budget as part of the other substation equipment, their financial details are covered by their own ACP.

For the assets remaining within the other substation equipment asset class, expenditure so far for the ACS Other asset class in RCP 2 has been slightly higher than what was initially forecast. This is due to unplanned NER replacements at Penrose substation.

The forecast for the remainder of RCP 2 will be below the original plan as fewer ODJB’s need replacing.

**RCP 3, 2020 to 2025**

We have carried out a high-level review of the replacement requirements for the other substation equipment asset class over the next RCP period and the preliminary findings are that the level of expenditure over the next 10 years would be equivalent to RCP 2. The forecast for this portfolio for RCP 3 and RCP 4 will be finalised in late 2017.

**RCP 4, 2025 to 2030**

As per above section.

**Operating Expenditure**

The forecast for operating expenditure over the next ten years is expected to be relatively flat and is related to ensuring that the assets are kept in a sufficiently safe condition and to ensure low whole of life cost.

**Key risks and uncertainties**

The main risks to achieving or delivering the forecast expenditure include undocumented assets and their condition and unplanned replacements. We plan to mitigate these by improved standard maintenance procedures, regular condition assessment, standardised designs and replacements.

**Summary, 2018 to 2030**

<table>
<thead>
<tr>
<th></th>
<th>RCP 2</th>
<th>RCP 3</th>
<th>RCP 4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2016</strong></td>
<td>1.7</td>
<td>1.2</td>
<td>-1.1</td>
</tr>
<tr>
<td><strong>2017</strong></td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td><strong>2018</strong></td>
<td>0.0</td>
<td>2.5</td>
<td>0.0</td>
</tr>
<tr>
<td><strong>2019</strong></td>
<td>0.0</td>
<td>0.0</td>
<td>3.2</td>
</tr>
<tr>
<td><strong>2020</strong></td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td><strong>2021</strong></td>
<td>7.6</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td><strong>2022</strong></td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td><strong>2023</strong></td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td><strong>2024</strong></td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td><strong>2025</strong></td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td><strong>2026</strong></td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td><strong>2027</strong></td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td><strong>2028</strong></td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td><strong>2029</strong></td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td><strong>2030</strong></td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Table 42: Forecast capital expenditure
ASSET CLASS PLAN – OUTDOOR 33 KV SWITCHYARDS: OUTDOOR TO INDOOR CONVERSIONS

This asset class plan describes our approach to the conversion of outdoor 33 kV Switchyards to indoor installations. This is known as our “outdoor to indoor conversion” (ODID) programme.

Outdoor 33 kV switchyards provide an interface point between our high voltage transmission network and medium voltage distribution customers. All our outdoor 33 kV switchyards were constructed before 1984. Since then, there has been no further construction of outdoor 33 kV switchyards, due to the availability of safer, more economic and reliable alternatives.

To mitigate safety hazards, improve reliability, and achieve least life cycle cost associated with outdoor 33 kV switchyards, in 2008 we commenced a nationwide programme for the conversion of most of our outdoor 33 kV switchyards. This programme will be on-going through the remainder of RCP 2 and RCP 3, and will be completed by early RCP 4.

Asset Characteristics

When the ODID programme commenced in 2008, there were 75 substation sites with outdoor 33 kV or 22 kV structures. Following the planned ODID conversions, the transfer of assets to customers, and the decommissioning of some points of supply, we expect there to be only 31 outdoor 33 kV switchyard sites remaining in service at the commencement of RCP 3 in 2020.

Of these, 18 sites are forecast to remain as outdoor switchyards. These sites are small installations where the hazards of close approach to live equipment can be effectively managed, or are N security sites where safe access for maintenance is achieved during a total shutdown.

Asset Health

There are several safety hazards associated with outdoor 33 kV switchyards, including the small clearances to adjacent live equipment, the lack of space to implement the requirements for working at heights, and the need to climb into structures to undertake work. We have had four fatalities of maintenance workers in the past 30 years at 33 kV switchyards. In addition, there have been numerous serious harm injuries, medical treatment injuries, and near miss incidents in these structures.

In addition to these safety and reliability issues, the equipment in many of our outdoor 33 kV switchyards is nearing end of life and is expensive to maintain. These issues are the primary drivers for the ODID programme.

Asset Criticality

We have undertaken a quantified risk analysis to assist in prioritising the ODID programme. The analysis considers each outdoor switchyard as a complete entity, and provides a site-specific quantified risk assessment of the potential for serious workplace safety incidents and for unplanned interruptions.

Asset Performance

Outdoor 33 kV switchyards have a much higher rate of planned and unplanned outages than equivalent indoor switchboards, owing to:

- Environmental factors leading to corrosion, the effects of wind-blown debris, and birds
- Small insulation clearances leading to increased risk of electrical failure in the outdoor environment
- Many of the existing circuit breakers are bulk oil types, with typically higher rates of unplanned outages than modern SF\textsubscript{6} circuit breakers
- Many of the outdoor 33 kV switchyards do not have bus zone protection or bus section circuit breakers. This means that any insulation fault in any of the busbar equipment, or any individual 33 kV circuit breaker failure will lead to a total loss of supply.

The performance history shows signs of increasing failures of ageing assets such as disconnectors. However, we anticipate that the number of unplanned equipment outages in our outdoor 33 kV switchyards will gradually reduce as we continue with the ODID programme. Figure 35 shows the outages by faulted item in our outdoor 33 kV switchyards.
The primary asset management drivers for undertaking ODID conversions are workplace safety, and poor reliability resulting from the deteriorated condition of aged bulk oil circuit breakers and other related equipment in outdoor 33 kV switchyards.

Strategic Planning
Our strategy for outdoor 33 kV switchyards is to decommission all outdoor 33 kV switchyards that have inadequate safety clearance and reliability characteristics, and replace them with indoor switchgear. The highest priority for ODID are those switchyards with small safety clearances, complicated structures and buswork, and aged bulk oil circuit breakers.

Tactical Planning
Our planning approach is to convert our outdoor 33 kV switchyards that do not meet current expectations for safety in design or reliability to modern equivalent indoor switchboards.

Condition Assessments
Outdoor 33 kV switchyards consist of multiple asset types including structure, buswork, disconnector, circuit breaker and instrument transformers. The condition of all major equipment in outdoor 33 kV switchyards is monitored during routine two monthly and annual station inspections. Most of the assets in outdoor 33 kV switchyards are subject to detailed condition assessment at four yearly intervals. We apply the formal condition assessment standard approach for the asset type. Details of these condition assessments are provided in the relevant Asset Class Plans.

Decision Framework
The work programme is determined by applying the four steps of the Decision Framework.

Need identification
All our outdoor 33 kV switchyards are to be decommissioned, except for the 18 sites where the hazards of close approach to live equipment are effectively managed as a result of their design, or because they are N security sites where safe access for maintenance is achieved during a total shutdown.

Options Assessment
The option assessment for ODID was undertaken for the ODID strategy.
Prioritise solutions

A quantified risk analysis has been undertaken to assist in prioritising the programme of outdoor to indoor conversions. The risk analysis is customised for each switchyard site, and considers the potential for serious workplace safety incidents and for unplanned interruptions. Projects are prioritised based on the ratio of risk reduction benefit to project cost. The analysis of interruption risk cost includes the value of the load at the substation, time to restore supply following a fault, and whether there is redundancy at the site and any back-feed capacity.

Develop a Programme Management Plan

The selected solution is considered in conjunction with other scheduled programmes of work to achieve synergies with other planned works such as power transformer replacements or customer upgrade requirements, which are occurring at the same site in a similar time frame.

Cost estimation

The ODID programme is high value, low volume work. We use a customised cost estimating approach to each project, as there is a high degree of diversity in our outdoor 33 kV switchyards. Standard building blocks are not a reliable basis for estimates, because specific requirements for individual sites can have a significant impact on the final project costs. To ensure that estimates are reliable, the identification of site requirements and full project scopes will be determined by a pre-design investigation.

Programming and scheduling

The ODID programme is based on safety and performance. The number of ODID conversions within an RCP period is based on the strategic objectives of programme completion in 2025, and deliverability constraints that may limit the number of parallel investigations and build projects.

An ODID conversion usually takes 36 months from inception to commissioning. This is a 12 months investigation phase followed by a 24 month delivery phase. ODID conversions are investigated, and designed in small batches of three to four projects, which allow design and procurement efficiencies. The civil and electrical work is tendered on a project or site basis. We may bundle other minor works at the site with the ODID conversion, such as local service transformer replacement, or LVAC system upgrade.

Project Delivery

The five aspects of project delivery are design, procurement, programme and project delivery, commissioning, and decommissioning and disposal.

Design

We explore design options that will optimise the delivery costs for indoor switchboards at these sites.

Procurement

Period supply agreements are used for indoor switchboards. These agreements incorporate standardised secondary systems in the panel design, to achieve significant efficiencies in ODID conversions.

For smaller sites with low forecast loadings, we procure indoor switchgear with a smaller busbar rating.

Programme and Project Delivery

ODID projects are amongst our largest scale construction works at substation sites. Accordingly, aspects of programme and project management are tailored to reflect expected management effort and support consistency across programmes. The ODID programme is a ‘superportfolio’ on its own, and performance of the delivery is tracked and made visible to the highest reporting levels.
Commissioning
The transition from the existing outdoor switchyards to indoor switchboards can be managed through either a temporary series connection, or a parallel connection. We usually specify a parallel connection as this leads to a simpler “roll-back” if difficulties occur during commissioning and it minimises time on N security.

Decommissioning and Disposal
The outdoor 33 kV switchyards to be converted to indoor switchboards, include a small number of 33 kV circuit breakers and other equipment that is of modern design, in good condition, and could provide many further years of useful service. This equipment is recovered for re-use, or sale to distribution network companies. Where re-use or sale of the equipment is not appropriate, we ensure all demolition, recovery, recycling and disposal work includes safe work and site management processes.

Remaining equipment is sold to scrap merchants who salvage and recycle all the metalwork and the oil is recovered by an oil regeneration company. The SF₆ gas is recovered and re-used.

When existing outdoor 33 kV switchyards are divested or decommissioned, the asset status information is updated to reduce the risk of data anomalies in our asset information systems.

Service Delivery
As the ODID conversions is a capital programme, maintenance activities are not relevant to this asset class plan.

Operate the Grid
We plan outages to provide a safe environment for employees and service providers to undertake the work, while minimising disruptions to customers and end users.

Forecast Expenditure
Our forecast expenditure for the ODID programme is described below.

Capital Expenditure
RCP 2, 2018 to 2020
The number of ODID projects forecast over RCP 2 remains the same as presented in the 2016 AMP, with 14 conversions. The forecast cost has increased from due to the updating of cost estimates for late RCP 2 projects, as part of their investigation. The original RCP 2 ODID estimates were based on a high-level cost estimation methodology before a detailed scope investigation was performed.

RCP 3, 2020 to 2025
The ODID programme of work for RCP 3 is slightly lower than the RCP 2, with 13 conversions compared to 14. Also, many of the switchyards to be converted are smaller, i.e. they require a smaller switch board and switch room building than those installed in RCP 2. With these two factors combined, the estimated costs for the ODID programme will decrease from $95 million in RCP 2 to $65 million in RCP 3 (-32%).

RCP 4, 2025 to 2030
The ODID programme of work is planned to be disbanded after RCP 3 as there will be few remaining candidate 33 kV switchyards for ODID conversion. Some of the smaller, lower risk outdoor 33 kV switchyards will have their case for ODID conversion revisited in the future, as innovations may change the most cost-effective solution. RCP 4 currently only contains one ODID (Carrington Street) at a cost of about $4 million.
Operating Expenditure

ODID conversions are a capital programme. Maintenance activities relevant to new indoor switchgear is detailed in the Indoor Switchgear Asset Class Plan.

Key risks and uncertainties

Key risks to this programme of work include:

1) Disruption to the programme from innovation initiatives, including non-standard design/build initiatives. However, these do have the potential for cost savings and/or individual project timeline shortening in the future.

2) Disruption to the programme from re-tendering the period supply agreement for 33 kV switchgear. However, this may result in the potential for cost savings in the future.

3) Internal and external resource constraints.

Summary, 2018 to 2030

<table>
<thead>
<tr>
<th>Outdoor to Indoor Conv</th>
<th>RCP 2</th>
<th></th>
<th>RCP 3</th>
<th></th>
<th>RCP 4</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>25.6</td>
<td></td>
<td>2017</td>
<td>18.3</td>
<td>2018</td>
<td>20.6</td>
</tr>
<tr>
<td>2019</td>
<td>26.8</td>
<td>3.7</td>
<td>2020</td>
<td>19.6</td>
<td>2021</td>
<td>13.2</td>
</tr>
<tr>
<td>2022</td>
<td>10.9</td>
<td>14.1</td>
<td>2023</td>
<td>7.7</td>
<td>2024</td>
<td>0.0</td>
</tr>
<tr>
<td>2025</td>
<td>0.2</td>
<td>0.0</td>
<td>2026</td>
<td>4.1</td>
<td>2027</td>
<td>0.0</td>
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<tr>
<td>2028</td>
<td>0.0</td>
<td>0.0</td>
<td>2029</td>
<td>0.0</td>
<td>2030</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Table 43: Forecast capital expenditure
BUILDINGS AND GROUNDS ASSET PORTFOLIO

The Buildings and Grounds asset portfolio covers all substation, control and switchgear buildings. It also includes buildings that house the National Grid Operating Centres and buildings that support the operations of our sites. These are incorporated into a single Buildings and Grounds Asset Class Plan. This summary provides an overview of our proposed activities for these assets.

Key Initiatives

We have several key initiates within the buildings and grounds portfolio. These are:

1. A Key initiative for the remainder of RCP 2 is to improve our asset data for buildings and grounds. This includes:
   - Mapping our highest spend asset groups (fences, metalling, cable trench covers and access way/roads) geospatially with our GIS platform
   - Continued development of our asset class health models for fences and roofs
2. We have a flat roof replacement programme. The objective of this programme is to replace flat roofed sites with pitched roofs to eliminate water ingress.
3. We have a programme of investigations into:
   - The condition of our underground infrastructure at critical sites to identify remedial works to underground services
   - A national condition assessment of outdoor cable trench covers nationally
   - Establishing the requirements for safe access onto substation roofs
   - Identification of sites under 25m above sea level that could be at risk of a Tsunami following an earthquake
   - Phase II seismic performance review of substations buildings upgraded in the 90’s against current building code
   - National asbestos survey of stations switchyard electrical equipment including switchyard metal and soil.
4. Continuing with trials of innovative technology for use in our substation environment including:
   - Hypoxic air fire prevention systems for improved fire risk management at a small number of critical control room sites
   - Intelligent video surveillance cameras at sites with high security risk

Expenditure Summary

Capital Expenditure

The portfolio is forecast to underspend against the RCP 2 allowance due to the deferral of capital replacement security fencing into RCP 3 and completion of the seismic upgrade project being under budget. The peak in expenditure in the years 2021 to 2024 is driven by:

- Savings of substation security fencing now required in RCP 3
- Condition assessment review of cable duct covers leading to a higher than anticipated RCP 3 and 4 replacement programme. The forecast numbers for replacement of cable duct covers in RCP 3 and 4 are being reviewed. When the surveys are completed, the data is assessed against the current specification requirements, and once the GIS mapping project is completed we will undertake a pre-scoping exercise of all forecasted projects greater than $150K to provide a higher level of certainty of the pricing with supporting condition data to assist with sound decision making. Where possible, the expenditure will be smoothed between the years.

<table>
<thead>
<tr>
<th></th>
<th>RCP 2</th>
<th>RCP 3</th>
<th>RCP 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portfolio Total</td>
<td>7.8</td>
<td>9.5</td>
<td>5.0</td>
</tr>
</tbody>
</table>

Table 44: Portfolio Capital Expenditure
Operational Expenditure

We have over 740 buildings at more than 200 locations. Our buildings house a wide range of equipment, the most critical being the substation control and indoor switchgear, as well as the National Grid Operating Centres. Our maintenance programme covers our buildings, building services, site infrastructure, grounds, planting, landscaping and fencing plus assuring compliance with legislation. Our specific maintenance approach varies between equipment items; however, our maintenance activities generally include:

- **Inspections**: inspection of station assets aims to ensure that facilities and equipment are in a safe and serviceable condition and that any abnormalities that represent a risk to grid reliability, safety of personnel, or the security of the site are identified and rectified.

- **Condition assessments**: to provide a standard assessment of the condition and expected remaining life of the assets.

- **Diagnostic testing**: this involves measuring electrical and mechanical parameters such as insulation, functional checks, and clearances.

- **Servicing**: this involves periodic servicing, aligned with inspections and condition assessments, to maintain asset condition.

- **Corrective maintenance**: this is work initiated as a result of faults, identified defects, or condition assessments.

We have developed the frequencies for our inspections, condition assessments, and servicing of our building and grounds equipment over several years, in line with common industry practice.

Our forecast operational expenditure increases slightly towards the end of RCP 2 and into RCP 3 as we plan to extend the operational life of our assets deferring replacement until the most economical intervention point. This includes planned minor repairs of damaged or deteriorated protective coatings, fences and other asset groups such as air-conditioning units to extend the practical life.

Risks and Uncertainties

Our forecast expenditure is dependent upon market costs of civil labour rates and general building material costs remaining constant. Depending on the location of work, the availability of resources to deliver the proposed programme can make this challenging. It is expected the cost of mitigating and the removal of asbestos will continue to present significant risks to the existing building and grounds budget and deliverables into RCP 3.

Asset Class Plan

The following section describes in more detail our asset management approach for our buildings and grounds portfolio. It describes the strategy, asset characteristics, management approach and expenditure profile.
ASSET CLASS PLAN – ACS BUILDINGS AND GROUNDS

This asset class plan describes the life cycle management approach of our buildings and grounds. We categorise these assets by their main function. This asset class plan covers the following categories:

- Buildings
- Building services
- Site infrastructure
- Security Fencing

The buildings and grounds included in this asset class provide the accommodation, services, and physical security for critical grid equipment and systems. Facilities Management of our buildings and grounds assets is outsourced.

Table 45 provides the population details of our buildings and ground assets.

<table>
<thead>
<tr>
<th>Type</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Buildings</strong></td>
<td></td>
</tr>
<tr>
<td>Station buildings</td>
<td>742</td>
</tr>
<tr>
<td>Warehouses</td>
<td>3</td>
</tr>
<tr>
<td>National Grid Operating Centres (NGOC’S)</td>
<td>2</td>
</tr>
<tr>
<td>Unmanned emergency operating centres</td>
<td>2</td>
</tr>
<tr>
<td><strong>Building services</strong></td>
<td></td>
</tr>
<tr>
<td>Heating and air-conditioning systems</td>
<td>777</td>
</tr>
<tr>
<td>Fire alarm systems (not part of integrated security alarm systems)</td>
<td>181</td>
</tr>
<tr>
<td>Sprinkler systems</td>
<td>64</td>
</tr>
<tr>
<td>Electronic access control &amp; security systems</td>
<td>177</td>
</tr>
<tr>
<td>Standby generators</td>
<td>4</td>
</tr>
<tr>
<td>Uninterruptible power systems</td>
<td>3 sites</td>
</tr>
<tr>
<td><strong>Site infrastructure</strong></td>
<td></td>
</tr>
<tr>
<td>Roading</td>
<td>170 sites</td>
</tr>
<tr>
<td>Water Supplies, stormwater and foul drainage systems</td>
<td>170 sites</td>
</tr>
<tr>
<td>Switchyard metalling</td>
<td>190 sites</td>
</tr>
<tr>
<td><strong>Fencing</strong></td>
<td></td>
</tr>
<tr>
<td>Switchyard and equipment fencing</td>
<td>87,340 m</td>
</tr>
<tr>
<td>Boundary and non-security fencing</td>
<td>95,246 m</td>
</tr>
</tbody>
</table>

Table 45: population of our buildings and grounds assets

Asset Characteristics

Urbanisation of populated growth areas such as Auckland is impacting the use of land around our substations. As rural areas change to residential zones and housing is built next to substations, risks associated with site security, and public health and safety increases. These changes have driven the need for further investment in our substation security and public safety management.

The bow-tie analysis indicates the predominant failure causes for structures and fence failure is degradation and corrosion, natural disaster, impact and collision, and overloading.
Age Profile
Our oldest substation buildings that are still in service were constructed in the 1930s. Most of our substation buildings were built in the 1950s to 1970s, with only a few new substations constructed since the 1980s. Overall, we have reduced building numbers through the demolition of redundant buildings and the divestment of sites.

Asset Health
Our buildings and grounds are in good condition. As shown in the table above, our buildings and grounds portfolio includes a diverse range of asset types in addition to the main station buildings. Asset condition is measured periodically for many types of assets within the portfolio.

As an example, Figure 36: shows the asset health summary for roof assets and fences. In most cases these are in good condition, with a few requiring investment.

![Figure 36: Roof and Fence Asset Health](image)

The majority of our buildings are located in either the severe and moderate corrosion zones. Roofs in the benign zone are in good condition, whereas roofs that are in poor condition are in the severe to extreme corrosion zones.

We have identified several building infrastructure items that need to be upgraded due to age, capacity, condition, integrity, level of resilience, and the level of fire protection currently provided. By way of example investigative work at the Haywards substation undertaken in 2015/16, found that the water mains and sewerage systems have reached the end of their serviceable life, requiring replacement. We expect several substations of a similar age are likely to experience similar issues.

The condition of protective coatings is also critical to the expected useful life and performance of the underlying building substrate. Protective coatings must be maintained and replaced in a cyclical manner, with consideration of the expected lifetime of the paint finish, which will vary with the corrosion zone and other factors.

11 For definitions of our corrosion zones, please refer to our Transmission Lines Asset Portfolio.
Access roads on our sites often reach only five to 10 years before significant maintenance or replacement is required. One challenge is the impact of heavy slow-moving, multi-wheel vehicles (such as transformer transporters) making sharp turns on narrow access roads. These can displace existing asphalt surfaces, leading to accelerated deterioration. There have been instances of vehicles becoming bogged because of unsatisfactory load-bearing performance of switchyard aggregate.

**Asset Criticality**

Modelling asset criticality for our buildings and grounds assets is challenging because of the diverse asset types, diverse modes of failure, and the wide range of potential consequences because of failure. We have an existing criticality model that can be used to rank substation sites for the purposes of prioritising investments in building fire detection and protection. We are currently revising our approach to asset criticality for buildings and grounds, to achieve better linkages with the framework used for other network assets.

**Asset Performance**

Our buildings and grounds assets have performed well. The probability of severe building failure is low. However, there are several issues that have the potential to affect performance. Of specific note, these are seismic performance, asbestos management, weather tightness performance, and animal intrusion. These are addressed below:

**Seismic performance**

Seismic performance is a key consideration for all buildings in New Zealand to ensure the safety of people within and near the buildings. The more robust and resilient our substation buildings and grounds are, will make outages less likely in the event of an earthquake, and improve restoration times when outages do occur. Overall, our buildings and grounds performed well in the Canterbury earthquakes of 2010 and 2011, and the Kaikoura earthquake of 2016. However, not all buildings have been assessed against the current building code, and a phase II seismic performance review of substation buildings upgraded in the 90’s is required. These buildings were excluded from the RCP 1 and 2 seismic upgrades, as they were deemed out of scope. Phase II building design investigations have been scheduled for RCP 3 with capital strengthening worked planned in RCP 4. To get this programme underway the first investigation planned for 2020/21 is required to establish engineering oversight and identify the criteria for upgrading these buildings.

**Asbestos management**

Due to the age of our buildings and grounds and associated equipment, asbestos containing materials (ACMs) have been widely used across our sites in a variety of applications ranging from building construction materials, to electrical equipment, and underground services.

We manage our asbestos risk in accordance with the Health and Safety at Work (Asbestos) Regulations 2016, our Asbestos Management Strategy (AMS), and our Asbestos Management Plan to ensure the health and safety of our workers and the public. Our AMS has been developed to establish clear objectives and strategies for management of workplace risks associated with asbestos contaminated dust or debris, and asbestos contaminated soils. We have asbestos specialists to assist with key areas of asbestos management in accordance with regulations and Worksafe New Zealand requirements on identification, testing and removal.

To date we have:

- Undertaken inspections on buildings and grounds at substations, remote radio repeater sites, regional offices, operating centres, and warehouses, including any leased depots
- Commenced an in-depth review of substation assets that are known, or likely, to contain asbestos
- A national asbestos register and management plan to evaluate and manage asbestos risk
- A specification outlining protocols to ensure a safe working environment
Asbestos management will have a significant financial cost associated with future mitigation and removal. The costs associated with mitigating measures are managed by the relevant portfolios to which the assets relate. Buildings and Grounds costs related to dealing with this hazard have been tagged as such within the programme.

**Cable Trench Covers performance**

We had a spate of incidents with vehicles damaging duct lids or cables within ducts. This highlighted issues with a lack of, or clear, vehicle-crossing locations within switchyards. This led to the development of a new duct cover lid and duct cover road crossing specification in 2017. This gathered information on the different cable duct lid types and construction to assist with planning a national staged replacement programme in RCP 3 and 4.

**Weather tightness performance**

In recent years, we have had several leaks or damage to substation buildings due to extreme weather conditions and high-risk design elements. There have been no reported transmission outages as the result of a weather tightness event. Flat or low-pitched roofs with butyl rubber membranes, internal gutters, and parapets are a common feature of control building design and pose significant risk as rainfall drains slowly from the rooftop. Any deterioration of the butyl membrane or seals typically leads to water ingress to the building. Given the age of many substation buildings, membrane deterioration is common and constant maintenance and remedial work is currently required to ensure weather tightness.

Extreme weather events producing heavy rain falls over a short period often overload the guttering systems. On buildings with external guttering systems, water overflow spills over the exterior of the building without causing issues. However, internal guttering systems are often unable to drain at a sufficient rate, allowing water to back up through roof cladding and enter the building via capillary action.

While water ingress through flat roofs can be attributed to a combination of design, component condition and extreme weather, the weather tightness of other substation claddings is largely attributed to component condition only. Deterioration of cladding materials, fixings and flashing of pitched roofs and exterior walls also has the potential to create weather tightness issues.

**Animal intrusion**

Animals in substations can be a cause of asset damage and unplanned outages. The history of unplanned outages caused by animals (other than birds) in substations since 2000 is illustrated in Figure 37: The electric wire system installed on switchyard security fences has generally proven to be effective in keeping possums out of substations. Rodents present a different threat, and there is evidence of significant rodent intrusion and damage to equipment. Although there have been few outages or interruption incidents directly attributable to rodent intrusion, evidence indicates that this remains a significant threat to network reliability.

![Figure 37: Unplanned outages caused by animals](image-url)
Asset Life Cycle Stages

Our asset management approach for buildings and grounds is to outsource the core asset management functions to a qualified facilities manager for reasons of efficiency and effectiveness. We manage the provision of the outsourced asset management service to ensure that our overall corporate and asset management objectives are met.

Strategic Planning

The following strategic objectives have been set for our buildings and grounds assets:

**Safety**
- No Loss Time Injury or Serious Harm Accidents from our buildings and grounds or facilities maintenance service providers
- All new building to conform to legislative and regulatory requirements
- Assets do not endanger human life or cause serious harm
- No unauthorised entry to substations
- The seismic strength of all essential buildings achieves at least 75% of the New Zealand Building Standard
- Asbestos hazards associated with building and grounds are managed to minimise the risk of exposure to personnel or members of the public.

**Service Performance**
- Zero unplanned outages of grid equipment arising from defects or faults in building and grounds assets or services
- High-impact, low-probability risks to buildings and grounds that have consequences for the integrity of transmission equipment are identified and mitigated where economically justified.
- Physical security and access control systems prevent or deter entry by unauthorised person
- The seismic strength of all essential buildings achieves at least 75% of the New Zealand Building Standard
- Minimise the risk of damage to operational assets caused by pests

**Cost Performance**
- New buildings and grounds facilities are designed to minimise life cycle cost
- Buildings and grounds are maintained at an economically optimum level
- Building components and ancillary services are replaced when maintenance becomes uneconomic

**Customers and Stakeholders**
- The operation and maintenance of buildings and grounds assets does not cause damage to third party property
- Buildings and grounds assets, and the operation and maintenance of those assets, does not cause damage to the environment
- Positive relationships are maintained with landowners and leaseholders

**Development Initiatives**
We review industry practices and materials employed to ensure modern, cost effective solutions are always being utilised. For example, we will investigate the potential for closed gutter systems to be either retrofitted to existing roofing, or used as the preferred guttering system when roofing is replaced, as closed guttering systems are not vulnerable to blockages from air-borne debris.

**Tactical Planning**
Our planning approach for our buildings and grounds assets is based on condition assessment and targeted to optimise the whole of life costs of assets. We address localised deterioration with repairs and minor replacements to enable deferment of major investment until maintenance is no longer an economic solution. In the case where specific hazards are identified then mitigation programmes are put in place.
The drivers for capital investment in our buildings and grounds include:

- Mitigation and removal of asbestos hazards
- The repainting of coated metal roofing to preserve the life of the asset, using condition-based intervention points and expected coating lifetimes that are adjusted based on corrosion zone. The metal roofing and guttering will be replaced when repainting is no longer an adequate solution
- Replacement of butynol flat roofs with pitched roof and colour steel finish
- Identification, prioritisation, and mitigation of remaining seismic risk exposures for essential buildings
- Replacement of security fences when the overall condition code scoring based on International Infrastructure Management Manual (IIMM) is 4 and maintenance of the fence components is no longer economic compared with total replacement
- Replacement or augmentation of switchyard crushed rock aggregate based on analysis of condition, risk, and cost
- Management of asbestos containing materials in our switchyard metal and soil
- Seismic performance review of substation buildings upgraded in the 90's
- Enhancement of fire protection systems at critical sites

Condition Assessments

Regular condition assessments of our buildings and grounds assets are undertaken. Our buildings and grounds assets are condition assessed based on IIMM assessment scale for building and infrastructure assets. Table 46 outlines our condition monitoring inspections that we undertake:

<table>
<thead>
<tr>
<th>Interval</th>
<th>Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monthly</td>
<td>The routine inspection interval for buildings and grounds is variable, and is adapted based on site-specific requirements and seasonal variations related to vegetation growth etc. A one month interval is a typical average, but there are wide variations within the outcome-oriented management regime. Ground level inspection of building exterior and interior, including fixtures, fittings and building services Hand operating fire-fighting equipment and fire signage checked (for buildings that require a Building Warrant of Fitness) Inspections of gravelled switchyards, fences, and gates Inspections of roads and access ways Inspection of drainage systems and waterways Inspection of grassed and planted areas, with routine maintenance as required</td>
</tr>
<tr>
<td>Annual</td>
<td>Independent qualified person inspects for issue of Building Warrant of Fitness (where required)</td>
</tr>
<tr>
<td>Annual</td>
<td>Condition assessment survey undertaken on approximately a third of assets annually, so all assets are covered in a three-year rotating cycle</td>
</tr>
<tr>
<td>2 yearly</td>
<td>VESDA smoke systems cleaned and air filters replaced</td>
</tr>
<tr>
<td>4 yearly</td>
<td>Re-calibration of VESDA smoke detectors</td>
</tr>
</tbody>
</table>

Table 46: Condition-monitoring inspections and servicing of our buildings and grounds assets
We have pressurised water sprinklers installed at a small number of sites. These are subject to a maintenance regime with monthly, three monthly, yearly and two yearly intervals in accordance with NZS4541:2013 Automatic fire sprinklers.

We monitor electronic access control and security systems, fire alarm systems, temperature and humidity monitoring systems, and emergency power supplies in real-time.

**Decision Framework**
The work programme for buildings and grounds is determined by applying the four steps of the Decision Framework.

**Need identification**
Asset performance, condition data, asset age, and corrosion zones are used to identify needs and associated need dates.

**Options Assessment**
Options to address identified needs are developed based on good industry practice in the buildings and grounds sector, that will achieve an acceptable level of performance and risk, and minimise whole of life cost.

**Prioritise solutions**
Solutions are prioritised based on need date.

**Develop a Programme Management Plan**
Linking prerequisite activities is important to planning for projects to be completed at the right time. For example, repair and replacement of underground services is undertaken prior to resealing a road or laying new switchyard metal. Like-for-like replacement projects such as air conditioning replacements are grouped regionally. Our plans may also be amended to account for programmes of work being planned within other portfolios. For example, fencing and metalling replacements may be deferred to allow installation of a new transformer.

**Cost estimation**
Replacements of air conditioning units are volumetric works as they are repetitive with similar scope. We have defined building block unit rates for air conditioning units. For our other assets, costs are derived from unit rates within our Asset Management Software based on the Rawlinson framework, which is reviewed annually.

**Contingency planning**
Our contingency plans for buildings and grounds ensures that we can respond appropriately to major buildings and grounds failures. We have a team of contracted designers, engineers and a contractor base available to respond to any major building failures. Standard designs enable rapid deployment of replacements for key operational buildings. We already have a mobile substation (15 MVA, 110/33 – 11 kV) and a mobile switchroom (33/22/11 kV) that can be used as part of our response to major failures.

Post-earthquake checks are carried out on our buildings and grounds in accordance with our Post-Earthquake Response Plan. A structural engineer checks the building structure and assesses any environmental hazards. Qualified personnel check all electrical equipment and systems. The purpose of the Post-Earthquake Response Plan is to ensure:

- A clear outline of evaluation procedures for accessing our sites and entering damaged buildings
- Plan activation
- Key buildings are inspected and evaluated following a major earthquake
- it is safe to enter the building.

**Programming and scheduling**
Replacements and upgrades are individually scoped and priced works. As such, they are scheduled according to need and resource availability, while accounting for other work at the same location.

**Project Delivery**
The five aspects of project delivery are design, procurement, programme and project management, commissioning, and decommissioning and disposal.
Design
We use standard design, specifications, and service levels for the design of our buildings and grounds assets. Our environments team is involved in the design of new and refurbished buildings and grounds to ensure we account for the requirements of the Resource Management Act 1991 and Building Act 2004.

Procurement
We work with local councils to obtain consents and waivers for buildings and grounds facilities. We have evaluation and project assessment processes to determine which consents are required under the RMA, and Regional and District Plans. A tender process is employed for construction projects.

Programme and Project Delivery
Our Programme and Project delivery is undertaken in accordance with our programme management framework. Our contracts specify response times for each site following a fault condition. We repair buildings and grounds assets with damage from adverse events as required.

Commissioning
We ensure all new buildings conform to legal and regulatory requirements. Commissioning includes the final calibration and configuration of systems such as air conditioning and security systems.

Decommissioning and Disposal
Where the use of a building or site changes over time we will review the building or site use. We will dispose of assets that have a significant maintenance cost and no strategic value.

Service Delivery
We undertake preventive, corrective, predictive and proactive maintenance activities as specified in our maintenance standards and service specifications.

Operate the Grid
There are no specific outage planning strategies for our buildings and grounds assets.

Forecast Expenditure
Our forecast expenditure for our buildings and grounds is described below.

Capital Expenditure
RCP 2, 2018 to 2020
The portfolio is forecast to be $6.7 million lower than 2016 ITP due to the following factors:
- The Warehouse portfolio and budget was moved into the Buildings and Grounds portfolio in December 2015, to complete urgent warehouse improvement projects at Addington, Bunnythorpe, and Otahuhu. Following scoping only a third of the works could be delivered under capital funding due to financial treatment
- Seismic strengthening upgrade project at Penrose (old control building) was cancelled due to asbestos that is unable to be mitigated
- The cost to deliver High Impact Low Probability, Fire Prevention projects at Bunnythorpe, Wilton, Ashburton, and Twizel were higher than originally estimated following final design of works.

RCP 3, 2020 to 2025
Improvements in our asset management planning including asset condition data improvement initiatives and development of a predictive tool used to forecast remaining life for assets, has provided key inputs for the future work plan. Based on condition and the age of assets this has driven an increase in the RCP 3 Capex expenditure required on fencing, metaling, cable trench lids, and prevention of water ingress through roofs and substrate materials. The current forecast is an estimate prior to finalising work scope.
This will be further refined post our national asbestos survey of stations switchyard electrical equipment that includes switchyard metal and soil contamination. This forecast signals a contingency sum for the mitigation and or removal of asbestos containing materials from contaminated switchyards that is likely to fall into this portfolio of work. Based on remedial work and condition information completed to date, such as Mangahao, and with an additional five switchyards identified in 2016, we need to allocate an appropriate amount of funding to mitigate these risks in RCP 3.

**RCP 4, 2025 to 2030**

At this stage, it is expected that there will be a slight decrease in expenditure based on asset condition predictive modelling and a similar forecast currently predicted moving into RCP 5.

**Operating Expenditure**

The following maintenance activities that have been grouped into programmes of work for efficient delivery, have increased the forecast operational expenditure for the RCP 2 period:

- Urgent warehouse improvement projects required at Addington, Bunnythorpe and Otahuhu in RCP 2 that cannot be capitalised
- Deferral of capital substation security fencing projects into RCP 3 resulted in an increase to the Opex maintenance spend as we plan repairs to extend the life of this asset
- Planned on going mitigation of building materials known to contain asbestos to meet legislative obligations
- Various other investigations, and waterproofing works
- Undertake planned and reactive repairs as appropriate to ensure service levels are maintained.

**Key risks and uncertainties**

The forecast is dependent upon the market costs of civil labour rates and general building material costs remaining constant. Depending on the location of work, the availability of resources to deliver the proposed programme can make this challenging. It is expected the cost of mitigating and removal of asbestos will continue to present significant risks to the existing Building and Grounds budget into RCP 3.

**Summary, 2018 to 2030**

<table>
<thead>
<tr>
<th></th>
<th>RCP 2</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Buildings and Grounds</td>
<td>7.8</td>
<td>9.5</td>
<td>5.0</td>
<td>4.3</td>
<td>2.6</td>
<td>10.7</td>
<td>9.4</td>
<td>10.9</td>
<td>9.4</td>
<td>8.5</td>
<td>5.6</td>
<td>5.7</td>
<td>4.1</td>
<td>2.5</td>
<td>3.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 47: Forecast capital expenditure

**Long-term forecast**

It is expected that expenditure during RCP 5 will be closer to the RCP 4 level, as we address specific programmes of work for fencing, metalling and cable trench lids including water ingress issues in RCP 3 and 4. It is also expected that the current levels of operational expenditure will continue.
TRANSMISSION LINES (TL) ASSET PORTFOLIO

The Transmission Lines asset covers all our primary transmission line assets. It consists of the following asset classes:

- TL Structures and Insulators
- TL Conductor and Hardware
- TL Grillages
- TL Foundations and Access

The primary purpose of transmission lines is to transport power from generators to consumers, located around the country. Within the asset class plans for the TL portfolio there are some common terms utilised. These are:

**Corrosion Zones**

The corrosiveness of the atmosphere significantly influences the condition and life expectancy of our transmission line assets. To account for this, we have allocated our transmission line assets to six corrosion zones to typical environments. Allocation of our assets to the corrosion zone is reviewed periodically. Table 48 sets out the corrosion zone and outlines the typical environment.

<table>
<thead>
<tr>
<th>Corrosion zone</th>
<th>Typical environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extreme</td>
<td>Geothermal/exposed</td>
</tr>
<tr>
<td>Very severe</td>
<td>Sea-shore (surf)</td>
</tr>
<tr>
<td>Severe</td>
<td>Sea-shore (calm)</td>
</tr>
<tr>
<td>Moderate</td>
<td>Sheltered/coastal with low salinity</td>
</tr>
<tr>
<td>Low</td>
<td>Arid/rural/inland</td>
</tr>
<tr>
<td>Benign</td>
<td>Dry, rural/remote from coast</td>
</tr>
</tbody>
</table>

Table 48: Corrosion Zones

**Condition Assessment (CA) scores**

We use a combination of patrols and CA inspections to inspect our transmission lines. Regular condition assessments give a good indication of the condition of individual assets and the asset class, enabling the optimisation of maintenance and replacement works. Line patrols are performed annually to manage safety, structural integrity, and operational reliability risks. Patrols focus on identifying defects which are expected to deteriorate significantly within the next year and include observable structural damage, vegetation encroachment, animal interactions, and incompatible corridor use.

The condition assessment programme monitors and records the condition of transmission line structures, foundations, conductors, and hardware. The assessment produces a CA score for various components on a scale from 100 (new) to 20 (replacement or decommissioning criteria) to 0 (where failure is likely under everyday conditions). It applies a consistent approach to assessment of line components and allows extrapolation of the assessed condition into the future.

The frequency of condition assessment visits is varied based on the structure/span criticality and health. New assets will first be assessed prior to the end of any defect liability period. Thereafter, each tower and pole structure has assessments that are performed at 8 and 6 year intervals respectively. In addition, partial assessments are to be undertaken every four years for tower lines, three years for pole lines where structures and spans contain components previously coded at less than CA50.
Expenditure Summary

Capital Expenditure

Overall there is a substantial increase in expenditure forecast for Transmission Line assets over RCP 3 and RCP 4. This is primarily driven by Tower Painting and Reconductoring as the network continues to age and degrade. With large portions of the network built at the same time we are forecasting large sections to reach end of life at a similar point in time. Other portfolios are not expected to see significant increase in expenditure. We continue to review our conductor replacement forecasts to ensure investments are timed appropriately as more data becomes available.

<table>
<thead>
<tr>
<th></th>
<th>RCP 2</th>
<th>RCP 3</th>
<th>RCP 4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Structures and Insulators</strong></td>
<td>43</td>
<td>49</td>
<td>52</td>
</tr>
<tr>
<td><strong>Conductors and Hardware</strong></td>
<td>8</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td><strong>Grillages</strong></td>
<td>9</td>
<td>13</td>
<td>11</td>
</tr>
<tr>
<td><strong>Foundations and Access</strong></td>
<td>2</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td><strong>Portfolio Total</strong></td>
<td>63</td>
<td>67</td>
<td>75</td>
</tr>
</tbody>
</table>

Table 49: Forecast TL Replacement Capital Expenditure

Listed projects

We are on track to have three submissions for listed projects in by June 2018. These cover CPK-WIL B, OTB-HAY A and BPE-WIL A lines. The BRK-SFD B line which was previously included as a listed project for RCP 2 has been delayed while we review the long-term system need for that section of the Grid and possible solutions that may not require the reconductoring of this line.

The listed projects for RCP 3 have been identified and we are going through a review of the scope and timing of the reconductoring to ensure projects are correctly categorised as either Base Capex or Listed projects for the RCP 3 submission. This reconductoring is also being considered by our Auckland Strategy team, where lines of interest include OTA-WKM A & B, ALB-HEN A, and BOB-OTA A. So far this wider review and categorisation has identified 3 projects nationally, of which BOB-OTA is likely to be listed; this is included in the table below. However, there is still a reasonable degree of uncertainty regarding all three projects. For RCP 4 the listed projects are based off the condition data and health modelling presently available. More work will be done to confirm the scope and timing of these projects. Based off our modelling we are expecting an increase in the volume of listed projects in RCP 4 from RCP 2 and RCP 3.
Table 50: Listed Projects

Operational Expenditure

Overall through RCP 3 and RCP 4 we expect a minor increase in operational expenditure for transmission lines portfolios. This is once again driven by conductor inspections and repairs and ongoing maintenance of our steel lattice towers through replacement and refurbishment of attachment points and minor steel members.

Table 51: Forecast TL Operational Expenditure

Risks and Uncertainties

The primary expenditure risk within this portfolio relates to the conductor replacement and repair work. As we collect more condition data for our conductors this may allow us to refine the scope and timing of some of the planned reconductoring work. This may result in increases or decreases to both the capital and operational expenditure depending on the results.

Asset Class Plans

The following sections describe in more detail our asset management approach for each of the asset class. These asset class plans describe the strategy, asset characteristics, management approach and expenditure profile for each asset class. The expenditure covers the capital requirements, along with any specific maintenance projects to be undertaken.
ASSET CLASS PLAN – TL STRUCTURES AND INSULATORS

This asset class plan describes our life cycle management approach for TL Structures and Insulators. It covers the following asset types:

- Steel lattice towers and components
- Pole structures and components
- Insulators and associated hardware
- Phase conductor and earthwire clamps.

Towers and Poles

Our towers consist of numerous designs dating from the original 110 kV lines built in the 1920s, the flat-top 220 kV designs in the 1950s, through to the double-circuit 220 kV tower designs in use since the 1970s. Whatever the design, all towers perform and degrade in largely the same manner, dependant on the corrosion zone where they are located.

In a similar manner to our tower design, the preferred pole construction material has changed over time. Untreated hardwood poles were installed from 1920-1970. Between 1970 and 1992 treated hardwood or “old” concrete (I beam, verindeel, hollow spun) were installed and from 1992 “new” concrete (octagonal hollow cast pre-stressed) poles are installed. A small number of steel poles have also been installed.

Table 52 shows our asset population for towers and poles.

<table>
<thead>
<tr>
<th></th>
<th>≤ 66 kV</th>
<th>110 kV</th>
<th>220 kV</th>
<th>HVDC 350 kV</th>
<th>400 kV</th>
<th>No Voltage Recorded</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tower</td>
<td>351</td>
<td>6,214</td>
<td>14,997</td>
<td>1,666</td>
<td>418</td>
<td>4</td>
<td>23,650</td>
</tr>
<tr>
<td>Pole</td>
<td>1,672</td>
<td>12,578</td>
<td>83</td>
<td>33</td>
<td>10</td>
<td>2</td>
<td>14,378</td>
</tr>
</tbody>
</table>

Table 52: Tower and Pole population

Insulators

Insulators attach energised conductors to supporting structures such as towers and poles. Until the mid-1980’s glass and porcelain insulators were the insulators used. More recently we have introduced composite insulators and use these in severe and extreme corrosion environments while glass insulators are preferred in all other environments. Composite insulators are made from a fibreglass rod with silicone rubber sheath and sheds. Table 53 shows our insulator population.

<table>
<thead>
<tr>
<th>Hardware type</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Composite</td>
<td>10,910</td>
</tr>
<tr>
<td>Glass and Porcelain</td>
<td>42,510</td>
</tr>
<tr>
<td>Other</td>
<td>786</td>
</tr>
</tbody>
</table>

Table 53: Insulator Population
Asset Characteristics

The corrosion zone within which our towers and poles are located is a significant determinant of the degradation rates and the maintenance requirements over time. We utilize a combination of painting and steel and bolt replacement as the mechanism to maintaining the health of our towers and we replace the older wooden poles with concrete where required. The overall performance of our towers and poles has been good and structural failures are very rare. Where they have occurred in the past it has primarily been due to severe weather events, ground subsidence or third-party interference.

Age Profile

Our tower and pole assets have been installed over time, with significant periods of network development in the 1930s and the 1950s to 1980s. Most towers are original, as they have been maintained in perpetuity. In recent years painting has been used to manage corrosion.

In contrast with towers, a significant number of poles have been replaced over time due to poor condition or when lines have been upgraded. Unfortunately, the installation date of each pole structure was not formally recorded until the introduction of our asset database in the early 1990s. Consequently, the exact age of many poles is unknown. However, pole material type, and line commissioning date can be used to estimate age for those poles that have not been replaced, by knowing the periods that the material type was used. Figure 38: shows the age profile for both our tower and pole population.

Figure 38: Age profile of towers and poles

Figure 39 shows the age profile for our insulator population.

Figure 39: Age profile of insulator population
Asset Health

Towers

The life expectancy of our towers varies significantly, depending on the corrosiveness of the local environment in which each tower is situated. We have allocated each tower structure to one of six corrosion zones.\(^\text{12}\) Our primary method for managing tower condition is through our painting and tower refurbishment programmes.

An increasing number of insulator attachment points on towers are showing significant signs of corrosion and wear. Designs with large flat plates at the ends of crossarms have proven particularly susceptible to corrosion. The plates shield the attachment from rain washing, creating a build-up of corrosive salts, leading to accelerated corrosion rates. Experience has shown that if the attachment point fasteners become too corroded then the entire crossarm must be lowered to the ground to remove the fasteners. This is expensive and requires longer outages than would have been required if the work had been completed earlier. To mitigate this, we have an ongoing programme of work replacing deteriorated insulator attachment points.

Figure 40 illustrates the asset health of our steel towers.

![Figure 40: Tower Asset Health](image)

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\(^{12}\) Corrosion Zones are outlined in TL Lines summary section above
Poles

Most of our poles are in good condition, as shown in Figure 40. Where pole degradation occurs, it is mainly caused by rot and loss of cross-sectional area on wooden poles, and by spalling on older concrete poles. Some of our older-type concrete poles also now have cracks, and rusting reinforcement.

Most of our poor condition poles are old hardwood poles that rot just below ground level, reducing section area to a point where the structure cannot reliably carry design loads. Significant above ground defects can occur such as splitting or pole top rot. Figure 41 illustrates the asset health of our poles.

Figure 41: Pole Asset health

Insulators

Glass and porcelain insulators invariably reach the end of their lives due to corrosion of the steel cap and pin, while composite insulators generally reach end of life when they lose their hydrophobicity or when the steel end fittings begin to corrode. We monitor this corrosion by regular visual condition assessments. Our asset health model for insulators utilises the condition scores and expected degradation based on corrosion zone. Figure 42 illustrates the asset health of our insulators.

Figure 42: Insulator Asset Health
Asset Criticality

Criticality for structures and insulators is based on our standard criticality framework as shown in Figure 43 (Towers), Figure 44 (Poles), and Figure 45 (Insulators).

![Figure 43: Tower Criticality](image)

![Figure 44: Pole Criticality](image)
Figure 45: Insulator Criticality

**Asset Performance**

Structural failures of towers and poles are very serious, but fortunately very rare. Where they do occur, they are usually associated with extreme weather events, ground subsidence or third-party actions.

**Asset Life Cycle Stages**

Our asset management approach for towers is to maintain them in perpetuity, at least life cycle cost. The strategy is to paint towers prior to significant rusting and to re-paint prior to paint failure. This approach can extend the life of towers indefinitely and has a lower life cycle cost than full tower replacement. The extent of preparation work and associated cost to paint a tower increases as the tower condition deteriorates.

Our asset management approach for poles, componentry and insulators is replacement based on condition.

**Strategic Planning**

The following strategic objectives have been set for structures and insulators:

**Safety**

- Zero injuries caused by tower or pole failures.
- No falls from heights involving towers or poles.
- Zero injuries requiring medical treatment for workers who climb or work on towers and poles.
- Prevent unauthorised tower climbing.
- The risk of injury to members of the public from step and touch potential is as low as reasonably practical.

**Service Performance**

- Pole or crossarm failures of one or less each year, excluding those events that exceed the current design loads. Currently this is 1.4 per year over last 20 years.
- Tower failure rate of one failure per annum or less. No major failure of assets with high or very high criticality
- Cost Performance
- Design, construct, and maintain towers and poles to minimise life cycle costs, while meeting required levels of performance.
Achieve improved efficiency through extension of the planning horizon
Minimise cost of capital projects through long-term third-party resource planning
Minimise cost of works by packaging work into blocks of consecutive spans wherever possible.

Customers and Stakeholders
- No significant environmental damage due to tower and pole works such as tower painting
- No damage to third party property due to tower, pole or component failures.
- Minimise noise pollution from cracking insulators in sensitive areas
- Minimise stakeholder disruption by packaging work into blocks of consecutive spans wherever possible
- Maintain effective relationships with stakeholders affected by insulator works

Tactical Planning
The drivers for capital investment in our structures and insulators include:
- New line developments or uprating existing circuits, driven by demand
- Tower painting, driven by condition
- Structure replacement, driven by condition and failure risk.

Towers
As the tower population ages, the volume of tower painting required is forecast to increase to keep pace with the degradation of galvanised surfaces, and to avoid the build-up of a large backlog of work. A significant proportion of the annual tower painting work is also required for re-coating towers previously painted. Subsequently the total number of towers protected by paint does not increase linearly with the painting effort over time. Accordingly, our approach to tower painting accounts for the risk associated with the long-term deterioration in the overall asset health of our towers while ensuring any work backlog is managed. Painting work is prioritised accounting for condition, asset criticality, and degradation rates.

Poles
We replace poor condition poles with pre-stressed concrete poles wherever practical as they are essentially maintenance-free and last longer than steel or hardwood poles. In inaccessible locations where transporting a concrete pole is impractical, a hardwood or steel pole may be used. When replacing poles, we also replace crossarms, insulators, conductor clamps, dampers, and other hardware when they are over half way through their expected life.
In addition to condition based replacements, we replace structures within 12 months when they are identified as not being able to withstand everyday or design loads.

Condition Assessment
Regular condition assessment of our structures and insulators is undertaken, as set out in the portfolio summary section above.

Decision Framework
The work programme for structures and insulators are determined by applying the four steps of the Decision Framework.

Need identification
Asset health, condition, and criticality are used to determine the need and associated need dates. System growth projects also drive the need for investment. Where a system growth project impacts on the need for a replacement, the timing and cost will be driven by the specific project.

Options Assessment
For Towers, we consider tower painting and steel and bolt maintenance as the two primary options for maintaining towers. We consider the overall tower condition, the corrosion zone and plans for the line or specific towers in determining which course of action is most appropriate.
Options for Poles include repairs where we believe we can defer replacement by several years or replacement if the structure cannot be repaired. Most poles cannot be repaired and require replacement; however, where feasible we consider repairs to extend life. In instances where only the cross arm is in poor condition we undertake cross arm replacements only rather than full pole replacements.

Prioritise solutions
Solutions are prioritised based on need date.

Develop a Programme Management Plan
For the tower painting program, we take the prioritised needs and aggregate the work into projects, to reduce mobilisation costs and satisfy landowner requirements of ‘one entry only.’ The effects of regional constraints such as resource availability, seasonal weather variation and accessibility are also accounted for. The result is that some towers in the work packages are refurbished slightly earlier, and some slightly later than forecast. Overall this results in project efficiencies with minimal increases in risk.

Poles and Insulator replacements are aligned based on the condition of the assets; however, there is generally less efficiencies to be made in grouping pole or insulator replacements and thus projects are primarily based on the condition of the assets.

Cost estimation
Tower Painting is volumetric work as it is repetitive with similar scope. We have defined building block unit rates for each tower type informed by actual cost of completed, equivalent historic projects.

Poles, insulators, steel and bolt, and hardware replacements are also considered volumetric with building block rates used to build project budgets.

Contingency planning
We maintain contingency response resources including sufficient field staff and emergency spares to enable rapid restoration following a failure. The spares are condition-monitored, maintained, and are ready for immediate installation and service.

Programming and scheduling
Volumetric work is undertaken under the TL Tower, TL Pole and TL Insulator Programmes. The works are integrated into a wider programme schedule that accounts for other works at the same locations and/or using common resources. Specifically, insulator replacement, pole replacements, attachment point, and crossarm replacements are aligned and packaged within annual delivery projects.

Steel and bolt replacement work under the TL Tower programme is aligned where practical and possible with other works at the same locations and/or using common resources, or performed under the Tower Painting programme (where this aligns).

Painting utilises specialist resources and work is delivered through a mixture of selective source and open tender work to help ensure we maintain and develop suitable resources and competencies whilst maintaining a competitive pressure on prices.

Pole replacements and Insulator replacements are delivered through the Yours to Lose contract and is split into regional projects. These works form part of the wider Yours to Lose programme that accounts for other works in the regions using common resources.

Project Delivery
The five aspects of project delivery are design, procurement, programme and project delivery, commissioning, and decommissioning and disposal.

Design
Painting works are not subject to design requirements. Poles, insulators and other components utilised for replacements are done in accordance with our standardised designs or, where the circumstances require, specific design work is undertaken. For example, we use glass discs for all new insulator installations except in highly corrosive environments or where audible noise is an issue. Where audible noise is an issue, we will install composite insulators.
Procurement
We apply a quality systems approach in the procurement process including careful selection of vendors, procuring from the minimum number of vendors, specification of quality requirements in the design and manufacturing process, and performance requirements for our environmental conditions such as seismic strength and corrosion protection.

Programme and Project Delivery
Our Programme and Project delivery is undertaken in accordance with our programme management framework. As a volumetric programme the delivery timeframes for painting is typically 12-24 months with the scoping and preparation work occurring in the year preceding the work on site.

Painting utilises specialist resources and work is delivered through a mixture of selective source and open tender work to help ensure we maintain and develop suitable resources and competencies whilst maintaining a competitive pressure on prices.

A challenge for the painting programme is procuring enough resource to paint our towers. The painting resource has grown over the past few years which has seen overall improvements in delivery, safety, and cost. With this increasing resource, we are now forecasting to catch up on the back log of overdue towers during RCP 3.

Pole and Insulator replacements are also planned on a 12-24 month horizon with the detailed design and planning occurring in the year preceding the work delivery where possible. At times due to poor condition some aspects of this process are accelerated to ensure components are replaced within suitable timeframes. Pole replacements and Insulator replacements are delivered through the Yours to Lose contract and is split into regional projects. These works form part of the wider Yours to Lose programme that accounts for other works in the regions using common resources.

Commissioning
Our commissioning plan outlines commissioning planning, hand over, operational, and maintenance processes.

Once all works are complete, our project close-out activities include final capitalisation of the project within our financial systems, provide feedback about actual costs to assist with future cost estimation, updating asset management information systems, archiving of the relevant documentation, and the review of ‘lessons learned’ including a review of health and safety performance.

Decommissioning and Disposal
Very rarely do we decommission a tower or pole site. However, where it does occur, consistent with our environmental objectives, our decommissioned sites are reinstated to integrate with their surrounding environment, and in some cases, to their original natural forms to allow the land to recover. In accordance with any Resource Consent conditions, we will monitor rehabilitated areas for a period after re-instatement.

Service Delivery
We undertake preventative, corrective, predictive, and proactive maintenance activities as specified in our maintenance standards. Minor maintenance and refurbishment works occur according to the relevant service specifications.

Operate the Grid
The outage requirements for structures and insulators is dependent on the specific task involved. Painting is carried out live except for painting within the minimum approach distance areas where outages are needed.
Forecast Expenditure

Our forecast expenditure for Structures and Insulators is separated into two components. The first covers structures and insulators generally, the second is for tower painting.

Forecast Expenditure – Structures and Insulators

Capital Expenditure

RCP 2, 2018 to 2020

The Structures and Insulators replacement programme is constantly reviewed accounting for new condition assessment data and refinements to health modelling. Because of this the forecast for Insulator replacement in RCP 2 has slightly reduced while Pole replacement is largely unchanged during this period.

RCP 3, 2020 to 2025

We have revised the RCP 3 forecast based on a review undertaken during 2016, and now expect to spend $61.0 million during RCP 3 on structures and insulators. This is an increase from the original RCP 2 budgets and is driven by the degradation and aging of the network and on-going replacement required.

RCP 4, 2025 to 2030

There is further growth in the structures and insulator program in RCP 4 to $73.5 million. This growth over RCP 3 and RCP 4 shows that large portions of the network are reaching end of life having been installed at similar points in time.

Operating Expenditure

Tower steel replacement is undertaken each year to replace steel members identified at replacement criteria. This work supplements the tower painting programme and helps ensure that the structural integrity of the towers is maintained. This work primarily focuses on the replacement of smaller steel members and tower bolts which tend to corrode quicker than the larger steel members on the tower.

Replacement of hardware and fittings is sometimes undertaken where there are known design issues or significant deterioration of these components only such that only a small component within the insulator set needs replacement.

Key risks and uncertainties

As noted in the Tower painting expenditure section, work is underway to investigate how to best manage the ends of crossarms on towers which are not painted. Once this is completed it may be possible that there is an increase in capital or operating expenditure to implement the chosen solution. This could see a combination of crossarm replacement and additional steel and bolt replacement being chosen as the preferred option in some instances.

Summary, 2018 to 2030

<table>
<thead>
<tr>
<th></th>
<th>RCP 2</th>
<th>RCP 3</th>
<th>RCP 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>10.7</td>
<td>10.3</td>
<td>14.7</td>
</tr>
<tr>
<td>2017</td>
<td>10.7</td>
<td>12.4</td>
<td>15.1</td>
</tr>
<tr>
<td>2018</td>
<td>13.5</td>
<td>12.5</td>
<td>15.4</td>
</tr>
<tr>
<td>2019</td>
<td>10.4</td>
<td>12.7</td>
<td>14.6</td>
</tr>
<tr>
<td>2020</td>
<td>9.8</td>
<td>13.1</td>
<td>14.6</td>
</tr>
<tr>
<td>2021</td>
<td>10.3</td>
<td>14.7</td>
<td>14.5</td>
</tr>
<tr>
<td>2022</td>
<td>12.4</td>
<td>15.1</td>
<td></td>
</tr>
<tr>
<td>2023</td>
<td>12.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2024</td>
<td>12.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2025</td>
<td>13.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2026</td>
<td>14.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2027</td>
<td>15.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2028</td>
<td>14.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2029</td>
<td>14.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2030</td>
<td>14.5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 54: Forecast capital expenditure

Long-term forecast

The long-term forecast for structures and insulators is one of moderate growth as these components continue to age and degrade. Our modelling is presently showing an increase in work volumes over the next 10-20 years as an increasing amount of the network reaches the required intervention point.
Forecast Expenditure - Tower Painting

Capital Expenditure

RCP 2, 2018 to 2020
The Tower Painting strategy has not changed since the 2016 AMP and the number of Towers forecast to be painted remains largely the same as presented in the 2016 AMP. There has been some movement in building block rates and accordingly the total Capex forecast has increased by $7 million compared to the 2016 AMP.

RCP 3, 2020 to 2025
During RCP 3 we are forecasting steady growth in the Tower Painting programme as more towers reach the optimal intervention point for painting. The increase of $33 million compared to the 2016 AMP is a result of a detailed revision of the Asset Health model and applying the Decision Framework to this portfolio which identified a steady increase in work is needed to manage the degrading condition of towers on the network.

RCP 4, 2025 to 2030
The steady growth of the Tower Painting programme is forecast to continue into RCP 4 with approximately 750 Towers per year forecast to be painted during this period. In RCP 4 the proportion of recoat towers starts to increase as towers painted during the beginning of the tower painting programme start to become due for recoat painting. This growth in the Tower Painting program is presently forecast to plateau at about 1,000 Towers per year in RCP6.

Operating Expenditure
There is no operating expenditure allocated to the TL Paint portfolio.

Key risks and uncertainties
Due to restrictions in working near live conductors some portions of the towers are unable to be painted if outages are not available. These areas of the tower are generally the ends of the crossarm. Work is commencing to identify the best way to address this issue going forward.

Summary, 2018 to 2030

<table>
<thead>
<tr>
<th></th>
<th>RCP 2</th>
<th>RCP 3</th>
<th>RCP 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paint</td>
<td>32.8</td>
<td>38.0</td>
<td>38.8</td>
</tr>
</tbody>
</table>

Table 55: Forecast expenditure

Long-term forecast
The long-term forecast for tower painting shows a steady growth in towers to be painted until the program plateaus at approximately 1,000 towers per year by about RCP6. This is presently forecast to cost approximately $350 million per RCP period.
ASSET CLASS PLAN – TL CONDUCTORS AND HARDWARE

This asset class plan describes our life cycle management approach for conductors and hardware. It covers the following asset types:
- Overhead conductor (including overhead HVDC, and earthwires)
- Conductor hardware (joints, spacers and dampers).

Conductors and their associated hardware are core components of our transmission network that enable electricity to flow from generators to consumers. The performance of conductors is critical to ensuring public safety and maintaining reliability of supply.

Our asset management approach for conductors seeks to achieve a high level of reliability, to mitigate safety hazards, and to achieve least life cycle cost. Table 56 provides a breakdown of our conductor length by voltage level.

<table>
<thead>
<tr>
<th>Voltage Level</th>
<th>≤ 66 kV</th>
<th>110 kV</th>
<th>220 kV</th>
<th>HVDC 350 kV</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Route km</td>
<td>350</td>
<td>4,275</td>
<td>6,174</td>
<td>595</td>
<td>11,393</td>
</tr>
<tr>
<td>Circuit km</td>
<td>633</td>
<td>6,088</td>
<td>9,554</td>
<td>1,167</td>
<td>17,442</td>
</tr>
<tr>
<td>Earthwire km</td>
<td>13</td>
<td>542</td>
<td>2,545</td>
<td>336</td>
<td>3,436</td>
</tr>
</tbody>
</table>

Table 56: Conductor length by voltage level

There are various hardware components associated with conductors. Table 57 provides a breakdown of the estimated hardware population by type.

<table>
<thead>
<tr>
<th>Component</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mid-span joints</td>
<td>37,667</td>
</tr>
<tr>
<td>Dead end and other joints</td>
<td>38,493</td>
</tr>
<tr>
<td>Spacers14</td>
<td>243,941</td>
</tr>
<tr>
<td>Dampers</td>
<td>317,077</td>
</tr>
</tbody>
</table>

Table 57: Hardware population

Asset Characteristics

There are a number of characteristics that impact on the life and condition of conductors and hardware. These primarily consist of the type of conductor, the corrosiveness of the environment in which they are located, the age, and the quality of the greasing within the conductors. The bow-tie analysis indicates that the predominant failure causes for conductors and hardware is joint failure and insulator deterioration. As such, the two key preventive controls are design, and undertaking inspections and maintenance. The design of attachment points for earth wires now provides for a double shackle arrangement, so that failure of an undetected deteriorated shackle will not result in an earth wire drop.

The changes in the type of conductors deployed over time mean there are a range of conductor types currently in service. Copper conductors were primarily used before the 1950s. The development of the 220 kV network from the mid-1950s utilised Aluminium Conductor Steel Reinforced (ACSR) conductors. Since 2010, All Aluminium Alloy Conductor (AAAC) conductors are used for new transmission lines and for most major conductor replacements, except where corridor width and ground clearances require the use of ACSR conductors.

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13 Total includes 600 km of Optical Ground Wire
14 Spacers maintain the distance between twin and triple conductor configurations.
Age Profile
Figure 46: shows the age profile of our conductors.

![Figure 46: Conductor age profile](image)

Generally new conductor hardware was installed at the same time as conductors are installed or replaced. However, many components also have shorter lifespan than conductors themselves, and as such the age profile of hardware is shorter.

Asset Health
Factors affecting the degradation of conductors are age, the type of conductor, the corrosiveness of the environment, and the quality of the greasing undertaken at the time of manufacture. Common issues that affect conductors as they age are corrosion, grease degradation, fatigue, annealing and fretting. As joints age, their resistance tends to rise. In extreme cases, this can lead to thermal runaway and physical joint failure. Corrosion is the main issue that affects spacers and dampers as they age.

Grease extends the life expectancy of ACSR and AAAC conductors. Conductors purchased prior to the mid-2000s had poor grease application with many conductors having patches of little or no grease. We refer to these as ‘grease holidays.’ We now ensure the conductor manufacturing process delivers full grease coverage to avoid untimely early replacement due to grease holiday defects.

Conductors are allocated the same corrosion zone as the steel towers on which they are supported. Table 58 describes the life expectancy of conductors by type and by corrosion zone.

<table>
<thead>
<tr>
<th>Type</th>
<th>Benign</th>
<th>Low</th>
<th>Moderate</th>
<th>Severe</th>
<th>Very Severe</th>
<th>Extreme</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACSR-GZ Greased*</td>
<td>157</td>
<td>126</td>
<td>99</td>
<td>73</td>
<td>54</td>
<td>38</td>
</tr>
<tr>
<td>ACSR-GZ Grease Holiday</td>
<td>121</td>
<td>96</td>
<td>74</td>
<td>53</td>
<td>38</td>
<td>26</td>
</tr>
<tr>
<td>ACSR-GZ Ungreased</td>
<td>114</td>
<td>90</td>
<td>70</td>
<td>50</td>
<td>35</td>
<td>24</td>
</tr>
<tr>
<td>ACSR-AC Greased*</td>
<td>180</td>
<td>143</td>
<td>113</td>
<td>91</td>
<td>70</td>
<td>47</td>
</tr>
<tr>
<td>ACSR-AC Grease Holiday</td>
<td>126</td>
<td>113</td>
<td>88</td>
<td>71</td>
<td>54</td>
<td>35</td>
</tr>
<tr>
<td>AAAC Greased</td>
<td>160</td>
<td>139</td>
<td>120</td>
<td>103</td>
<td>87</td>
<td>70</td>
</tr>
<tr>
<td>Copper</td>
<td>117</td>
<td>104</td>
<td>90</td>
<td>77</td>
<td>65</td>
<td>54</td>
</tr>
<tr>
<td>SC/GZ</td>
<td>80</td>
<td>63</td>
<td>49</td>
<td>35</td>
<td>25</td>
<td>17</td>
</tr>
<tr>
<td>SC/AC &amp; SC/CC</td>
<td>96</td>
<td>75</td>
<td>59</td>
<td>48</td>
<td>36</td>
<td>23</td>
</tr>
</tbody>
</table>

Table 58: Conductor Life Expectancy by Type and Corrosion Zone
We use a degradation model to predict end of life for each span of conductor. The model initially uses the expected life for each conductor type in each corrosion zone and then the results from condition assessment are reviewed and incorporated into the model so that it represents the best estimate of conductor asset health. We are continuing to develop and refine the degradation model to assess the asset health of our conductors to incorporate the complex condition assessment data. We currently have this complex condition information on 3% of the conductor circuit spans.

Figure 47 summarises the asset health of our conductors.

Figure 47: Conductor Asset Health

We do not have asset health models for conductor hardware. Replacement planning is based on the condition assessment information collected and the replacement criteria defined within the condition assessment specification and asset class strategy.

Asset Criticality

Criticality for conductors and associated hardware is based on our criticality framework. The criticality of our conductors and hardware is shown in Figure 48.

Figure 48: Conductor Criticality
Asset Performance
The majority of conductor drops occur during severe weather events such as high winds, snow build-up or in rare instances when hit by lightning. Loss of tensile strength is the most common failure mode in ACSR, although if the aluminium is severely deteriorated the final failure mode occurs when the steel core attempts to carry the current.

The physical reliability of our hard-drawn copper conductors is poor by comparison with ACSR and other modern conductors. The relatively small copper conductor is more likely to fail under snow load, when hit by lightning or during other faults. The ratio of copper to ACSR related failures (excluding jointing failures) exceeds 10 to 1. Copper conductors are less than 10% of the current total conductor population.

Four joint failures have occurred since 2001. In almost every case the cause was attributed to poor workmanship at the time of installation. The most significant event occurred in 2009 when a mid-span joint failed in urban Auckland, dropping a conductor onto houses below. A significant programme of joint testing and refurbishment was instigated following this and continues to test joints and monitor those joints in high criticality spans. Joints are then planned for refurbishment from this testing.

Asset Life Cycle Stages
Our asset management approach to conductors and hardware is to maintain, build new, and uprate existing conductors to ensure that the required service performance is achieved whilst mitigating safety hazards and minimising life cycle costs.

Strategic Planning
The following strategic objectives have been set for conductors:

Safety
- Zero conductor drops over spans with very high and high safety criticality
- Reduce the overall number of conductor drops (due to conductor breakage, joint failure, or hardware failure) to below 1.5 each year. Historical average is 2.8 each year.

Service Performance
- Average annual unplanned outage rate (expressed in events for each 100 km each year) less than 0.5 for 110 kV lines and 0.15 for 220 kV lines.

Cost Performance
- Design, construct, and maintain conductor systems to minimise life cycle costs, while meeting required levels of performance.
- Achieve improved efficiency through extension of the planning horizon.
- Minimise cost of capital projects through long-term third-party resource planning.
- Minimise cost of works by packaging work into efficient blocks of consecutive spans wherever possible.

Customers and Stakeholders
- No significant environmental damage (such as from bush fires) due to component failure.
- No damage to third party property due to conductor component failures.
- Minimise stakeholder disruption by packaging work into blocks of consecutive spans wherever possible.
- Maintain effective relationship with stakeholders affected by conductor works.

Development Initiatives
We will continue to monitor new and emerging technologies, including variable and dynamic line rating and high temperature conductor. We also continue to monitor new condition assessment techniques such as UAVs and other non-destructive testing to better understand the condition of the conductor and support replacement planning.
Tactical Planning

Our tactical planning for conductors and conductor hardware is targeted at condition-based replacements, prioritised based on asset health models, criticality, and risk.

Our risk management techniques aim to optimise the timing of large-scale conductor replacements by addressing localised deterioration with repairs and minor replacements. This enables deferral of the major investment, but leads to an increasing proportion of the line reaching replacement criteria before major replacement of the conductor is initiated. Where feasible, we integrate conductor replacements with identified and approved grid development upgrades.

As part of a reconductoring investigation, special assessments are required to identify if the conductor life can be extended by replacement of short sections of line, or if a larger project is required to replace the entire circuit.

Once the decision for a complete conductor replacement is made a detailed design process is initiated, including review of the appropriate conductor type and capacity. A robust cost benefit analysis is used to select the preferred re-conductoring option to balance project cost with lifetime performance and cost.

Unless otherwise required to mitigate a high priority risk, hardware replacements are bundled by location to minimise the costs. We also undertake a programme of work to mitigate known under-clearance spans. This work is prioritised using a risk based approach.

Condition assessments

We carry out regular condition assessments on our conductors and conductor hardware as part of the routine condition assessment cycles. Due to the limitations in observing the conductor from the structure, and the nature of the deterioration we experience in ACSR conductors we also undertake Cormon testing which utilises eddy current technology to assess the remaining galvanising or protective cladding on the steel core wire. Due to the cost and complexity of this testing we presently undertake this on a sample basis only and prioritise the inspections based on the expected condition of the conductor. Close aerial inspections, looking for signs of corrosion such as white powder (corrosion product) or conductor bulging are used to complement the Cormon testing and structure-based visual assessments to ensure we identify areas requiring repairs or further monitoring.

When nearing end of life, the assessment frequency and sample size may be increased and where the circumstances warrant, samples are taken for analysis to help confirm when a conductor section will be at end of life.

Decision Framework

Our work programme for conductors and hardware is determined by applying the four steps of our Decision Framework.

Need identification

Needs and associated need dates are identified based on condition and criticality.

Options assessment

The only option considered for conductor hardware is replacement. The options considered for conductors is on-going repairs and maintenance or replacement. Extensive investigation is undertaken into the conductor type, the impact on towers and location, including any appropriate undergrounding options. We use economic analysis to determine the most cost-effective approach.

Prioritise solutions

Solutions are prioritised based on need date.

Develop Programme Management Plan

We endeavour to coordinate work by location to minimise cost, disruption, and outages.

Cost estimation

Experience has shown that the final cost to re-conductor transmission lines is subject to large variation depending on the context, characteristics, and location of each line. As such we apply a detailed process to determine a customised estimate approach for major reconductoring projects. For all other projects (small scale conductor replacement, earthwire, hardware renewal and complex maintenance projects) volumetric building block based estimates are used.
Contingency planning
We maintain contingency response resources including sufficient field staff and emergency spares to enable rapid restoration following a failure. The spares are condition-monitored, maintained, and are ready for immediate installation and service.

Programming and Scheduling
Large scale conductor replacement is specific and as such they are planned individually and where applicable co-ordinated with grid upgrade developments. For small works and conductor hardware replacements, as a volumetric programme, the works are integrated into a wider programme schedule that accounts for other works at the same locations using common resources.

Project Delivery
The five aspects of project delivery are design, procurement, programme and project delivery, commissioning and decommissioning and disposal.

Design
Our design standards specify key activities to be considered during the design process. Factors considered in this process include our safety, service performance, and cost performance objectives; our legal obligations; existing and future network requirements; conductor losses; existing land use rights; easement requirements; visual impact; structure and foundation capacity; structure height requirements; and corrosiveness of the environment.
We also have conductor selection guidelines in place. Where possible we install AAAC conductors which we expect to last longer than ACSR conductors. We have a list of pre-approved conductors from which all new conductors are selected. The same applies for conductor hardware.

Procurement
Our procurement programme ensures the quality control of conductor grease application in the conductor manufacturing process. Conductor projects are put out to tender.

Programme and Project Delivery
Our Programme and Project delivery is undertaken in accordance with our programme management framework. The delivery timeframes for reconductoring are generally quite long with substantial investigation and design required prior to the physical work on site. The timeframes can vary depending on the complexity of the scope but would be expected to take approximately 4-5 years from need identification through to works completion.
Other works within the Conductor Portfolio can generally be delivered at shorter notice and timeframes of 12-24 months would be expected to allow suitable design and planning to precede the delivery works.

Commissioning
Our commissioning plan outlines commissioning planning, testing, livening, hand over, operational, and maintenance processes.
Once all works are complete, our project close-out activities include final capitalisation of the project within our financial systems, provide feedback about actual costs to assist with future cost estimation, updating asset management information systems, archiving of the relevant documentation, and the review of ‘lessons learned’ including a review of health and safety performance.

Decommissioning and Disposal
We follow an appropriate decommissioning process. Requirements for recycling and disposal work include safe work and site management, and environmental management processes. Conductors that are not recycled are sold as scrap.
Service Delivery
We undertake preventative, corrective, predictive, and proactive maintenance activities as specified in our maintenance standards. Minor maintenance and refurbishment works occur according to the relevant service specifications.

Operate the Grid
Where practical conductor hardware replacement is undertaken under live line conditions. However, generally works require significant co-ordination of outages. This is carried out through the normal outage management process.

Forecast Expenditure
Our forecast expenditure for the TL Conductor Portfolio is described below. This includes both Base and Major Capital projects.

Capital Expenditure
RCP 2, 2018 to 2020
There is no material change in the base capital expenditure planned within the TL Conductor portfolio compared to the 2016 AMP. Work within this Portfolio includes conductor and earthwire replacement, Aerial Laser surveys and under clearance rectifications. There has been a reduction in the commissioning of some of the major capital investments as several have been deferred into RCP 3 as further refinement of scope is completed.

RCP 3, 2020 to 2025
RCP 3 represents the start of a large increase in the volume of reconductoring needed on the network due to condition. This is planned to be managed through a combination of base and major capital projects depending on the size and complexity. In total, the present forecast is approximately $380 million in RCP 3, made up of $110 million of base and $272 million of major capital expenditure. The other expenditure on items such as Aerial Laser Surveys and under clearance rectifications are reasonably consistent from the RCP 2 forecast with no significant change in this work volume.

RCP 4, 2025 to 2030
The expenditure in RCP 4 is uncertain and the present forecast will be further refined over the coming years as we collect more condition assessment information to help us time the replacement of conductors and earthwires on the network. The volume of work in RCP 4 is expected to be relatively consistent with RCP 3 as more conductors reaches end of life and requires replacement.

Operating Expenditure
There is a significant program of conductor assessment, joint testing and on-going repairs that supports the capital replacement program. This is presently forecast at approximately $15 million in RCP 2 but will grow to $25 million in RCP 3 to help support the increase in conductor replacement and ensure the again network has sufficient condition assessment information.

Key risks and uncertainties
Due to the cost and complexity we do not have CA data for all conductor spans on the network. Over RCP 2 and RCP 3 we intend to increase this programme of work to help ensure we have suitable data to support replacement works and support better long-term planning. As this data becomes available we may change the funding to repair and replace conductors within each future RCP period.
Summary, 2018 to 2030

<table>
<thead>
<tr>
<th>Conductors and Hardware</th>
<th>RCP 2</th>
<th>RCP 3</th>
<th>RCP 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>8.4</td>
<td>2.9</td>
<td>7.6</td>
</tr>
<tr>
<td>2017</td>
<td>6.3</td>
<td>21.5</td>
<td>6.3</td>
</tr>
<tr>
<td>2018</td>
<td>10.7</td>
<td>40.0</td>
<td>10.7</td>
</tr>
<tr>
<td>2019</td>
<td>21.5</td>
<td>8.1</td>
<td>21.5</td>
</tr>
<tr>
<td>2020</td>
<td>40.0</td>
<td>17.5</td>
<td>40.0</td>
</tr>
<tr>
<td>2021</td>
<td>16.1</td>
<td>17.5</td>
<td>16.1</td>
</tr>
<tr>
<td>2022</td>
<td>8.1</td>
<td>17.5</td>
<td>8.1</td>
</tr>
<tr>
<td>2023</td>
<td>23.8</td>
<td>17.5</td>
<td>23.8</td>
</tr>
<tr>
<td>2024</td>
<td>17.5</td>
<td>17.5</td>
<td>17.5</td>
</tr>
<tr>
<td>2025</td>
<td>17.5</td>
<td>17.5</td>
<td>17.5</td>
</tr>
<tr>
<td>2026</td>
<td>17.5</td>
<td>17.5</td>
<td>17.5</td>
</tr>
<tr>
<td>2027</td>
<td>17.5</td>
<td>17.5</td>
<td>17.5</td>
</tr>
<tr>
<td>2028</td>
<td>17.5</td>
<td>17.5</td>
<td>17.5</td>
</tr>
<tr>
<td>2029</td>
<td>17.5</td>
<td>17.5</td>
<td>17.5</td>
</tr>
<tr>
<td>2030</td>
<td>17.5</td>
<td>17.5</td>
<td>17.5</td>
</tr>
</tbody>
</table>

Table 59: Conductors and hardware forecast capital replacement and operational project expenditure

Long-term forecast

The present long-term forecast for conductor replacement shows a further increase out beyond RCP 4 with work volumes expected to double over RCP 5 and RCP 6. As more condition information becomes available we will continue to refine these forecasts.
ASSET CLASS PLAN – TL GRILLAGES

This asset class plan describes our life cycle management approach for grillage assets. It covers the following asset types:

- Steel grillage foundations
- Concrete over steel grillage foundations

The performance of grillage foundations is fundamental to ensuring the structural integrity, reliability, and public safety of the overhead structures and conductors they support. The type of foundations we use vary depending on design loads, soil type, and the preferred construction practices of the time in which they were installed.

Steel grillage foundations were widely used until the late 1960s and support approximately one half of our steel lattice towers. However, steel grillages are susceptible to corrosion-driven degradation. Various methods have been used to refurbish our steel grillages, such as re-galvanising and cathodic protection. Since the mid-2000s, our preferred refurbishment method for steel grillages is to encase them in concrete. We have a long-term refurbishment programme in place to encase our steel grillage foundations in concrete.

Table 60 details our grillage population by type.

<table>
<thead>
<tr>
<th>Foundation type</th>
<th>Description</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel grillage</td>
<td>Grillages that have not yet been refurbished</td>
<td>10,612</td>
</tr>
<tr>
<td>Concrete over steel grillage</td>
<td>Refurbished grillage foundations (by encasement in concrete)</td>
<td>2,907</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>13,519</strong></td>
</tr>
</tbody>
</table>

Table 60: Grillage Population

Asset Characteristics

Concrete over grillage designs have many advantages over replacing buried steel, including lower cost, less risk to the structure during installation, increased performance, longer life expectancy and reduced requirements for future condition assessment. Most significantly, they bring the steel interface above ground, simplifying maintenance and condition assessment requirements, therefore reducing future risk.

Age Profile

Grillages are treated as new from refurbishment date. Figure 49 shows the age profile of our grillages by type.
Asset Health

Many towers with buried steel grillage foundations are now showing corrosion on tower legs and bracing below the ground-line. Having rusting foundations is a major risk, compounded by the fact that as below ground assets, they cannot be readily assessed for condition. We are investigating whether tower steel degradation curves are applicable for forecasting condition at the foundation level. Timely refurbishment is required to avoid them deteriorating to a point where much higher cost tower propping and major steel replacement is required.

The life expectancy of grillages depends on the type, location, environmental conditions, and construction quality. Table 61 shows the average age and life expectancy of our grillages.

<table>
<thead>
<tr>
<th>Foundation Type</th>
<th>Average Age (yrs)</th>
<th>Life Expectancy (yrs)</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel Grillage</td>
<td>57</td>
<td>70</td>
<td>Life expectancy varies from 50 to over 100 years depending on location, environmental conditions, and construction quality.</td>
</tr>
<tr>
<td>Concrete over grillage</td>
<td>3</td>
<td>120</td>
<td>Assumes concrete/steel interface is maintained periodically</td>
</tr>
</tbody>
</table>

Table 61: Grillage average age and life expectancy

Our grillage asset health model incorporates age, location, condition, and reliability of each foundation. The asset health model is used to indicate the intervention timeframe.

The asset health for our grillages is shown in Figure 50.

![Figure 50: Grillage Asset Health](image-url)
Criticality

Criticality for grillages is based on our criticality framework. Figure 50 shows the proportion of grillages in each service performance criticality category.

![Figure 51: Grillages Criticality](image)

**Asset Performance**

Our foundations are designed, monitored, and maintained to withstand severe loading conditions in extreme weather. Complete structural failures of foundations are rare and are usually a result of erosion or flooding.

**Asset Life Cycle Stages**

Our asset management approach is to ensure the integrity and reliability of the structures by maintaining grillages in perpetuity at least life cycle cost. Should the structures they support no longer be required in the future, we will manage these grillages in line with the required remaining life of the line.

**Strategic planning**

The following strategic objectives have been set for grillages:

- **Safety**
  - Zero injuries caused by foundation failures
  - No major failure of foundation assets with high or very high public safety criticality

- **Service Performance**
  - Fewer than 1 major foundation failure every 5 years

- **Cost Performance**
  - Design, construct and maintain foundations to minimise life cycle costs while meeting required levels of performance
  - Improved efficiency through extension of the planning horizon
  - Minimise cost of capital projects through long-term resource planning of Service Providers
  - Minimise cost of works by packaging work into blocks of consecutive structures wherever possible
Customers and Stakeholders

- Compliance with RMA 1991 requirements, such as erosion and sediment control during site works
- Disestablished site foundations should be re-instated to their former natural forms to allow the land to recover
- No damage to third party property due to foundation failures
- Minimise stakeholder disruption by packaging work into blocks of consecutive spans wherever possible
- Maintain effective relationships with stakeholders affected by foundation works

Development Initiatives

We review industry practices and materials employed to ensure modern, cost effective solutions are always being utilised. For example, we now use fibre-reinforced concrete when encasing grillages with concrete. We are also considering using cathodic protection, which may be a suitable method in some situations.

Tactical Planning

Our planning approach for grillages is to refurbish grillages, prioritised based on asset health and criticality. Forecasting is used to predict the intervention timeframe. Concrete over grillage (grillage encasement) is the preferred steel grillage refurbishment option whenever it can be installed in a cost-effective manner. In limited cases, we replace grillages, such as where difficult or costly access to a site makes it impractical to use concrete encasement. The proportion of grillage replacements is less than 5% compared to the number of concrete over grillages.

Condition assessments

Currently, there is no reliable, non-intrusive method to accurately predict the condition of buried steel grillages. The only reliable method is excavation. However, this is expensive, disrupts landowners, and can cause accelerated corrosion. Consequently, condition assessments have been carried out on a sampling basis. Approximately 1,000 tower legs have had their interface condition and steel grillage foundations condition assessed and compared through full excavation. Additionally, we have captured the condition of both the interface and the foundations at the time of concrete over grillage. This helps us refine our understanding of condition below the ground-line. Data from the sampling and the as-found condition during refurbishment has enabled us to form a reliable relationship between the ground-line condition and the overall grillage condition. Accordingly, and given the high cost and landowner disruption, we now use the ground-line interface condition as a proxy for the steel grillage foundation condition.

Decision Framework

The work programme for grillages is determined by applying the four steps of the Decision Framework.

Need identification

Asset health information is used in combination with asset criticality data to determine needs and associated need dates. Additionally, system growth projects can result in the upgrading of existing lines with larger or additional conductors, which may require stronger foundations. The timing and cost of this will be driven by the relevant conductor works.

Options assessment

Concrete over grillage is the preferred steel grillage refurbishment option. Where this is impractical an assessment will be undertaken to ascertain if it is more cost effective to refurbish the grillage by re-galvanising or replace with a new grillage.

Prioritise solutions

Solutions are currently prioritised based on need date and a desire to undertake sequential blocks of work where feasible to minimise disruption and mobilisation costs.

Develop a Programme Management Plan

We take the prioritised needs and aggregate the work into projects, to reduce mobilisation costs and satisfy landowner requirements of ‘one entry only.’ The effects of regional constraints such as resource availability, seasonal weather variation and accessibility are also accounted for. The result is that some grillages in the work packages are refurbished slightly earlier than forecast. Grillage refurbishment work is not currently aligned or bundled with other transmission lines work, because of the specialist nature of the work.
Cost estimation
Grillage refurbishment is categorised as volumetric works for estimation purposes.
As more of the smaller and easier to access sites have been refurbished, we are now completing work on some of the larger and more difficult to access structures. We are constantly reviewing the building block rates to ensure they reflect the cost of undertaking work and possible as the increase in scope associated with these difficult sites can have a significant impact on final costs.

Contingency planning
We maintain contingency response resources including sufficient field staff and emergency spares to enable rapid restoration following a failure. The spares are condition-monitored, maintained, and are ready for immediate installation and service.

Programming and Scheduling
As a volumetric programme, grillage refurbishments are undertaken through the Yours to Lose programme of work. The typical delivery timeframe is 12-24 months with the detailed design and planning occurring in the year prior to delivery.

Project Delivery
The five aspects of project delivery are design, procurement, programme and project management, commissioning, and decommissioning and disposal.

Design
When refurbishing with concrete over grillage we aim to ensure that the refurbished foundation is at least as strong as the structure it supports.
There are significant economies of scale in increasing foundation capacity at the same time as undertaking refurbishment or replacement, as the installation cost is relatively constant. When refurbishing with concrete over grillage the only additional cost is for extra concrete and for replacement slightly larger grillage members are required.

Procurement
We outsource our foundations works to pre-qualified service providers. Detailed specifications are used to ensure that the technical requirements are achieved safely.

Programme and project management
Our programme and project delivery is undertaken in accordance with our Programme Management Framework and applicable Programme Management Plan. Where practical, work is packaged to maximise efficiency, to ensure that any travel time, and landowner disruption is minimised. We also ensure that potential environmental and safety hazards are identified and managed.

Commissioning
Our commissioning plan outlines commissioning planning, testing, livening, hand over, operational, and maintenance processes.
Once all works are complete, we our project close-out activities include final capitalisation of the project within our financial systems, provide feedback about actual costs to assist with future cost estimation, updating asset management information systems, archiving of the relevant documentation, and the review of ‘lessons learned’ including a review of health and safety performance.

Decommissioning and disposal
Consistent with our environmental objectives, our decommissioned foundation sites are reinstated to integrate with their surrounding environment, and in some cases, to their original natural forms to allow the land to recover. In accordance with any Resource Consent conditions, we will monitor rehabilitated areas for a period after re-instatement.
Service Delivery
We undertake preventive, corrective, predictive, and proactive maintenance activities as specified in our maintenance standards. Minor maintenance and refurbishment works occur according to the relevant service specifications.

Operate the Grid
Very few foundation works require outages. When works do require an outage, we coordinate with stakeholders to ensure that any unavoidable system disruptions and outages are notified well in advance.

Forecast Expenditure
Our forecast expenditure for Grillage Refurbishment is described below.

Capital Expenditure
RCP 2, 2018 to 2020
The grillage encasement approach has been through a significant review and update since the 2016 AMP. As a result of the review, 280 fewer grillages are forecast to be completed in RCP 2, with a corresponding reduction in the RCP 2 expenditure forecast by $5.5 million.

RCP 3, 2020 to 2025
During RCP 3 we are forecasting to complete approximately 1250 grillage encasements for a total cost of $43.9 million. This is a reduction of $17.1 million compared to the 2016 AMP.

RCP 4, 2025 to 2030
We are forecasting a similar volume of work in RCP 4 as RCP 3. The present indications are that over the next 10-15 year the grillage encasement program will have a relatively flat profile with no significant increase or decrease in the volume of work being undertaken.

Operating Expenditure
There is no operating expenditure allocated to the TL Grillage portfolio.

Key risks and uncertainties
Further work is underway reviewing our approach to grillage refurbishments to confirm we have the best set of solutions available. Should Cathodic Protection be feasible it may result in a change to the volumes of work being undertaken in RCP 3 and RCP 4.

Summary, 2018 to 2030

<table>
<thead>
<tr>
<th></th>
<th>RCP 2</th>
<th>RCP 3</th>
<th>RCP 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016 Grillages</td>
<td>9.2</td>
<td>9.4</td>
<td>7.5</td>
</tr>
<tr>
<td>2017 Grillages</td>
<td>13.0</td>
<td>8.6</td>
<td>7.5</td>
</tr>
<tr>
<td>2018 Grillages</td>
<td>13.5</td>
<td>8.3</td>
<td>7.5</td>
</tr>
<tr>
<td>2019 Grillages</td>
<td>11.3</td>
<td>8.9</td>
<td>7.5</td>
</tr>
<tr>
<td>2020 Grillages</td>
<td>9.2</td>
<td>8.7</td>
<td>7.5</td>
</tr>
<tr>
<td>2021 Grillages</td>
<td>9.4</td>
<td>7.5</td>
<td>7.5</td>
</tr>
<tr>
<td>2022 Grillages</td>
<td>8.6</td>
<td>7.5</td>
<td>7.5</td>
</tr>
<tr>
<td>2023 Grillages</td>
<td>8.3</td>
<td>7.5</td>
<td>7.5</td>
</tr>
<tr>
<td>2024 Grillages</td>
<td>8.9</td>
<td>7.5</td>
<td>7.5</td>
</tr>
<tr>
<td>2025 Grillages</td>
<td>8.7</td>
<td>7.5</td>
<td>7.5</td>
</tr>
<tr>
<td>2026 Grillages</td>
<td>7.5</td>
<td>7.5</td>
<td>7.5</td>
</tr>
<tr>
<td>2027 Grillages</td>
<td>7.5</td>
<td>7.5</td>
<td>7.5</td>
</tr>
<tr>
<td>2028 Grillages</td>
<td>7.5</td>
<td>7.5</td>
<td>7.5</td>
</tr>
<tr>
<td>2029 Grillages</td>
<td>7.5</td>
<td>7.5</td>
<td>7.5</td>
</tr>
<tr>
<td>2030 Grillages</td>
<td>7.5</td>
<td>7.5</td>
<td>7.5</td>
</tr>
</tbody>
</table>

Table 63: Grillage forecast capital replacement and operational project expenditure

Long-term forecast
The long-term forecast for grillage refurbishment is flat with no significant increase or decrease in work volumes forecast.
ASSET CLASS PLAN – TL FOUNDATIONS AND ACCESS

This asset class plan describes our life cycle management approach for foundations and access civil assets. It covers the following types:

- Concrete plug (bored/dug) used for steel towers
- Foundation connection components
- Access bridges

The performance of foundations is fundamental to ensuring the structural integrity, reliability, and public safety of the overhead structures and conductors they support. The type of foundation utilised varies depending on design loads, soil type, and the preferred construction practices of the time in which they were installed. Anchor bolts, baseplates, and cast-in stubs are the predominant types of connection components used for concrete foundations.

Well maintained access bridges are essential to ensure safe and efficient access to our transmission lines and structures for fault responses, routine patrols, and condition assessments.

Table 63 sets out our foundations and access population.

<table>
<thead>
<tr>
<th>Type</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete plug (bored/dug)</td>
<td>9,467</td>
</tr>
<tr>
<td>Other tower foundations</td>
<td>534</td>
</tr>
<tr>
<td>Access bridges</td>
<td>368</td>
</tr>
</tbody>
</table>

Table 63: Foundations and Access Population

Asset Characteristics

Our foundations are designed, monitored, and maintained to withstand severe loading conditions in extreme weather. Foundations vary in size and type depending on design load, soil type, and the preferred construction method at the time. Most of our foundations are used to support steel lattice towers, but we also have a small number of monopole foundations and special types of foundations used in riverbeds. Structural failures of foundations are rare and are usually a direct result of erosion, land slips, or flooding.

For access bridges, we maintain these to ensure we have access via light four-wheel drive vehicle. In instances where the bridge is insufficiently rated to allow plant machinery to cross for specific project work we replace or strengthen the bridge to the required level when no other means of access is available.

Age Profile

The life expectancy for each type of foundation is shown in Table 64. It is based on observed life and typical degradation rates for each foundation type. However, the actual life achieved will depend on the specific site, weather exposure, and construction quality.
<table>
<thead>
<tr>
<th>Foundation Type</th>
<th>Average Age (yrs)</th>
<th>Life Expectancy (yrs)</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete plug, bored or dug</td>
<td>36</td>
<td>120</td>
<td>Assumes concrete/steel interface is maintained periodically</td>
</tr>
<tr>
<td>Other – Driven pile with concrete pile cap</td>
<td>37</td>
<td>120</td>
<td>Generally, in more aggressive environment than standard concrete plug</td>
</tr>
<tr>
<td>Other – Pad and chimney</td>
<td>28</td>
<td>120</td>
<td>As for concrete plug</td>
</tr>
<tr>
<td>Other - Other foundations</td>
<td>27</td>
<td>50</td>
<td>Timber or steel piles driven into riverbeds</td>
</tr>
</tbody>
</table>

Table 64: Foundation types, average Age, and life expectancy

Asset Health

The inputs used for our asset health model for foundations are condition, age, degradation profile, location, and corrosion zone. The model is evolving, and will continue to develop as we gain a better understanding of the relevant parameters and factors for input. For example, as conditions at the foot of the tower can vary significantly from the remainder of the tower, we are investigating whether tower steel degradation curves are applicable for forecasting condition at the foundation level.

Concrete pile foundations built before 1983 were designed with limited soil testing and with assumptions made about soil properties, leading to undersized bored concrete foundations being installed. A strengthening programme has been implemented, with priority given to sites whose failure would pose significant risk to people, property, or service performance.

The asset health for our foundations is shown in Figure 52.
Foundation connection components are a small part of the overall foundation and tower structure. However, their failure has the potential to result in a structure collapse with significant implications for safety and network performance. Moisture ingress into the grout under the baseplate has subsequently led to corrosion of the anchor bolts and baseplate. Where this is identified through condition assessment the original grout is replaced with water-proof grout, thus reducing corrosion risk. The anchor bolts and baseplate are refurbished where appropriate or replaced if corrosion is significant. Several cast-in stub connections are also starting to corrode at the concrete and steel interface. Refurbishment by blasting and painting has been successful in stopping this corrosion.

**Criticality**

Criticality for foundations is based on our criticality framework. Figure 53 shows the foundations in each criticality category.
Asset Performance
Our foundations are designed, monitored, and maintained to withstand severe loading conditions in extreme weather. Structural failures of foundations are rare and are usually a direct result of erosion, land slips, or flooding.

Asset Life Cycle Stages
Our asset management approach is to ensure the integrity and reliability of the structures by maintaining foundations in perpetuity at least life cycle cost. This includes strengthening critical undersized foundations, replacing poor condition pile foundations, undertaking waterway protection work on defective foundations in riverbeds, and refurbishment of foundation components prior to the onset of significant corrosion.

Access bridges are to be refurbished or replaced as needed to ensure safe and secure access to our assets is provided.

Strategic planning
The following strategic objectives have been set for foundations, including foundation connection components:

Safety
- Zero injuries caused by foundation failures
- No major failure of foundation assets with high or very high public safety criticality

Service Performance
- Fewer than 1 catastrophic foundation failure every 5 years

Cost Performance
- Design, construct and maintain foundations to minimise life cycle costs while meeting required levels of performance
- Improved efficiency through extension of the planning horizon.
- Minimise cost of capital projects through long-term resource planning of Service Providers.
- Minimise cost of works by packaging work into blocks of consecutive structures wherever possible.

Customers and Stakeholders
- Compliance with RMA 1991 requirements, such as erosion and sediment control during site works
- Disestablished site foundations should be re-instated to their former natural forms to allow the land to recover
- No damage to third party property due to foundation failures
- Minimise stakeholder disruption by packaging work into blocks of consecutive spans wherever possible
- Maintain effective relationship with stakeholders affected by foundation works

Development Initiatives
- We review industry practices and materials employed to ensure modern, cost effective solutions are being utilised at all times.

Tactical Planning
Our tactical planning approach for foundations is targeted refurbishment, prioritised based on asset health. Forecasting is used to predict the intervention timeframe. While age and environmental factors assist with predicting future needs, replacement and refurbishment work is planned based on asset health.

Condition assessments
Regular condition assessment of our foundations is undertaken. This involves determining a condition score for each leg and for the foundation connection.

The condition assessment for our access bridges provides an initial assessment of condition, and where defects or deteriorating condition are identified, a structural bridge engineer is engaged to undertake a full structural assessment against the standards set out in the Transit NZ Bridge Manual.
Decision Framework

The work programme for foundations, foundation connection components, and access bridges is determined by applying the four steps of the Decision Framework.

Need identification

Asset health and criticality are used to determine needs and associated need dates. Where the need relates to undersized foundation, the need date is based on a risk assessment. System growth projects also drive the need to invest in foundations. The timing and cost of this will be driven by the relevant conductor works.

Work requirements for access bridges are identified from the structural engineer’s report where the bridge has been identified as unsafe or below requirements for our expected use.

Options assessment

Options considered for foundations are either refurbishment or replacement. When determining the preferred option factors such as foundation loads, constructability and future plans for the line are considered along with an economic assessment to ensure least whole of life cost solutions are chosen.

Options considered for access bridges are either refurbishment or replacement. Factors considered are engineers’ assessment, economic assessment, any other alternative access that might be available, pre-existing agreements with landowners, and how many structures the bridge provides access to.

Prioritise solutions

Solutions are prioritised based on need date.

Develop an Programme Management Plan

We take the prioritised needs and adjust the plan to allow for aggregation of work into projects, to reduce mobilisation costs and satisfy landowner requirements of ‘one entry only.’ The effects of regional constraints such as resource availability, seasonal weather variation and accessibility are also accounted for. The result of this is that some foundations in the work packages are refurbished slightly earlier than forecast, and others slightly later than forecast.

Cost estimation

Standard foundation refurbishments and replacements, are volumetric works as they are repetitive with similar scope. TEES building blocks form the basis for all volumetric work.

For more bespoke foundation projects, such as waterway protection, works on defective foundations in river beds, or foundations in marine environments, and for access bridges cost estimates cannot be determined volumetrically due to the high level of variation and relatively small number of works. For these we use a customise cost estimating approach, which account for site specific factors.

Contingency planning

We maintain contingency response resources including sufficient field staff and emergency spares to enable rapid restoration following a failure. The spares are condition-monitored, maintained, and are ready for immediate installation and service.

Programming and Scheduling

As a volumetric programme, foundations works are integrated into a wider programme schedule that accounts for other works within the related Transmission Line programmes at the same locations, using common resources enabling Service Provider resource levelling and the benefits accruing from that.

Works for access bridges are generally sub-contracted to a civil contractor.

Project Delivery

The five aspects of project delivery are design, procurement, programme and project delivery, commissioning and decommissioning and disposal.
Design
We design replacement foundations to carry the anticipated design loads of likely future replacement conductor options, where it is likely that future tower strengthening is also able to accommodate these loads. We also aim to ensure that the foundation is stronger than the tower it supports.

Access bridges are designed in accordance with the standards set out in the Transit NZ Bridge Manual.

Procurement
We reduce overall lifetime costs and risk by using pre-qualified vendors, detailed specifications, and economies of scale approach.

Programme and Project Delivery
Our Programme and Project delivery is undertaken in accordance with our programme management framework and applicable Programme Management Plan. Where practical, work is packaged to maximise efficiency, to ensure that any travel time and landowner disruption is minimised. We also ensure that potential environmental and safety hazards are identified and managed.

The delivery timeframes for foundations is dependent on the size and complexity of the work. The delivery timeframes for access bridges is typically run over two years, with the first year being used for detailed design and consenting and the second year used for the installation. This reduces delivery risk and ensures sufficient time is allowed for design and consenting.

Commissioning
Our commissioning plan outlines commissioning planning, testing, livening, hand over, operational, and maintenance processes.

Once all works are completed, our project close-out activities include final capitalisation of the project within our financial systems, providing feedback about actual costs to assist with future cost estimation, updating asset management information systems, archiving of the relevant documentation, and the review of ‘lessons learned’ including a review of health and safety performance.

Decommissioning and disposal
Consistent with our environmental objectives, our decommissioned foundation sites are reinstated to integrate into their surrounding environment, and in some cases, to their original natural forms to allow the land to recover. In accordance with any Resource Consent conditions, we will monitor rehabilitated areas for a period after re-instatement.

Service Delivery
We undertake preventative, corrective, predictive, and proactive maintenance activities as specified in our maintenance standards. Minor maintenance and refurbishment works occur according to the relevant service specifications.

Operate the Grid
There are no specific outage planning requirements for foundation works, and they can often be undertaken without an outage. Works on access bridges do not require any outages.
Forecast Expenditure

Our forecast expenditure for the TL Foundations and Access is described below.

Capital Expenditure

RCP 2, 2018 to 2020
Through RCP 2 we are not expecting any material change to the Foundations and Access portfolio with the main workstreams such as bridge replacement, river piles and marine and understrength foundation refurbishments continuing to occur as planned.

RCP 3, 2020 to 2025
During RCP 3 we are forecasting a similar level of expenditure to RCP 2. This will continue to address issues such as bridge replacements, river piles and marine and understrength foundation refurbishments.

RCP 4, 2025 to 2030
We are forecasting a slightly lower volume of work in RCP 4 as RCP 3. The present indications are that over the next 10-15 years this portfolio has a relatively flat expenditure profile.

Operational Expenditure

We are expecting minor increases to the operational expenditure in the Foundations and Access portfolio as some of the foundation connections and interfaces continue to degrade and require refurbishment. In addition, on-going repairs and protection work is expected for those foundations in rivers and floodways.

Summary, 2018 to 2030

<table>
<thead>
<tr>
<th></th>
<th>RCP 2</th>
<th>RCP 3</th>
<th>RCP 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foundations and Access</td>
<td>2.2</td>
<td>2.8</td>
<td>2.2</td>
</tr>
</tbody>
</table>

Table 65: Foundations and Access capital replacement

Long term

Overall in the long term we are presently not expecting any significant change to the profile of expenditure in the foundations and access portfolio.
HVDC ASSET PORTFOLIO

The HVDC asset portfolio covers all assets associated with the HVDC excluding the HVDC line which is covered under lines portfolio. These are incorporated into a single HVDC Asset Class Plan. This summary provides an overview of our proposed activities for these assets.

Key Initiatives

Pole 2 is reaching its expected design life and a reasonable level of life extension work is required to achieve the estimated 50-year operational life. This work will be carried out across RCP 2 and RCP 3. The refurbishment work will reduce the availability of Pole 2 due to outages required to carry out this work.

The Cook Strait HVDC cables have been in service for more than 25 years in one of the world’s roughest submarine environments. All three cables are expected to reach their end of life between RCP 3 and RCP 6. Replacement of these cables and the commissioning of another submarine cable will be investigated and a major Capex build could proceed within RCP 3-5.

There are also several HVDC assets that are at their end of life will be replaced to reduce the risk of asset failures and consequent service performance impacts. This also includes replacement of aging control and protection systems to address cyber security threats and obsolescence issues.

Expenditure Summary

Capital Expenditure

The capital expenditure within RCP 2 is mainly driven by the replacement of aging Pole 2 assets and condition based replacement of reactive power assets in the AC switchyards.

RCP 3 capital expenditure is mainly driven by the midlife refurbishment of Pole 2. This includes refurbishment of converter transformers, replacement and refurbishment of primary HVDC and AC assets, and life extension of AC reactive support assets. We will also address several ongoing Pole 3 issues and risks to improve Pole 3 reliability. On-going replacement and refurbishment of other HVDC assets such as cable station and electrode station assets will be carried out across RCP 3.

The capital expenditure following RCP 3 will mainly focus around ongoing refurbishment and replacement of aging HVDC assets. Beyond RCP 5 HVDC portfolio will see an increase in capital (and operational) expenditure due to refurbished Pole 2 assets reaching their end of economic life and Pole 3 assets needing life extension work. A major capital project may be required for the replacement of the HVDC control system and Pole 2. The replacement of HVDC cables is subject to a major Capex investigation and so is not included in the forecast presented below.

Expenditure Summary

<table>
<thead>
<tr>
<th>Portfolio Total</th>
<th>RCP 2</th>
<th>RCP 3</th>
<th>RCP 4</th>
</tr>
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<tbody>
<tr>
<td>2016</td>
<td>2.2</td>
<td>12.5</td>
<td>22.4</td>
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<tr>
<td>2017</td>
<td>0.6</td>
<td>13.1</td>
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<td>2018</td>
<td>2.1</td>
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<td>2019</td>
<td>3.6</td>
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<td>2020</td>
<td>16.8</td>
<td>5.9</td>
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<tr>
<td>2030</td>
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</tbody>
</table>

Table 66: Forecast Capital R&R expenditure

Operational Expenditure

The HVDC link provides a critical high-capacity connection between the North and South Islands. Preventive maintenance is particularly important for HVDC assets due to the criticality of the asset and the inherent difficulty in undertaking remedial work.

HVDC maintenance covers HVDC primary assets (thyristor valves, synchronous condensers etc.), converter transformers, circuit breakers and other switchgear, control and protection equipment, and reactive power assets dedicated to the HVDC system. The programme includes the following activities.

- Inspections: these are undertaken at intervals appropriate for the equipment type and technology in use and can range from 1 month to 12 years. HVDC station assets undergo visual inspections, servicing and diagnostic testing in
accordance with maintenance standards.

- **Special inspections**: these focus on the submarine cables and include patrolling of the HVDC Cable Protection Zone and annual inspections of the cable using a submersible remote operating vehicle and divers.

- **Corrective maintenance**: this includes minor repairs of HVDC station equipment identified during site inspections and condition assessment.

We have developed the current frequencies for our inspections and the target rectification times for our corrective maintenance over several years with reference to industry standards and good practice. Warranty conditions dictate some Pole 3 maintenance requirements.

**HVDC cable management**

HVDC submarine cable management covers a range of contracted activities including maritime patrol and shallow water response, Remotely Operated Vehicle (ROV) availability (for deep water response), maritime markers and lights maintenance, and spares maintenance.

<table>
<thead>
<tr>
<th></th>
<th>RCP 2</th>
<th>RCP 3</th>
<th>RCP 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>10.2</td>
<td>12.2</td>
<td>9.9</td>
</tr>
<tr>
<td>2017</td>
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<tr>
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<td>10.1</td>
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<tr>
<td>2019</td>
<td>10.2</td>
<td>10.5</td>
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<tr>
<td>2020</td>
<td>10.2</td>
<td>10.2</td>
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<tr>
<td>2021</td>
<td>12.2</td>
<td>10.2</td>
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<tr>
<td>2022</td>
<td>12.2</td>
<td>10.2</td>
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<tr>
<td>2023</td>
<td>12.2</td>
<td>10.2</td>
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<tr>
<td>2024</td>
<td>12.2</td>
<td>10.2</td>
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<tr>
<td>2025</td>
<td>12.2</td>
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<td>2026</td>
<td>12.2</td>
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<tr>
<td>2027</td>
<td>12.2</td>
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<tr>
<td>2028</td>
<td>12.2</td>
<td>10.2</td>
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<tr>
<td>2029</td>
<td>12.2</td>
<td>10.2</td>
<td>10.2</td>
</tr>
<tr>
<td>2030</td>
<td>12.2</td>
<td>10.2</td>
<td>10.2</td>
</tr>
</tbody>
</table>

*Table 67: HVDC Opex*

**Risks and Uncertainties**

The material risks and uncertainties associated with this portfolio are:

- Our HVDC assets are relatively unique and there are a significant number of unique individual assets per converter station. International and internal Transpower experience in this area is relatively scarce and we rely on manufacturer recommendations and international user groups (i.e. Cigre) for expert knowledge. Due to this, we may encounter unexpected failures requiring reprioritisation of the plan and the consequent deferral of some planned work.

- Our access to accurate cost information is restricted due to unique nature of the asset. Transpower doesn’t hold an accurate cost library of HVDC assets. Where possible we base our estimates on available historical cost estimates, quotes or cost information of similar AC assets. There are only a limited number of HVDC suppliers which restricts our bargaining power. Similarly, the global HVDC market is becoming less competitive with a significant amount of new larger HVDC projects. These are a significant risk as we may be required to pay a premium price to obtain HVDC services in the future. We may also experience long lead times as the suppliers commit to larger projects overseas.

- HVDC asset failures is a significant risk to the operation of the HVDC system. We hold spares to cover most of our assets which will reduce the downtime following an asset failure. A Cook Strait cable(s) failure will reduce the HVDC capacity leading to market constraints and costly repairs. We are actively managing this risk by regular monitoring of the cable protection zone and educating the public about the Cable Protection Zone and its purpose. Regular condition assessment of HVDC cables and other HVDC assets also ensure that we will discover potential issues as early as possible. Unexpected asset failures will increase the expenditure and could defer other planned work.

- We are expecting to conduct a significant amount of refurbishment work within RCP 3. Successful commissioning of this work will depend on the availability of specialised technical resources (i.e. engineering knowledge), outage availability, and timely manufacturer support. If we experience delays this could lead to reprioritisation of the plan and deferral of some work in to RCP 4.

**Asset Class Plans**

The following section describes in more detail our asset management approach for our HVDC assets. It describes the strategy, asset characteristics, management approach and expenditure profile.
ASSET CLASS PLAN – HVDC

This asset class plan describes the life cycle management approach of our HVDC assets for the following asset types:

- Converter Stations, thyristor valves, converter transformers, HVDC yard equipment, and related AC switchyard equipment
- Systems and control equipment, including reactive power control (RPC) systems,
- Electrode Stations, incorporating earthing electrodes, isolating switches, roof bushings, and buildings
- Submarine cables and cable station assets, incorporating submarine cables, cable terminations, and buildings.

The HVDC link provides a high-capacity connection between the North Island and South Island electricity systems, enabling the operation of an efficient national electricity market.

The original HVDC link was commissioned with Pole 1 in 1965. There was a substantial HVDC upgrade in 1991, when the Pole 2 converter stations (Pole 2) were commissioned and three new HVDC submarine power cables were installed. The upgrade process continued with the commissioning of the new Pole 3 converter stations (Pole 3) in 2013 replacing Pole 1 which was decommissioned in 2012. The HVDC link now comprises of Pole 2 and Pole 3.

The role of the HVDC link is continually evolving. For example, since April 2014, we have used the frequency keeping control (FKC) delivered as part of the Pole 3 project. FKC has enabled the implementation of national reserves and frequency keeping markets, which provide significant benefits to the electricity market through considerably reduced frequency keeping and reserve costs.

Figure 54 provides a simplified high-level overview of the HVDC link.

![Figure 54: High-level overview of the HVDC link](image)

Table 68 provides a breakdown of our HVDC population.

<table>
<thead>
<tr>
<th>Asset Type</th>
<th>Quantity</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Converter Stations</td>
<td>2</td>
<td>Each station has 2 Poles/Converters</td>
</tr>
<tr>
<td>Electrode Stations</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Cable Stations</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Submarine Cables</td>
<td>3</td>
<td>38 km per submarine cable</td>
</tr>
</tbody>
</table>

Table 68: HVDC population
Asset Characteristics

The HVDC link plays a key role in the electricity network and market. It is a unique blend of technologies, and consists of the older Pole 2 and the new Pole 3. Because of this blend of technologies, it is more analogous with generators than transmission and requires market and non-market products to enable transfer at higher levels of operation.

Age Profile

The age of the HVDC components is as follows:

**Converter stations**

Pole 2 was commissioned in 1991, with several of its assets replaced during the Pole 3 project. Pole 3 was commissioned in 2013. It is projected with the necessary asset replacements and refurbishments Pole 2 and 3 will achieve 50 years of operational life.

**Electrode stations**

Both electrode stations were constructed in 1965 and subsequently electrodes were extended between 1989 and 1993 to increase their current rating.

**Cable Stations**

The cable stations were constructed in 1991 and have a nominal life expectancy of 30 years. With refurbishment and strengthening works, these are expected to last for significantly longer.

**Submarine cables**

Our submarine cables were installed in 1991 and have a life expectancy of 40 years. We have undertaken a desktop life expectancy study of our submarine cables. The study indicated that the cables may have different life expectancies due to their geographical separation and the resulting differences in submarine environment exposure.

Asset Health

Due to the unique nature of the HVDC assets, asset health modelling is not required. They are subject to specialist and individual condition monitoring and assessment. The condition of many of our HVDC assets is monitored in real time and telemetry data is continuously feed back into our systems.

HVDC assets are subject to specialist and individual condition monitoring and assessment. The condition of many of our HVDC assets is monitored in real time and telemetry data is continuously feed back into our systems. Where possible we trend these and analyse them for early detection of asset failures.

Most Pole 3 assets are in relatively good condition and still under warranty. Majority of Pole 2 assets require replacement or refurbishment work to extend their operational life to 50 years. Reactive power assets dedicated for HVDC support (i.e. filter banks) are in a reasonably good condition and future refurbishments should be sufficient to maintain their availability. Cook Strait HVDC cables are performing well but will require replacements around RCP 5-6. Cable stations require major refurbishment work to ensure their continuous operation until a major upgrade along with cables replacement. Electrode stations and related assets are in good condition and regular maintenance is sufficient to maintain them in good condition.

Asset Criticality

The HVDC is a key component of the grid. We are in the process of revising how we assess the HVDC criticality as its role in the grid is evolving and the performance of the HVDC link can heavily influence electricity prices, frequency keeping, and national reserves products.
Asset Performance

The availability of the HVDC link varies from year to year, due to the number and length of planned and forced outages. Overall, the HVDC link has achieved world-class levels of availability since it was commissioned.

The HVDC submarine cable performance has been reliable, with only one failure, in October 2004, due to an internal electrical fault. The cable was successfully repaired and returned to service within the same year. The most significant risk to the submarine cables is damage caused by illegal fishing and anchoring in the Cook Strait Cable Protection Zone (CPZ). We are actively managing this risk by patrolling the CPZ and educating the public. Submarine environmental features such as boulders and unsupported long cable suspensions are also risks to submarine cables.

Asset Life Cycle Stages

Our asset management approach for the HVDC enables continued high levels of availability and reliability on a sustainable and safe basis while achieving least life cycle cost. We take a risk based approach in prioritising and managing our HVDC expenditure. Our long-term replacement and refurbishment plans are informed by expected lives, which are based on manufacturer recommendations, and international best practices. Specialist condition assessments and historical asset knowledge is also used in forming long-term plans.

Strategic Planning

The following strategic objectives have been set for our HVDC assets:

Safety
- Zero medical treatment injuries arising from the maintenance or operation of the HVDC assets.
- Ensure that risks to the public from the operation of the HVDC link is as low as reasonably practical.

Service Performance
- Achieve at least 98.5% annual energy availability for Poles 2 and 3 (Bipole)

Cost Performance
- Minimise least life cycle cost in asset management decision-making (such as evaluation of replacement versus refurbishment, and capital versus maintenance expenditure).
- Minimise impact of major submarine cable failures by maintaining necessary resources to undertake a prompt ‘cut and cap’ operation, to reduce water propagation in the insulation, in the event of a fault.

New Zealand Communities
- Proactively mitigate any complaints from the public.
- No significant release of oil to the environment.
- SF6 emissions as low as reasonably practical.
- Effective relationships with landowners of the access routes to cable terminal and electrode stations.
- Effective relationships with the fishing industry in relation to the CPZ.

Development Initiatives
- As the HVDC’s role has evolved over time, we have implemented additional functionalities, such as the cable overload scheme allowing a 15 minute 700 MW overload of Pole 2. We will continue to assess alternative, innovative, and cost-effective ideas to increase the HVDC’s utilisation and reliability.
**Tactical Planning**

Our planning approach for the HVDC link is to seek continued high levels of availability and reliability through continuous monitoring and planned renewals and active maintenance of our systems, assets, and supporting facilities.

We are looking to refurbish and replace Pole 2 assets to extend its approximate 30-year life to 50 years. We also recognise the potential for changes in the market to impact the role of the HVDC link. Accordingly, we are working closely with the System Operator and stakeholders to ensure that the HVDC will meet the future needs of the electricity market.

We replace and refurbish HVDC site buildings and grounds infrastructure and building services based on condition assessment to ensure a suitable level of safety, security, and functionality. Most HVDC building services have been upgraded as part of the Pole 3 project and the remainder is being carried out as planned work in RCP 2. Due to their uniqueness, the HVDC buildings are managed by the HVDC portfolio with guidance from Buildings and Grounds.

The various components of the electrode stations continue to be maintained, refurbished, or replaced as required to retain the required condition and function of the stations.

**Condition Assessments**

The Pole 3 project installed online-monitoring systems which enable us to monitor the condition of HVDC assets in near real time. Additionally, there are several, interval based, visual condition inspections. Table 69 outlines the condition assessments we undertake for HVDC equipment.

<table>
<thead>
<tr>
<th>Asset Type</th>
<th>Measured condition parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Majority of HVDC assets</td>
<td>Visual inspections – HAY/BEN/OTB/FTB monthly inspections, BGR/THW 2 monthly inspections</td>
</tr>
<tr>
<td>Transformers including converter transformers</td>
<td>Dissolved Gas Analysis (DGA) online monitoring – continuous online monitors + 1 yearly laboratory tests</td>
</tr>
<tr>
<td>Pole 3 Buildings</td>
<td>Seismic event and deflection monitoring – only at Haywards – checked after significant seismic events</td>
</tr>
<tr>
<td>Converter stations</td>
<td>Thyristor diagnostic inspections in line with manufacturers requirements (Check back signals continuously monitored and specific diagnostic tests are not scheduled)</td>
</tr>
<tr>
<td>Filter bank circuit breakers</td>
<td>Monitoring circuit breaker operation count – checked during monthly inspections.</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Asset Type</td>
<td>Measured condition parameters</td>
</tr>
<tr>
<td>-------------------</td>
<td>-------------------------------</td>
</tr>
<tr>
<td>Cable stations</td>
<td>Cable bushing gas analysis (10 yearly)</td>
</tr>
<tr>
<td></td>
<td>Hydrophobidity testing of cable bushings (1 yearly)</td>
</tr>
<tr>
<td></td>
<td>Monitoring of internal bushing gas pressure (monthly inspection) and top-up intervals (unscheduled)</td>
</tr>
<tr>
<td>Submarine cables</td>
<td>Time domain reflectometry tests, 2 yearly</td>
</tr>
<tr>
<td></td>
<td>Line Resonance Analysis (LIRA), 4 yearly</td>
</tr>
<tr>
<td></td>
<td>Dive spot checks and surveys – Oteranga bay yearly, Fighting Bay a spot check every 4 years.</td>
</tr>
<tr>
<td></td>
<td>Remotely operated vehicle surveys and checks (Yearly)</td>
</tr>
<tr>
<td>Shore Electrodes (THW)</td>
<td>Current sharing tests (2 yearly) and resistance measurements (unscheduled)</td>
</tr>
<tr>
<td></td>
<td>Lift and clean electrodes of salt deposits (unscheduled)</td>
</tr>
<tr>
<td>Land Electrodes (BGR)</td>
<td>Current sharing tests (2 yearly) and resistance measurements (unscheduled)</td>
</tr>
</tbody>
</table>

Table 69: HVDC condition assessment tasks

Decision Framework

The work programme for HVDC assets are determined by applying the four steps of the Decision Framework.

Need identification

Needs and associated need dates are based on age, condition assessments, manufacturers’ recommended operating or duty limits, level of compliance with standards (for example seismic standards), spares coverage, and consequence of failure. These are targeted at reducing the risk of asset failures which could affect the availability of the HVDC link.

Options Assessment

Options and their expected costs are identified for each need. Depending on the asset involved, the options assessment includes running to failure, refurbishment, or replacement.

Prioritise solutions

Solutions are prioritised on need date and risk. The probability and the consequence of the asset failing is used.

Develop a Programme Management Plan

The selected solution is considered in conjunction with other scheduled programmes of work to achieve synergies with other planned works, outage planning, and to minimise market impacts.

Cost estimation

HVDC capital works are characteristically one-off unique projects. This reduces the extent to which historic project costs can be relied on to forecast future projects. Therefore, cost estimation for each large capital project is customised, accounting for the specific context, risks and requirements of the project, cost of specialist manufacturer support, the installation site, consenting and environmental costs, market costs, and the number of outages expected.

Contingency planning

Our contingency plans for HVDC ensures we have an adequate level of emergency preparedness. This includes maintaining specialist contracts for short notice emergency work and the holding of emergency spares and equipment.

Programming and scheduling

HVDC replacements and upgrades are individually scoped and priced works. As such, they are scheduled according to the need and resource availability, while accounting for other work across all six sites. Majority of the work is planned to be delivered around the annual HVDC outage to ensure that the annual availability target can be met.
**Project Delivery**
The five aspects of project delivery are design, procurement, programme and project delivery, commissioning and decommissioning and disposal.

**Design**
The design of large HVDC projects is incorporated into the complete design-build solution. As our HVDC assets are relatively unique they are designed and built to meet specific requirements.

**Procurement**
Although there is limited competition in the HVDC market, we undertake a competitive tender process where possible. We procure high-risk components and materials from the original equipment manufacturer for compatibility reasons.

**Programme and Project Delivery**
Our Programme and Project delivery for larger projects is undertaken in accordance with our programme management framework. The delivery timeframes for HVDC account for detailed design, procurement, availability of specialised resources, outage planning, electricity market impacts, and coordination with other major works across the HVDC link. This is typically two to three years in duration. Larger projects require highly skilled specialised engineering and service provider resources which are normally obtained through consultants and service providers from other regions. Service Delivery Managers deliver the smaller, less complex, projects as this is more cost effective. Engineering support is provided by a dedicated team of field engineers.

**Commissioning**
Our commissioning plan outlines commissioning planning, testing, livening, system tests under market conditions, hand over, operational, and maintenance processes.

Once all works are complete, our project close-out activities include final capitalisation of the project within our financial systems, feedback about actual costs to assist with future cost estimation, updating asset management information systems, archiving of the relevant documentation, and the review of 'lessons learned' including a review of health and safety performance. Due to the unique nature of the HVDC assets, one key aspect of HVDC project closeouts is training. It is important to ensure that our staff are well trained to operate and maintain the new assets delivered through the project.

**Decommissioning and Disposal**
Where possible and if useful, we donate retired equipment to education institutions. We recycle as much of the equipment as possible. The legacy Cook Strait submarine cables that are no longer used have been left in place as the costs and risks of recovery outweigh any benefit from recycling. There are no significant environmental effects from the old cables remaining in place.

**Service Delivery**
We undertake preventive, corrective, predictive, and proactive maintenance activities as specified in our maintenance standards for HVDC assets. Due to their unique nature, most HVDC assets require special maintenance tasks prescribed by original equipment manufacturers. We also seek feedback from the international HVDC community which is reflected in our standard maintenance procedures. The majority of the HVDC maintenance work is carried out during the annual maintenance outage.

**Operate the Grid**
We generally plan HVDC outages in summer when the HVDC demand is lowest. We endeavour to minimise the number of outages on the HVDC system as the availability of the HVDC system affects the operation of the electricity market (energy transfer and price), frequency keeping, and the national reserves market. Due to increasing HVDC demand, it is becoming increasingly difficult to obtain HVDC outages. More planning and preparation is required with the industry to ensure the work can be completed without major system impacts. Due to Pole 2 mid-life refurbishment work the annual HVDC outage is expected to be longer during RCP 2 and following this period of major refurbishments we will utilise shorter annual outages for the remainder of the work.
Forecast Expenditure

Our forecast expenditure for the HVDC is discussed below.

Capital Expenditure

RCP 2, 2018 to 2020

There has been a review of the necessary work carried out in RCP 2 which has reduced the RCP 2 expenditure reported in the 2016 AMP. The HVDC Pole 2 Valve Based Electronics project has been moved into the final year to coincide with the longer duration HVDC re-conductoring work in 2019/20. This has changed the phasing of the expenditure.

RCP 3, 2020 to 2025

A Pole 2 mid-life refurbishment programme is required to be carried out over RCP 2 and RCP 3 to achieve an asset life of 50 years. If we delay the midlife work the risk of asset failure increases.

Over RCP 3 the key midlife work that we plan to carry out are:

- Refurbishing converter transformers including transformer bushings replacement
- Replacing wall bushings (both AC and HVDC)
- Replacing / refurbishing HVDC primary assets

RCP 4, 2025 to 2030

The costs for this period are expected to reduce to cover routine capital expenditure as the midlife expenditure on Pole 2 will be complete.

Operating Expenditure

The operating expenditure on the HVDC link is very low compared to other assets as most assets are replaced rather than repaired continuously. A failure of the HVDC link will affect the entire network rather than a small region or a site. Therefore, replacements are necessary to maintain the required level of availability and reliability.

Key risks and uncertainties

The material risks and uncertainties associated with this portfolio are:

- Our HVDC assets are relatively unique and there are a significant number of unique individual assets per converter station. International and internal Transpower experience in this area is relatively scarce and we rely on manufacturer recommendations and international user groups (i.e. Cigre) for expert knowledge. Due to this, we may encounter unexpected failures requiring reprioritisation of the plan and the consequent deferral of some planned work.
- Our access to accurate cost information is restricted due to unique nature of the asset. Transpower doesn’t hold an accurate cost library of HVDC assets. Where possible we base our estimates on available historical cost estimates, quotes or cost information of similar AC assets. There are only a limited number of HVDC suppliers which restricts our bargaining power. Similarly, the global HVDC market is becoming less competitive with a significant amount of new larger HVDC projects. These are a significant risk as we may be required to pay a premium price to obtain HVDC services in the future. We may also experience long lead times as the suppliers commit to larger projects overseas.
- HVDC asset failures is a significant risk to the operation of the HVDC system. We hold spares to cover most of our assets which will reduce the downtime following an asset failure. A Cook Strait cable(s) failure will reduce the HVDC capacity leading to market constraints and costly repairs. We are actively managing this risk by regular monitoring of the cable protection zone and educating the public about the cable protection zone and its purpose. Regular condition assessment of HVDC cables and other HVDC assets also ensure that we will discover potential issues as early as possible. Unexpected asset failures will increase the expenditure and could defer other planned work.
We are expecting to conduct a significant amount of refurbishment work within RCP 3. Successful commissioning of this work will depend on the availability of specialised technical resources (i.e. engineering knowledge), outage availability, and timely manufacturer support. If we experience delays this could lead to reprioritisation of the plan and deferral of some work in to RCP 4.

**Summary, 2018 to 2030**

<table>
<thead>
<tr>
<th></th>
<th>RCP 2</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Portfolio Total</strong></td>
<td>2.2</td>
<td>0.6</td>
<td>2.1</td>
<td>3.6</td>
<td>16.8</td>
<td>12.5</td>
<td>13.1</td>
<td>12.4</td>
<td>9.5</td>
<td>22.4</td>
<td>5.9</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Table 70: Forecast capital expenditure

**Long-term forecast**

The midlife work on Pole 3 is planned to occur during RCP 5 which will lift expenditure to a similar level to RCP 3.
REACTIVE ASSETS PORTFOLIO

The Reactive asset portfolio covers all our reactive assets. These are incorporated into a single Reactive Asset Class Plan. This summary provides an overview of our proposed activities for these assets.

Key Initiatives
The future thermal decommissioning of the Huntly units will create voltage stability issues and the need for additional reactive assets in the Waikato and Upper North Island regions. We are currently assessing the detailed options to address the need and the issues. As part of this process, we will be considering the criticality of the existing reactive assets in this region.

During RCP 2 we will be collecting capacitor can level information to improve the accuracy of our capacitor bank asset health model. We are presently implementing a more detailed asset data structure which will lead in to better asset information.

Expenditure Summary
The capital expenditure within RCP 2 is driven by the replacement of aging cooling towers associated with Haywards synchronous condensers, replacement of end of life components of SVCs, repairing the fire damaged SVC9 at Islington, and several small projects addressing ongoing issues/risks.

Expenditure during RCP 3 is driven by the replacement of capacitor banks at the end of their operational and economic life, life extension and refurbishment of SVCs, life extension and condition assessment work on reactors and synchronous condensers, addressing emerging issues, and procurement of spares to minimise the risk exposure due to asset failures.

The capital expenditure in RCP 4 and beyond will focus on replacing capacitor banks and reactors at the end of their operational/economic life, procuring spares for risk mitigation, refurbishment of SVCs and STATCOMs, uprating synchronous condensers, and addressing asset class issues.

As highlighted in the Operational expenditure section below, the extension of capacitor bank operational life to 30 years (potentially even longer) will result in a reduced short to medium term capital forecast with a trade-off of higher operational expenditure.

<table>
<thead>
<tr>
<th>Portfolio</th>
<th>RCP 2</th>
<th>RCP 3</th>
<th>RCP 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>1.6</td>
<td>1.3</td>
<td>4.4</td>
</tr>
<tr>
<td>2016</td>
<td>1.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2017</td>
<td>1.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2018</td>
<td>4.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2019</td>
<td>2.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2020</td>
<td>1.8</td>
<td>15.8</td>
<td>0.6</td>
</tr>
<tr>
<td>2021</td>
<td>13.6</td>
<td>6.1</td>
<td>8.0</td>
</tr>
<tr>
<td>2022</td>
<td>7.9</td>
<td>13.3</td>
<td>3.4</td>
</tr>
<tr>
<td>2023</td>
<td></td>
<td>0.6</td>
<td>0.6</td>
</tr>
<tr>
<td>2024</td>
<td></td>
<td></td>
<td>18.4</td>
</tr>
<tr>
<td>2025</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2026</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>2027</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>2028</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2029</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2030</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 71: Reactive Capex forecast

Operational Expenditure
Majority of the operational expenditure arises from corrective and preventative maintenance. We conduct regular inspections and testing to reduce the risk of asset failure and to identify failed components. Any failed assets such as capacitor cans are replaced as corrective maintenance. Due to the modular nature of the asset class, replacement of the components is more economic than repairing them.

We are extending the life of our capacitor banks to 30 years and expect the capacitor can failure rate to increase with the age. We will continue with reactive replacement of failed capacitor cans which will increase the short to medium term operational expenditure. In the absence of reliable capacitor can failure data this is expected to be the least whole of life cost. If a capacitor bank is experiencing a higher than anticipated failure rate, we will proactively replace the bank or a population of the cans to address the issue. The Opex costs for reactive assets is captured within the stations portfolio.
Risks and Uncertainties
The primary risks for the reactive portfolio are:

- an unexpected asset failure in a region results in reduced transmission capacity requiring unplanned replacement of reactive assets
- while we are not expecting to require immediate replacements, there are a high percentage of capacitors in the upper North Island that are close to their original design life.
- risk of catastrophic or major asset failures leading to early asset replacements
- A major uncertainty associated with the reactive power asset class is the future state of the network. Factors such as distribution generation, commissioning of new transmission lines and/or under grounding of existing lines, generation and load pattern changes, network topology changes, and many other factors will influence the reactive power demand. Hence the forecast could change significantly requiring reprioritisation of the work plan.

If any of the above risks eventuate it will be necessary to adjust the forecast and reprioritise the work plan to reflect the funding and resources required for addressing these.

Asset Class Plan
The following section describes in more detail our asset management approach for our Reactive assets. It describes the strategy, asset characteristics, management approach, and expenditure profile.
ASSET CLASS PLAN – REACTIVE ASSETS

This asset class plan describes our life cycle management approach for reactive assets. It covers the following:

- Synchronous condensers
- Static Var Compensators (SVCs) and STATic synchronous COMpensators (STATCOMs), including those located at the HVDC converter stations
- Capacitor banks and reactors

Reactive power is needed to support the transfer of real power over the network. However, it needs to be carefully controlled to optimise system capacity, reduce system losses, and maintain voltage levels.

We use capacitor banks and reactors to provide most of the reactive power support required. To ensure stability under transient or abnormal conditions, the system also needs fast-acting sources of dynamic reactive power. Dynamic reactive power can be provided by a combination of generators, synchronous condensers, SVCs, and STATCOMs. Modern power electronic technologies used in SVCs and STATCOMs combines the functions of capacitor banks and shunt reactors to provide fast-acting, variable reactive power. Capacitors and reactors are also integral components of filter banks. Together they are used to limit in-rush currents (reactors) and filter potentially damaging harmonic frequencies.

Table 72 provides a breakdown of the population of our reactive power assets by type.

<table>
<thead>
<tr>
<th>Type</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Synchronous condensers</td>
<td>8</td>
</tr>
<tr>
<td>SVCs</td>
<td>3</td>
</tr>
<tr>
<td>STATCOMs</td>
<td>7</td>
</tr>
<tr>
<td>Capacitor Banks</td>
<td>101</td>
</tr>
<tr>
<td>Reactors</td>
<td>152</td>
</tr>
</tbody>
</table>

Table 72: Reactive assets population
Asset Characteristics

Reactive power assets are important components of the grid. They support regions rather than specific end customers. Dynamic reactive power assets assist the recovery of the power system following transient conditions. Under steady state operation the balance between static and dynamic reactive support is managed to ensure that enough dynamic capacity is available for system recovery.

Age Profile

Our reactive power assets have been installed through large reactive support projects to address regional needs. Hence groups of assets were commissioned around the same time across an entire region (i.e. Upper North Island). The age profile graphs below reflect the timeframe a certain regional need was addressed.

![Figure 55: Statcom, SVC and Syncro condensor age profile](image)

![Figure 56: Capacitor bank age profile](image)
The primary drivers for the health of our reactive assets are asset condition, age, and performance history. Overall our reactive assets are performing well. Ongoing refurbishment and replacement work will be required to ensure that their performance meets future network requirements. Table 73 summarises the condition of our Reactive Assets.

<table>
<thead>
<tr>
<th>Type</th>
<th>Condition/asset health</th>
</tr>
</thead>
<tbody>
<tr>
<td>Synchronous condensers</td>
<td>Have been refurbished recently. Ongoing work will ensure good performance.</td>
</tr>
<tr>
<td>SVCs</td>
<td>Most SVCs will require midlife refurbishments within next 10 years to extend their life expectancy. SVC3 at ISL is in a very poor condition which needs to be addressed soon.</td>
</tr>
<tr>
<td>STATCOMs</td>
<td>Relatively new, in good condition.</td>
</tr>
<tr>
<td>Capacitor Banks</td>
<td>Several capacitor banks are reaching their end of life and will require replacements within the next 510 years. R&amp;R work on other banks will ensure that the regional needs can be met in the future.</td>
</tr>
<tr>
<td>Reactors</td>
<td>Most reactors are in good condition. Several reactors are reaching their end of life and will be replaced with larger reactors at more optimal locations. Ongoing R&amp;R will ensure that the asset class meets their availability requirements.</td>
</tr>
</tbody>
</table>

Conservative design together with proper maintenance has enabled some capacitor banks and reactors to operate beyond their design life. We have decommissioned most capacitor banks that have a history of explosive failures. We are also in the process of planning to decommission aged oil filled reactors and capacitors at Stoke which will further reduce the risk.

Life expectancy of capacitor cans within the capacitor banks are difficult to estimate. The probability of failure does increase with age, but it is difficult to identify the failure point due to the random distribution of failures. We have experienced an increase in capacitor can failures during the last few years. To address this, we plan to improve capacitor bank protection design which will minimise the consequences of asset failures through early detection of faults.

Synchronous condensers are also reaching their end of design life. However, the refurbishments carried out in RCP 1 have minimised the risk of a major failure and we have installed improved online monitoring to indicate performance issues. We experienced several significant failures during the last few years which have or are being addressed. We are also addressing cooling system issues which will improve the availability and reduce the operational cost.
Asset Criticality

Reactive power assets do not fit into standard network asset criticality frameworks. While they are primary equipment, their function serves regions, rather than individual substations, circuits, or branches. In terms of criticality, we classify our reactive assets as low, medium, or high criticality based on the level of redundancy, spare reactive power capacity within the region, system stability limits, and the failure mode. Table 74 shows the criticality categories that have been allocated for our reactive power assets.

<table>
<thead>
<tr>
<th>Type</th>
<th>Criticality from system perspective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Synchronous condensers</td>
<td>Low (due to redundancy)</td>
</tr>
<tr>
<td>SVCs</td>
<td>Moderate-high dep on spare capacity in the region</td>
</tr>
<tr>
<td>STATCOMs</td>
<td>Moderate-high dep on spare capacity in the region</td>
</tr>
<tr>
<td>Capacitors</td>
<td>Moderate-high dep on spare capacity in the region</td>
</tr>
<tr>
<td>Reactors</td>
<td></td>
</tr>
</tbody>
</table>

Table 74: Reactive Assets criticality

Asset Performance

A failure of reactive power assets affects regions of the grid and, except in the worst case, is unlikely to cause a power outage. In the worst case, load shedding would be required to avoid stability issues resulting from lack of reactive support. Figure 58 shows the failures of our reactive power assets by year.

![Unplanned outages for Reactive assets](image)
Asset Life Cycle Stages

Our asset management approach for our reactive power assets is designed to ensure a high level of operational reliability from our assets with lowest life cycle cost.

Strategic Planning

The following strategic objectives have been set for our reactive power assets:

Safety
- No fatalities or Medical Treatment Incidents (MTIs) from operation or maintenance of reactive power assets
- Minimise the risk of explosions or fires due to operation of Haywards synchronous condensers
- Minimise the risk of catastrophic failures due to capacitor can failures by addressing issues in a timely manner

Service Performance
- Ensure continuing high reliability and availability (average greater than 94.5%) for each Haywards synchronous condenser until 2035, including scheduled unavailability of 5% or less and forced unavailability of 0.5% or less
- 98% or better availability of SVCs and STATCOMs
- Less than 3 unplanned outages and 4 planned outages for each synchronous condenser each year
- Less than 4 unplanned outages each year from each SVC or STATCOM
- Less than 10 unplanned outages each year for capacitor banks
- 5-year rolling average of less than 1 unplanned outage each year for reactors

Cost Performance
- Minimise life cycle costs

Customers and Stakeholders
- No significant oil leaks to the environment
- No asbestos released to the environment
- Minimise interference to customer ripple control systems
- Minimise harmonic distortion
- Comply with local or regional acoustic noise requirements

Development Initiatives

We have installed remote engineering access across our dynamic reactive power assets. In case of an asset failure or a network event, we are capable of remotely logging into the control system for troubleshooting or fault record downloading. We also constantly monitor the performance of our reactive assets through available online monitoring systems.

Several data improvement initiatives are presently underway which will assist with refining asset health modelling. To reduce the business impact due to these additional data requirements and to speed up the data collection process, we have introduced spreadsheet models to gather asset data. From work carried out to date, we have already identified that some of our asset failure rates are underestimated.

Tactical Planning

Our planning approach for reactive assets is to maintain and refurbish as required and then, if economic, replace based on condition and asset health. Safety is a key driver for the replacement and refurbishment of reactive power assets. For example, some capacitor bank models have a history of disruptive failures, warranting various modifications to minimise safety risks. High risk items such as hydrogen in the condensers are managed by investing in controls to reduce the likelihood of the risks eventuating. Other remedies such as stricter maintenance regimes and appropriate control and protection equipment will also reduce the likelihood and consequences of a failure.
Reactive power requirements at a given location also change as the power system evolves over time. Therefore, as part of our planning, we also consider the effectiveness and the need for the reactive power asset at a given location and if it is beneficial and economical we will consider relocation of the bank as part of our options analysis.

**Condition Assessments**

We complete regular condition assessments of our reactive power assets. We undertake visual inspections and thermo-vision inspections for early detection of potential issues. We have recently introduced new maintenance practices for detailed condition assessment of our assets. This will provide more details about failure modes and improve our asset knowledge.

Synchronous condenser condition assessments include visual and thermal inspections as well as electrical, mechanical, and gas tests, and two-to-four-year equipment services. We have also installed several smart monitoring systems to continuously monitor the condition of the synchronous condensers. We carry out internal inspections of the synchronous condensers from time to time to ensure reliable operation of the condensers by identifying issues in advance.

Capacitors and reactors have four-yearly inspections to monitor signs of corrosion, paint peeling, leaks, or physical deformation. We have also introduced new Standard Maintenance Procedures for conducting unplanned work which will gather more information during unplanned maintenance that occurs in between planned four-yearly maintenance.

**Decision Framework**

The work programme for our reactive assets is determined by applying the four steps of the Decision Framework.

**Need identification**

The need and need dates for our reactive assets are based on either condition or asset health, dependent on the specific asset involved.

**Options Assessment**

We consider partial replacement options as an alternative to complete replacement of an asset. In deciding on the appropriate approach, we consider the impact on reliability, life expectancy, and capital cost of each option.

In the case of any capacitor bank replacements, we also plan to revisit the optimum location for each bank as this could vary with changes in network conditions. However, this will require further work before we fully incorporate this into our decision framework.

**Prioritise solutions**

Solutions are prioritised based on safety risk, and the identified need date.

**Develop a Programme Management Plan**

For reactive power assets, projects are generally site specific or part of a larger programme covering an entire region. Complex projects such as dynamic reactive power projects are delivered as design build solutions. Where possible we will combine several projects into a programme (i.e. UNIDRS/WUNIVM projects).

**Cost estimation**

Due to the unique nature of reactive assets there are no accurate building blocks for cost estimation. As such, all estimates are customised. For capacitors, bottom-up estimates are used. Reactors and reactive power assets require individual cost estimates from suppliers as they are specialised assets.

**Contingency planning**

We review and maintain spare holdings, and ensure an adequate level of emergency preparedness, to enable rapid restoration of transmission service following reactive power asset failure. The spares include entire capacitor banks and spare components for capacitor banks, power electronics components, and synchronous condensers consumables and components, as many of the components for these systems require significant lead time to procure.
Programming and scheduling
Reactive asset replacements and upgrades are individually scoped and priced works. As such, they are scheduled to need and resource availability, while accounting for other work at the same location, such as major site upgrades, using common resources.

Project Delivery
The five aspects of project delivery are design, procurement, programme and project management, commissioning, and decommissioning and disposal.

Design
Larger projects generally require detailed design work, which is undertaken by an Engineering Consultant or the supplier with support from specialists within Transpower. Refurbishment and other minor projects have a relatively small design component, which are carried out by Transpower engineers or service providers, as part of the delivery phase.

We plan to standardise many of our design standards. These include:

- Developing a new standard capacitor bank protection design including a new specification for unbalanced current transformers
- Developing a standard capacitor bank design that will include a mechanically switched capacitor with damping network design to minimise harmonic levels. This design will provide broad spectrum damping of harmonic frequencies
- Design for future expansion of capacitor banks to meet future network demands
- Standardising the use of cascaded multi-level converter technology that provides reduced losses and maintenance requirements for future STATCOM installations
- Standardising the MVar rating and configuration for future SVCs
- Standardising the capacitor bank components to improve the management of emergency spares and to gain cost efficiencies.

Procurement
We remain in contact with the original equipment manufacturers so that we receive notice of declining availability of spare parts. This enables us to purchase additional spare components for the remaining life of the main equipment, before these parts are no longer available.

Most of the major reactive power projects are design-build contracts to meet our specifications.

Programme and Project Delivery
Our Programme and Project delivery is undertaken in accordance with our programme management framework. The delivery timeframes for reactive assets account for detailed design, procurement, outage planning and co-ordination with other major works at the site. This is typically one to two years in duration and can be much longer (five+ years) for larger programmes.

Smaller projects for dynamic reactive power assets are delivered through the Service Delivery managers as this is more cost effective.

Commissioning
Our commissioning plan outlines commissioning planning, testing, livening, system testing, hand over, operational, and maintenance processes. Due to their regional impact, commissioning and testing of reactive power assets require System Operator approval prior to conducting onsite work.

Once all works are completed our project close-out activities include final capitalisation of the project within our financial systems, feedback about actual costs to assist with future cost estimation, updating asset management information systems, archiving of the relevant documentation, and the review of ‘lessons learned’ including a review of health and safety performance. Due to the unique nature of reactive assets, specialised training and skills are required for maintaining these assets during and following the warranty period.
Decommissioning and Disposal
Disposal of used capacitor cans and other oil filled assets follow our standard protocols.

Service Delivery
We undertake preventive, corrective, predictive, and proactive maintenance activities as specified in our maintenance standards. Dynamic reactive power assets require specialised maintenance to be carried out during the warranty period and these requirements become standard maintenance practices following the warranty period. The costs associated with these are set out in the Reactive Portfolio summary.

Capacitor banks and reactors are maintained through regional service provider agreements while dynamic reactive power assets have a separate service provider agreement.

Operate the Grid
Reactive power assets are normally controlled by the System Operator due to their regional impact. Unavailability of reactive power assets creates voltage stability issues and in a worst-case scenario could create regional constraints.

Outage planning of reactive power assets requires extensive network studies. Commissioning and testing of these assets also require System Operator test plans and in some cases liaising with generators for voltage management.

Forecast Expenditure
Our forecast expenditure for Reactive Power Assets is described below.

Capital Expenditure

RCP 2, 2018 to 2020
The original RCP 2 forecast was predominantly driven by age based replacement of capacitor banks. A capacitor bank asset review indicated that these aging capacitor banks can be safely operated till RCP 3 with ongoing maintenance alone. Haywards synchronous condenser cooling tower replacement projects are also delivering significant savings. These factors significantly reduced the revised RCP 2 forecast.

In contrast, newer dynamic reactive power assets required several unplanned projects to address emerging issues. Failure and consequential repair of Islington SVC9 resulted in $3.5m of unplanned capital expenditure which will be recovered through insurance in due course. Overall $4.5m of savings have been delivered through two reactive power asset portfolios.

RCP 3, 2020 to 2025
Several capacitor bank replacements that were deferred from RCP 2 will meet the replacement criteria in RCP 3. Further life extension is possible and will be considered during the options assessment stage. Asset data improvement initiatives that are underway will assist with making these Capex / Opex trade-offs.

Haywards synchronous condensers require internal inspections to be carried out which is a significant expense in RCP 3. Three Static Var Compensators (SVC) require midlife refurbishments to be carried out in RCP 3 to enable life extensions. The remainder of the expenditure is mainly focused on replacement of minor reactive power components at the end of their life. We are also expecting to procure more power electronic spares while they are still readily available. The overall forecast for RCP 3 is $57 million. In addition to this base capital expenditure, several major capital investment projects will be delivered across RCP 3 and RPC 4 (i.e. Waikato Upper North Island Voltage Management Project).

RCP 4, 2025 to 2030
RCP 4 expenditure is predominantly related to capacitor banks and STATCOM related works. Several aging capacitor banks will be replaced in RCP 4. All the STATCOM installations are expected to undergo control system upgrades and primary asset refurbishments. Depending on the reactive power demand we are also planning to uprate Haywards synchronous condensers which will be the largest single expenditure for this RCP ($14m). The total expenditure for the RCP 4 is expected to be $24m.
Operating Expenditure

Our RCP 2 submission had no allocated budget for maintenance projects for reactive power assets. All the maintenance work required for reactive power assets is captured under ongoing operational cost. With the extended operational life, we expect the operating expenditure to increase which in turn is expected to reduce the whole of life cost due to delayed capital replacement. Several minor maintenance projects are forecasted for dynamic reactive power projects to address several ongoing issues.

In future RCP forecasts, more funding will be allocated for procuring capacitor bank spares to mitigate the increased operational risks associated with life extension.

Key risks and uncertainties

A major risk associated with reactive power assets is the lack of asset knowledge and experience.

Present capacitor bank data structure doesn’t require recording of capacitor can failures. Therefore, historical capacitor can failure rates are difficult to obtain. Without a good understanding of capacitor can failure rates, extending capacitor bank operational life is a risk that needs to be managed well. It is necessary to procure more spares to achieve future availability requirements.

Apart from Haywards synchronous condensers, much of the dynamic reactive power asset class is relatively new technology with minimal operating experience. Hence there are some uncertainties associated with the forecast for dynamic reactive power assets.

Both capacitor banks and dynamic reactive power assets have experienced catastrophic failures. With extended operational lives, the risk of a catastrophic failure increases and it is important to conduct regular inspections to identify any issues in advance.

Haywards synchronous condensers experienced several major failures in recent years which were isolated incidents. Major failure of a synchronous condenser is a significant cost that hasn’t been considered in the forecast.

A major uncertainty associated with reactive power assets is the future state of the network. Factors such as distributed generation, commissioning of new transmission lines and/or under grounding of existing lines, generation and load pattern changes, network topology changes, and many other factors influence the reactive power demand. As seen in the Auckland area commissioning or decommissioning of transmission assets alone could have a significant impact on the regional reactive power demand. Hence the forecast could change significantly.

If any of the above risks eventuate it will be necessary to adjust the forecast to reflect the extra funding required for addressing these.

Summary, 2018 to 2030

<table>
<thead>
<tr>
<th></th>
<th>RCP 2</th>
<th>RCP 3</th>
<th>RCP 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assets</td>
<td>1.6</td>
<td>1.3</td>
<td>4.4</td>
</tr>
</tbody>
</table>

Table 75: Forecast capital expenditure

Long-term forecast

Long-term Opex forecast is expected to increase with the forecasted commissioning of more reactive power assets and due to extended service life of existing assets. It is expected that several aging capacitor banks and dynamic reactive power assets will reach their end of useful life requiring capital replacements rather than ongoing preventative and corrective maintenance.
SECONDARY ASSETS (SA) ASSET PORTFOLIO

Secondary Assets cover our assets that support substation operation and management. They consist of the following asset classes:

- Protection, Battery Systems and Revenue Meters
- Substation Management Systems

The primary purpose of secondary assets is to enable measurement, monitoring and control of the primary grid assets.

Key Initiatives
We have several key initiatives within the Secondary Assets portfolio. These are:

1. Management of legacy assets. This includes:
   - Replacement of legacy serial Remote Terminal Units (RTUs) with new IP-based Substation Management Platforms and related peripherals;
   - Delivery of Remote Engineering Access (REA) services to allow for remote device configuration and rapid response to grid events;
   - Life cycle replacement of protection schemes; and
   - Life cycle replacement of station batteries and DC system assets.

2. Improve the quality asset data across all portfolios:
   - Enhance the asset data structure to make the asset class easier to manage;
   - Increase the information we have on key assets to improve our planning;
   - Identify and address missing and inconsistent data.

3. Optimisation of asset life cycle management:
   - Development of a new criticality framework relating to the asset failure.
   - Monitor reliability of our asset classes to optimise the replacement timeframes;
   - Identification of new cost-effective technologies that can assist in the drive to reduce total cost of ownership;
   - Optimise alignment across portfolios to manage capacity and ensure delivery efficiency.

Expenditure Summary

Capital Expenditure
Our expenditure forecast for protection remains similar to what we reported in the 2016 AMP. Most of the metering work in RCP 2 is under review with the potential to use our existing numerical relays to provide the fault records rather than having dedicated Transient Fault Recorders. Therefore, work originally planned for FY16, FY17 and FY18 has been delayed to later in RCP 2 (FY19 and FY20) to allow time for this investigation to finalise the preferred option.

The number of SMS upgrades to be completed over RCP 2, and the timing for these, has changed due to extensive re-planning work undertaken in the past 12 months. This work also corrected the cost estimation deficiencies in the RCP 2 submission, and added initiatives to streamline delivery, to implement REA services at RCP 1 delivered sites, and to bring existing sites up to current SMS design standards. This will result in an increase expenditure of $22.7 million to the portfolio.

The planned expenditure for protection is expected to increase in RCP 3. This accounts for replacing feeder protection schemes not previously included. For batteries and DC systems the forecast has lifted significantly in RCP 3 onwards due to a higher number of replacements and an estimated $12.9 million increase in costs to meet black start requirements. In addition, a total of 76 sites are expected to be migrated to SMS during RCP 3 which will complete the RTU replacement programme.
Due to the age profile of our meters, the replacement tends to be cyclical. During RCP 3 several meters will also require replacement, at an estimated cost of $13.4 million. RCP 5 is the next cyclical period for meter replacement.

During RCP 4 we expect the expenditure profile for protection to continue, along with the increased requirements to replace batteries and DC systems. Metering replacements are expected to be lower than for RCP 3 and our SMS portfolio transitions into a largely maintenance-based programme of work, commencing with the replacement of SMS devices deployed in RCP 1 which will be approaching the end of their design lives. For any given site, the SMS life cycle replacement costs are estimated to be approximately 40% of the initial deployment costs.

<table>
<thead>
<tr>
<th>Protection, Batteries and Meters</th>
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<td>31.7</td>
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</table>

Table 76: Secondary Assets capital forecast

Operational Expenditure

We have a requirement under the Electricity Industry Participation Code for regular testing of relays of all types; ten-yearly testing for numerical relays and four-yearly for electromechanical, static, and microprocessor relays. We test our relays at these intervals or more frequently. The post-2000 numerical relays have advanced levels of self-monitoring so generally require less frequent testing than older relays. Condition assessment is not required on protection devices as they are considered to either pass or fail their testing. In addition to protection scheme maintenance, there is also maintenance required on station DC battery supply systems, revenue metering and station control and monitoring systems. Our specific preventive maintenance will generally include the following activities.

- **Inspections:** inspection of secondary assets aims to ensure that systems and equipment are in a safe and serviceable condition and that any abnormalities that represent a risk to Grid reliability, safety of personnel or the security of the site are identified and rectified.

- **Diagnostic testing:** this involves measuring electrical and sometimes mechanical parameters such as insulation, gas operated relay checks, alarm operations, and DC battery bank performance.

- **Servicing:** this involves periodic servicing, aligned with inspections and to maintain asset condition.

- **Corrective and preventative maintenance:** this is work initiated as a result of faults, identified defects or proactively in response to condition assessments. The work also includes responding to remote monitoring (SCADA) alarms and protection relay data collection.

We have developed the frequencies for our inspection, condition assessment and servicing for secondary assets in conjunction with the Electricity Industry Participation Code, historical performance over a number of years, and in line with common industry practice. The Opex costs for secondary assets is captured within the stations portfolio.
Risks and Uncertainties

The material risks and uncertainties associated with this portfolio are largely related to the “brown fields” nature of the sites that constitute the majority of the planned and unplanned work. This leads to some specific risks and uncertainties which can impact the cost of delivered work:

1. Most projects find it necessary to address existing site issues and defects before deployment of deliverables can commence. The scope of such work is varied but often comes at significant additional cost resulting in high cost uncertainties.

2. New business cases for SMS are preceded by a site-specific high-level design and cost estimates to identify the likely scope and cost of the proposed work. This provides increased certainty but cannot address the fact that RCP 2 Building Blocks generally do not make allowances for addressing existing site deficiencies.

3. Design work is undertaken in the first year of a project, with delivery occurring in the second. This provides a planning lead time to mitigate resourcing issues, but as the work is specialised it is not possible to fully alleviate all labour constraints.

4. There is increasing penetration of ICT services into the substation which is resulting in a growing level of sophistication and complexity. As a result, the transition from the current state to the post-project state can be difficult to manage leading to delivery risks, particularly at the larger sites.

Asset Class Plans

The following sections describe in more detail our asset management approach for each of the asset classes. These asset class plans describe the strategy, asset characteristics, management approach and expenditure profile for each asset class. The expenditure covers the capital requirements, along with any specific maintenance projects to be undertaken.
ASSET CLASS PLAN – PROTECTION, 125V DC BATTERY SYSTEMS AND REVENUE METERS

This asset class plan describes our life cycle management approach for the following assets:

- Protection equipment
- 125V DC systems used for protection
- Revenue meters

Protection equipment is used to rapidly detect and initiate isolation of electrical faults to protect primary equipment and ensure the safety of employees, service providers and the public.

The 125V DC systems, are installed at substations to provide essential power supply to our substation secondary assets, which include protection schemes, circuit breaker trip and close coils, control, and metering equipment.

Revenue meters supply electricity volume information, which is used for reconciliation and billing within the wholesale electricity market.

The following describes each of the assets in this plan.

**Protection**

Protection equipment is used throughout the grid. It is used to rapidly detect and initiate isolation of electrical faults to protect primary equipment and ensure the safety of employees, service providers and the public. Special Protection Schemes are used to delay or replace new investment in the grid. Our protection equipment comprises of electromechanical, static, microprocessor, and numerical types. The type of equipment in service is largely dependent on the prevailing technology at the time it was installed. We classify its use under nine categories:

- Bus protection
- Feeder protection
- Line protection
- Transformer protection
- Capacitor and Reactor protection
- Special Protection Schemes (SPS).
- Arc Flash protection
- Circuit Breaker protection
- Transient Fault recorders

Table 77 shows the breakdown and average age of the population by type.

<table>
<thead>
<tr>
<th>Type</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bus protection</td>
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</tr>
<tr>
<td>Feeder protection</td>
<td></td>
</tr>
<tr>
<td>Line protection</td>
<td></td>
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<tr>
<td>Transformer protection</td>
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<tr>
<td>Capacitor and Reactor protection</td>
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<tr>
<td>Special Protection Schemes (SPS)</td>
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<tr>
<td>Arc Flash protection</td>
<td></td>
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<tr>
<td>Circuit Breaker protection</td>
<td></td>
</tr>
<tr>
<td>Transient Fault recorders</td>
<td></td>
</tr>
</tbody>
</table>

Table 77: Protection Asset population
DC battery supply systems

The 125V DC systems, are installed at substations to supply power to protection schemes and other items such as circuit breaker trip and close coils, control, and metering. These assets are required to operate not only during normal operation but also when the local AC service supply has failed. They typically consist of both batteries, the battery charging systems, the fuse boxes, primary DC panel, secondary DC panels, and any associated assets like the DC condition monitoring relay. Table 78 shows the population of our DC battery supply systems by type.

<table>
<thead>
<tr>
<th>Type</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery banks</td>
<td>383</td>
</tr>
<tr>
<td>Battery chargers</td>
<td>545</td>
</tr>
</tbody>
</table>

Table 78: Population of battery supply systems

Revenue Metering

Revenue meters supply electricity volume information, used for wholesale market reconciliation and billing. We have approximately 400 revenue meters installed at 145 different sites.

Asset Characteristics

The assets within this plan are small but critical components for the operation of both the grid and the electricity market. As such, the health and the reliability of their operation is paramount.

The bow-tie analysis indicates the predominant failure causes for 125V DC battery systems is degradation and corrosion, and damage caused by pests and vermin. The key preventive controls are staggering battery replacements, improve procurement specifications, and regular functional testing.

Age Profile

The life expectancies for the different protection schemes and relay types range from 15-25 years for numerical relay schemes and 35-40 years for electromechanical relay schemes. Static and microprocessor protection schemes sit in between these at 20-25 years.

Figure 59 shows the age profile for the DC Supplies portfolio. Life expectancy is 8-12 years for batteries and 20-30 years for chargers.

All revenue meters were replaced in RCP 1, so are between 3 and 7 years old. The life expectancy for revenue meters is 10 to 12 years.

15 Newly installed batteries can achieve longer life and we anticipate a minimum of 12 years’ service from our newer batteries.
Asset Health

The predominant factors that contribute to deteriorating health for this asset class are age, design, manufacturing, and batch type. For the protection assets, relays from different manufacturers have varying health deterioration rates.

Our protection, battery supply systems, and revenue meters are all in good condition. Due to the nature of these assets they are regularly monitored, tested, and replaced as required. As they also have relatively short expected lives the evolution of technology types is also evident with older technology retired from the population relatively quickly. The only longer life equipment is the electromechanical protection with a life expectancy of 40 years compared with 20 to 25 years for all other types of protection schemes.

Existing batteries typically remain in reasonable condition throughout their first eight years of service while the newly installed batteries are expected to be in good condition for the first twelve years of service. After this time, they are replaced. Figure 60 shows the asset health of our batteries.

![Figure 60: Battery Asset Health](image)

All our revenue meters are in good condition. Their life expectancy is fifteen years. After this time, they are replaced.

Asset Criticality

The criticality for the assets in this plan is dependent on the circuit, site, and the asset it is protecting. We are currently quantifying and monetising the direct cost from planned and unplanned replacements, the service performance impact from unserved energy, and workplace and public safety. We also consider redundancy or duplication of the asset, self-monitoring capability to report failures back to SCADA, and the likelihood of primary plant failure or fault in the network. The values are then used in conjunction with the probability of failure to determine the optimal replacement interval. This is consistent with our criticality framework.
Asset Performance

Major failures for 125V DC systems is defined as the inability of the DC system to provide DC supply to secondary assets and/or operate circuit breaker trip coils which results in either interruption of supply or unplanned outages. The following chart shows the number of historical major failures on an annual basis:

Figure 61: Historical DC system major failures by types

In 2003, there were several charger failures which led to the identification of an inherent design issue with a particular type of charger which causes the charger to turn off when there is a power fluctuation on the local AC service supply. Since then, we have repaired units of the same type in our network and have not experienced a similar failure.

Asset Life Cycle Stages

Our asset management approach seeks to ensure safety and reliability, at least life cycle cost. Due to the criticality of the systems, while it varies slightly between asset types, our approach is to replace based on age. However, other factors are also considered such as the unavailability of spares and/or manufacturer support, the equipment is not able to provide the required functions, the primary equipment that the protection relay is protecting is being replaced, and the relay is at more than 60% of its nominal design life, a small model population where lack of engineer and technical familiarity with the model is an issue, and replacement as part of an optimised integrated works plan.

Strategic Planning

We have the following strategic objectives for our protection, 125V DC systems and revenue meters:

Safety
- Zero fatalities and injuries while maintaining, repairing, or installing protection, batteries or revenue meters

Service Performance
- Zero instances of failures leading to interruption of supply
- Meet carryover requirements set out by the System Operator

Cost Performance
- Minimise life cycle cost

New Zealand Communities
- Minimise environmental impact through appropriate disposal of lead-acid batteries through accredited service providers
Development Initiatives
We continually assess alternative technologies available in the market and develop standard designs for viable new technologies.

Tactical Planning
Our tactical planning approach for this asset class is targeted at replacement, accounting for the criteria outlined above. Batteries are replaced based on age, unless tests reveal the need for an early replacement or if a higher capacity battery or charger is required due to upgrades to the site i.e. Outdoor to Indoor Conversions. Battery replacements at a site are also staggered to ensure that when battery bank 1 is replaced battery bank 2 still has half its life remaining.
Revenue meters are replaced based on their age.

Condition Assessments
Condition assessments are carried out on the majority of the network assets so that any deteriorating assets can be identified and scheduled for repair or replacement. However, the condition assessments of this asset class are generally binary pass/fail assessments, some of the assets are self-monitored, with failure resulting in replacement.
The functionality of protection schemes are regularly tested at the following intervals:
- 4 years for schemes with electromechanical, static and microprocessor relays; and
- 8 years for schemes with numerical relays.
We regularly test 125V DC systems by performing functional checks on alarms, float voltage and supply voltage. Monthly and Annual visual inspections are also performed regularly on protection schemes and 125V DC systems. Annual visual inspections are conducted on the revenue meters. Meter maintenance, calibration, and data logger maintenance are carried out every three years.

Decision Framework
The work programme for protection, 125V DC systems, and revenue meters is determined by applying the four steps of the Decision Framework.

Need identification
Age, obsolescence, risk, and functional requirements are used to identify needs and associated need dates.

Options Assessment
In most cases the only option is to replace the asset, as refurbishment is not cost effective. The exception occurs for some batteries and DC systems, where a more detailed analysis of options is needed.
For all asset replacements, the options are also dependent on the technology available at the time the need is assessed.

Prioritise solutions
Solutions are prioritised based on need date.

Develop a Programme Management Plan
We combine plans for work by site, scheme, or by circuit. For example, protection works may be combined with Substation Management System replacements or our 33 kV Switchyards Outdoor to Indoor conversions, and replacement of primary equipment. Battery and charger replacement work is mostly grouped by service area.
Cost estimation
Protection, batteries, and revenue meter replacements are volumetric works as they are repetitive with similar scope. We use TEES building blocks to form the basis for estimates for this.

Costing of non-volumetric protection and DC system replacement and installation works are based on customised designs and estimation. This applies to:
- SPS
- High Impact Low Probability investigations involving protection assets
- Bus Zone Protection works
- Transient Fault Recorder Replacement Plan
- Minor works to increase capacity of supply transformers.

Contingency planning
We maintain contingency response resources including sufficient field staff and emergency spares to enable rapid restoration following a failure. The spares are condition-monitored, maintained, and are ready for immediate installation and service. In some cases, we also bring replacements forward for certain legacy battery chargers to keep as spares for the remaining asset class.

Programming and scheduling
As a volumetric programme, works are integrated into a wider programme schedule that accounts for other works at the same locations using common resources.

Project Delivery
The five aspects of project delivery are design, procurement, programme and project management, commissioning, and decommissioning and disposal.

Design
To ensure a consistent approach to design we use standard designs where possible.

Procurement
We reduce overall life cycle costs and risk by using pre-qualified vendors, detailed specifications, and economies of scale approach. For all components, experience has shown that quality in manufacture is fundamental to lifetime performance. Therefore, sourcing of quality products is fundamental.

Programme and Project Delivery
Our Programme and Project delivery is undertaken in accordance with our programme management framework. The delivery of protection, significant 125V DC systems, and revenue metering replacement works typically comprise of detailed design, procurement, outage planning and co-ordination with other major works at the site. The delivery timeframes for this work is typically 2 years in duration.

The delivery timeframes for all other 125V DC systems work is typically 1 year in duration.

Commissioning
Our commissioning plan outlines commissioning planning, testing, livening, hand over, operational, and maintenance processes.

Once all works are complete, our project close-out activities include final capitalisation of the project within our financial systems, provide feedback about actual costs to assist with future cost estimation, updating asset management information systems, archiving of the relevant documentation, and the review of ‘lessons learned’ including a review of health and safety performance.
Decommissioning and Disposal
There are specific requirements for decommissioning DC supply systems and components. For example, batteries mostly consist of lead acid which can be recycled. Elemental lead is toxic and is kept from being released to the environment.

Service Delivery
Due to the modular nature of the assets there are no corrective or predictive maintenance activities undertaken. Preventive maintenance activities are limited to the inspection regime described above.

Operate the Grid
We plan and manage outages in a way that creates a safe environment for employees while minimising the disruption for customers.

Forecast Expenditure
Our forecast expenditure for protection, battery systems and revenue meters is described below.

Capital Expenditure

RCP 2, 2018 to 2020
Overall, the expenditure on protection for RCP 2 remains close to what was reported in the 2016 AMP. The key differences from the original RCP 2 allowance are driven by increasing costs for duplicated line protection schemes by $40,000; and a delay of protection works at Penrose into the RCP 3 period. RCP 2 costs for batteries and DC systems is lower than forecast due to cost savings across the asset class. However, forecasted work volumes for 2019 will increase the overall outcomes for RCP 2.

The majority of metering work in RCP 2 comprised the replacement of existing Transient Fault Recorders. An investigation was started in early RCP 2 to identify the feasible and most effective option in providing fault records after a disturbance on the network. One of the options identified involved using existing numerical relays to provide the fault records versus having dedicated Transient Fault Recorders. This option could potentially save significant costs relative to the budget for this work. Therefore, work originally planned for FY16, FY17 and FY18 has been delayed to later in RCP 2 (FY19 and FY20) to allow time for this investigation to finalise the preferred option.

RCP 3, 2020 to 2025
The planned expenditure for protection is expected to increase in RCP 3 to account for replacing feeder protection schemes not previously included. For batteries and DC systems the forecast has lifted significantly in RCP 3 onwards due to:
- an estimated $12.9m increase in costs to meet black start requirements
- a higher number of forecast charger replacements in RCP 3, 4 and 5 compared to RCP 2. This is due to a larger number of chargers reaching end of life.

Due to the age profile of our meters, the replacement tends to be cyclical. During RCP 3 several meters will also require replacement, at an estimated cost of $13.4m. RCP 5 is the next cyclical period for meter replacement.

RCP 4, 2025 to 2030
During RCP 4 we expect the expenditure profile for protection to continue, along with the increased requirements to replace batteries and DC systems. Metering replacements are expected to be lower than for RCP 3.
Operating Expenditure

The portfolio has a small Opex budget which is funding a number of small tactical upgrades to address reliability issues where these have been identified.

Key risks and uncertainties

The scale of the projects tends to be smaller for this asset class and as such the primary risks and uncertainties are associated with delivery of the volume of expected work than necessarily the one-off costs of individual projects.

Summary, 2018 to 2030

<table>
<thead>
<tr>
<th></th>
<th>RCP 2</th>
<th>RCP 3</th>
<th>RCP 4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2016</td>
<td>2017</td>
<td>2018</td>
</tr>
<tr>
<td>Protection,</td>
<td>11.4</td>
<td>12.4</td>
<td>11.6</td>
</tr>
<tr>
<td>Batteries and</td>
<td>14.2</td>
<td>12.4</td>
<td>30.4</td>
</tr>
<tr>
<td>Meters</td>
<td>26.1</td>
<td>25.8</td>
<td>23.4</td>
</tr>
<tr>
<td></td>
<td>26.5</td>
<td></td>
<td>20.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20.2</td>
<td>21.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>24.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>29.2</td>
</tr>
</tbody>
</table>

Table 79: Forecast capital expenditure

Long-term forecast

Over the long term we expect there will be a steady requirement to replace assets as they reach end of life. However, RCP 5 will see an increase in the number of meters needing to be replaced, leading to increase asset class costs for the period.
ASSET CLASS PLAN – SA SUBSTATION MANAGEMENT SYSTEMS (SMS)

This asset class plan describes the life cycle management approach of our SMS. This plan covers:

- Legacy Remote Terminal Units (RTUs)
- Station Gateways, also known as Substation Management Platforms (SMPs)
- GPS Clocks

SMS have been specifically designed to operate in electricity utility environments. They enable the remote control and real-time monitoring of the equipment at our substations and are used to connect a substation to Transpower’s SCADA/EMS System. This is how we control and manage any given site. There are two main types currently in service. One is a legacy serial-based RTU, and the other is an Ethernet-capable Substation Management Platform (SMP). The older serial-based RTUs are being phased out and will soon all be replaced with modern SMP devices.

GPS clock systems are used to provide high-precision time synchronisation across all substation devices to support protection functions and to ensure accurate time tagging of events as they occur at substations. Our GPS Clock assets are divided into Ethernet and non-Ethernet devices, however neither type of clock will meet our longer-term requirements and a new device has been selected as the future platform for time synchronisation.

Table 80 shows the populations of our legacy RTUs and modern SMPs. Table 81 shows the population of GPS clocks by type.

Table 80 - Type and Populations of RTU and SMP Devices

<table>
<thead>
<tr>
<th>Type</th>
<th>Age Range</th>
<th>Units in Service</th>
<th>No of Sites</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>SG-4250</td>
<td>&lt; 1 years</td>
<td>0</td>
<td>0</td>
<td>2nd generation SMP (now commencing deployment).</td>
</tr>
<tr>
<td>SMP16</td>
<td>&lt; 5 years</td>
<td>49</td>
<td>42</td>
<td>1st generation SMP.</td>
</tr>
<tr>
<td>GE Harris D200</td>
<td>6 to 10 years</td>
<td>19</td>
<td>19</td>
<td>No longer supported and spares unobtainable (legacy units).</td>
</tr>
<tr>
<td>GE Harris D20VME</td>
<td>1 to 16 years</td>
<td>70</td>
<td>67</td>
<td></td>
</tr>
<tr>
<td>GE Harris D20ME</td>
<td>2 to 13 years</td>
<td>14</td>
<td>12</td>
<td>No longer supported; no Ethernet and spares unobtainable (legacy units).</td>
</tr>
<tr>
<td>GE Harris D20M++</td>
<td>5 to 18 years</td>
<td>26</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Foxboro C50</td>
<td>11 to 20 years</td>
<td>67</td>
<td>8</td>
<td>Legacy units</td>
</tr>
</tbody>
</table>

Table 81 - GPS Clock by Type

<table>
<thead>
<tr>
<th>Type</th>
<th>Units in Service</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serial</td>
<td>97</td>
<td>Obsolete model</td>
</tr>
<tr>
<td>Ethernet Capable</td>
<td>87</td>
<td>Deprecated model</td>
</tr>
<tr>
<td>Multi-LAN PTP Capable</td>
<td>0</td>
<td>New model due to enter service in 2017</td>
</tr>
</tbody>
</table>

Asset Characteristics

When the current generation of substation telemetry technologies was first installed in the early 1990s the system was based on serial RTUs. This technology is now obsolete, as RTUs are now no longer supported by manufacturers, we cannot obtain spares, and modern protocols are not supported. Additionally, our in-service RTUs have insufficient computing (CPU) capacity as modern intelligent electronic devices (IEDs) require more signal processing than their predecessor’s capability.

16 Also known as time synchronisation clocks
We are in the process of replacing our RTU technology with modern IP-based Station Gateway technology. The new gateways deliver fast communication between devices, support all modern protocols, and can enable new applications such as special and advanced protection schemes. In addition, the new platform provides remote engineering access (REA) which permits the direct and immediate retrieval of information captured by IEDs without the need to send a person to the substation. This facilitates prompt analysis of data following a fault which directly leads to a faster restoration of service to our customers.

**Age Profile**

The age profile for our SMP is shown in Figure 62.

![Figure 62: Distribution of SMP Age Profile by Device Type](image)

Figure 62: Distribution of SMP Age Profile by Device Type

Figure 63 shows the age profile of our GPS Clocks.

![Figure 63: GPS Clock Age Profile](image)
Asset Health

Overall the asset health of our SMS assets is fair, but as RMUs age the condition of these assets are declining.

RTUs

Legacy RTU technology has reached the limit of its capacity and functionality and this is increasingly constraining our ability to control and monitor our substations.

There are also an increasing number of RTU failures, caused predominantly by the loss of their input/output (I/O) modules. Most I/O modules are well past their expected life as they were not replaced when the RTUs were upgraded in the early 2000s. Figure 64 shows the age profile of our I/O modules compared to the manufacturer’s recommended replacement age.17

![Figure 64: I/O Module Age Profile](image)

SMPs

SMPs commenced deployment in 2011 so this group of assets is in excellent health with an expected design lifetime of 15 years with life cycle replacement projects scheduled commencing RCP 4. The newly deployed IO modules have an expected design lifetime of 25 years, but many are expected to be eliminated by future protection upgrades, and as such no replacements have yet been scheduled.

GPS Clocks

GPS clocks are generally in good health. A review in 2016 identified several devices in need of urgent replacement and this field work is currently underway. The remainder of the asset class will be replaced as part of planned RTU upgrades, or through programmed life cycle replacement projects.

Asset Criticality

Our prioritisation for SMS investment recognises the differing levels of site criticality, based on the amount of sustained load or generation lost after a High Impact Low Probability event at the site, the amount of load that is transferred through the substation; and the grid exit point’s long-term performance targets (if applicable).

---

17 C50 I/O modules also date to 1991-1997 but are not shown here as we lack the information to provide a breakdown by model.
Asset Performance
RTU and I/O failures are increasing. These failures are of concern as any loss of real-time monitoring and control over our primary assets impacts directly on grid reliability, safety, and the System Operator’s role in the electricity market. Reliability performance of existing RTUs is forecast to continue to decline at an accelerating rate as the asset class continues to age.
We do not have sufficient reliability data for the SMS installations to be meaningful because we are at a very early stage of the SMP deployment programme.

Asset Life Cycle Stages
Our asset management approach is to phase out legacy RTUs and I/O modules when they reach 15 years of age, or at the latest by the end of RCP 3, replacing them with a modern Station Gateway platform. We will no longer undertake RTU only replacements where interfaces remain with existing legacy I/O modules as this approach will lead to increasing life cycle cost and does not address deteriorating asset class condition.

Strategic Planning
The following strategic objectives has been set for SMS:

Safety
- Increase remote plant status visibility for operators and field staff
- Enable network operations to be carried out remotely

Service Performance
- Reduced interruption duration times with use of remote access to engineering information and reduced overall average network fault resolution time
- Average of six or less RTU and SMS failures each year by 2020
- 5 year rolling average of 30 or less I/O module failures by 2020.
- Comply with the latest information security standards, as recommended for critical infrastructure

Cost Performance
- Reduced annual telemetry maintenance costs

Tactical Planning
We are continuing our staged replacement of RTU-based telemetry systems with SMS, (SMP) and expect this to be completed by 2025. We have not yet been able to connect some of our remote sites to our communications fibre network. These sites generally feed a small load with few IEDs and would not be able to realise the full range of benefits of the migration to SMS. We are prioritising the migration to SMS based on the condition and technical obsolescence of the existing RTUs and site-level benefits. The specific investment drivers are:
- Replacement of RTUs and I/O modules with SMS equipment when they reach the manufacturer’s recommended age of 15 years
- Replace GPS clocks based on obsolescence drivers subject to a maximum age of 15 years
- Implementation of REA when deploying SMS.

Condition Assessment
Condition is difficult to assess because the assets are static and are either functioning correctly or have failed. There is no observable degradation in performance that can be used to check on asset condition. Condition assessments for these assets are limited to a visual inspection of the physical condition of an asset in accordance with service specifications.

Decision Framework
The work programme for protection, 125V DC systems, and revenue meters is determined by applying the four steps of the Decision Framework.
Need identification
The need is to replace obsolete RTUs with SMS. The need date is allocated on site criticality and technical obsolescence of the existing RTUs.

Options Assessment
There is no separate option assessment completed for SMS, as our strategy is to replace all legacy RTUs with SMS-IP equipment.

Prioritise solutions
Solutions are prioritised based on need date.

Develop a Programme Management Plan
In developing the prioritised work plan into a detailed asset management plan consideration is given to factors such as asset age, site criticality, related projects, and resource loading. This is an iterative process and work is brought forward and/or deferred as required until a workable plan is achieved. Changes in dependent projects will often result in significant planning re-work as the impact of the adjustments are mitigated.

Cost estimation
SMS deployments are categorised as volumetric work and we use a building block approach for cost estimation. However, building block costs have varied significantly from average outturn costs and by site. To mitigate this, we undertake detailed site investigations so that all site-specific factors have been accounted for when the business case is prepared and authorised.

Contingency planning
As we can no longer purchase RTUs, we salvage legacy RTUs for spare parts when we decommission them. This enables us to keep RTUs in service through repairs and component replacements until they are scheduled for replacement with SMS. Although RTU I/O modules can still be purchased, we salvage I/O modules that are less than 15 years of age when deploying SMS at a site.

Programming and scheduling
As a volumetric programme, works are integrated into a wider programme schedule that accounts for other works at the same locations using common resources.

Project Delivery
The five aspects of project delivery are design, procurement, programme and project delivery, commissioning, and decommissioning and disposal.

Design
We use standardised solutions when deploying SMS to reduce deployment risks and the costs associated with bespoke designs.

Procurement
To reduce life costs and procurement risks we currently use one vendor as our standard system solution provider. We have ensured we received extended technical support of existing equipment from the vendor. We purchase all necessary licenses when we deploy SMS.

Programme and Project Delivery
Our Programme and Project delivery is undertaken in accordance with our programme management framework. The delivery timeframes for SMS account typically comprise of detailed design, procurement, outage planning and co-ordination with other major works at the site. The delivery timeframes for this work is typically 2 years in duration. The delivery timeframes for GPS clock and Human Machine Interface (HMI) work is typically 1 year in duration.
Commissioning
Our commissioning plan outlines commissioning planning, testing, livening, hand over, operational, and maintenance processes.

Once all works are complete, our project close-out activities include final capitalisation of the project within our financial systems, provide feedback about actual costs to assist with future cost estimation, updating asset management information systems, archiving of the relevant documentation, and the review of ‘lessons learned’ including a review of health and safety performance.

Decommissioning and Disposal
We salvage all useable RTU spare parts when they are decommissioned. Other non-useable or unnecessary components are sent to a specialist electronics disposal company for recycling.

Service Delivery
Due to the modular nature of the assets there are no corrective or predictive maintenance activities undertaken. Preventive maintenance activities are limited to the inspection regime described above.

Operate the Grid
We plan and manage outages in a way that creates a safe environment for employees while minimising the disruption for customers.

Forecast Expenditure
Our forecast expenditure for SMS is described below.

Capital Expenditure
RCP 2, 2018 to 2020
The number of SMS upgrades to be completed over RCP 2, and the timing for these, has changed due to extensive re-planning work undertaken in the past 12 months. This work also corrected the cost estimation used in the RCP 2 submission, and added initiatives to streamline delivery, to implement REA services at RCP 1 delivered sites, and to bring existing sites up to current SMS design standards. This will resulted in an increase expenditure of $22.7m to the portfolio.

Work on standalone Human Machine Interface and GPS clock replacements also continues but overall these constitute only a minority cost in the overall portfolio.

RCP 3, 2021 to 2025
The forecast for RCP 3 remains relatively unchanged. A total of 76 sites are expected to be migrated to SMS during RCP 3 which will complete the RTU replacement programme.

RCP 4, 2026 to 2030
From RCP 4 the SMS portfolio transitions into a largely maintenance-based programme of work, commencing with the replacement of SMS devices deployed in RCP 1 which will then be approaching the end of their design lives. For any given site, the SMS life cycle replacement costs are estimated to be approximately 40% of the initial deployment costs.

Operating Expenditure
This portfolio has no operating expenditure budget.

Key risks and uncertainties
The forecast assumes that all planned work will proceed as scheduled and that all interdependencies have been identified. Changes in the overall work plan, delays in the approval of work, or resourcing constraints that impact delivery will result forecast updates. Likewise, the “brown fields” nature of sites will continue to provide scope and cost challenges as unbudgeted site-specific remediation work is often required as a prerequisite to delivery.

The forecast is also dependent upon the market costs of materials and resources remaining constant.
Summary, 2018 to 2030

<table>
<thead>
<tr>
<th></th>
<th>RCP 2</th>
<th></th>
<th></th>
<th>RCP 3</th>
<th></th>
<th></th>
<th>RCP 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMS</td>
<td>6.4</td>
<td>10.8</td>
<td>15.3</td>
<td>11.7</td>
<td>13.0</td>
<td>18.8</td>
<td>12.9</td>
</tr>
</tbody>
</table>

Table 82: Forecast capital expenditure

Long-term forecast

It is expected that expenditure during RCP 5 and RCP 6 will be closer to the RCP 4 level, as life cycle replacement continues. There may be an increase in expenditure in RCP 6 if it becomes clear that significant numbers of SMS peripherals require replacement. These devices will be reaching end-of-life in RCP6, but as many are expected be replaced as part of the ongoing protection scheme upgrades the device count and distribution in RCP6 cannot be forecast at the present time.
7. ICT ASSET PORTFOLIOS

This section describes our asset management approach, plans, risks, and expenditure forecasts for the ICT Portfolios. The five ICT portfolios are:

- Asset Management
- Transmission Systems
- Corporate Systems
- Shared Services
- Telecommunications, Network, and Security Services

Each portfolio plan covers the business requirements, life cycle needs and the forecast investment required path for the planning period.

PORTFOLIO PLAN OVERVIEW

Together our Asset Management and Transmission Systems portfolios describe the business requirements for managing and operating the grid. We have categorised these grid business requirements into 12 functional business themes. Delivery and operation of the wider ICT environment is described by the three supporting portfolios, shared services, corporate systems, and telecommunications, network, and security services. This structure is illustrated in Figure 65.

![Functional Business Themes Diagram]

Each functional business theme represents the business capability and systems required to deliver transmission services to...
our customers and stakeholders. Table 83 defines the scope of each area.

<table>
<thead>
<tr>
<th>ICT Portfolio</th>
<th>Business Theme</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asset Management Systems Portfolio and Transmission Systems Portfolio</td>
<td>Strategy &amp; Planning</td>
<td>The creation and management of strategies and plans to guide the development of Grid capabilities and systems in alignment with all stakeholder’s needs.</td>
</tr>
<tr>
<td></td>
<td>Asset and Work Planning &amp; Delivery</td>
<td>Enables the effective and efficient delivery of asset build and asset maintenance activities.</td>
</tr>
<tr>
<td></td>
<td>Asset Operations &amp; Control</td>
<td>Provision of real-time visibility and control of grid assets to manage risks and ensure security of supply.</td>
</tr>
<tr>
<td></td>
<td>Power Systems Engineering</td>
<td>Capabilities and tools to support the power systems design process, simulation, and testing.</td>
</tr>
<tr>
<td></td>
<td>Grid Risk &amp; Performance Management</td>
<td>Capabilities and systems required to effectively understand and manage the Grid risks at component and network level.</td>
</tr>
<tr>
<td></td>
<td>Outage Planning &amp; Switch Management</td>
<td>Capabilities and systems to optimise Grid outages to maximise service availability, while ensuring planned Grid works can be carried out safely.</td>
</tr>
<tr>
<td></td>
<td>Asset Management</td>
<td>Capabilities and systems to ensure Transpower has complete, accurate and current information on all Grid assets, how they are deployed and configured.</td>
</tr>
<tr>
<td></td>
<td>Situational Intelligence</td>
<td>Systems, and services to acquire, analyse and present real-time event information both internally and externally to field crews.</td>
</tr>
<tr>
<td></td>
<td>Mobility Services</td>
<td>Capabilities and services to enable Transpower and service provider staff to receive information and enable updates to be made from the field.</td>
</tr>
<tr>
<td></td>
<td>Process Automation &amp; Integration</td>
<td>Automated exchange of asset information and business processes execution between Transpower, service providers and customers.</td>
</tr>
<tr>
<td></td>
<td>Asset Data, Information &amp; Business Intelligence</td>
<td>Effective creation, management and use of asset master and transactional data as well as semi-structured and unstructured information. This includes support for time-series and analytics capabilities for improved decision support.</td>
</tr>
<tr>
<td></td>
<td>Support Services</td>
<td>Support services provide the grid capabilities and systems for enterprise wide services.</td>
</tr>
</tbody>
</table>

| Corporate Systems Portfolio | Our Corporate systems support Transpower to efficiently operate its core day to day business functions, providing shared capabilities across all business teams. |
| Shared Services | Enabling platforms for business solutions and the development and oversight of corporate information management. These include design, build and maintenance of our core technologies comprising hardware, operating systems, middleware technologies, and our Northern and Southern data centres. |
| Telecommunications, Networks and Security | Provides a secure, high capacity, fibre optic national communications network allowing telecommunication between all our sites and locations that support grid operations, critical switching, and the grid protection functions. |

Table 83: Portfolio Business themes
Expenditure Summary
Table 84 summarises the ICT capital expenditure by Portfolio.

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Asset Management</td>
<td>2.4</td>
<td>5.0</td>
<td>5.5</td>
<td>13.8</td>
<td>10.6</td>
<td>7.2</td>
<td>11.9</td>
<td>7.1</td>
<td>3.9</td>
<td>7.0</td>
<td>2.7</td>
<td>6.0</td>
<td>6.0</td>
<td>6.0</td>
<td>6.2</td>
</tr>
<tr>
<td>Transmission Systems</td>
<td>16.5</td>
<td>3.7</td>
<td>4.0</td>
<td>5.5</td>
<td>5.3</td>
<td>15.1</td>
<td>3.9</td>
<td>3.8</td>
<td>4.2</td>
<td>14.0</td>
<td>8.0</td>
<td>8.0</td>
<td>6.0</td>
<td>6.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Corporate Systems</td>
<td>1.6</td>
<td>5.3</td>
<td>1.4</td>
<td>4.0</td>
<td>0.0</td>
<td>1.7</td>
<td>5.8</td>
<td>1.6</td>
<td>1.5</td>
<td>1.1</td>
<td>4.7</td>
<td>4.0</td>
<td>3.9</td>
<td>2.3</td>
<td>4.0</td>
</tr>
<tr>
<td>Shared Services</td>
<td>6.1</td>
<td>5.9</td>
<td>4.3</td>
<td>12.1</td>
<td>5.2</td>
<td>6.2</td>
<td>7.5</td>
<td>5.7</td>
<td>4.8</td>
<td>5.1</td>
<td>4.8</td>
<td>7.0</td>
<td>6.2</td>
<td>5.5</td>
<td>5.6</td>
</tr>
<tr>
<td>Telecommunications, Network, and Security</td>
<td>5.1</td>
<td>20.5</td>
<td>11.0</td>
<td>2.8</td>
<td>10.2</td>
<td>3.6</td>
<td>11.8</td>
<td>35.5</td>
<td>26.9</td>
<td>3.0</td>
<td>9.0</td>
<td>8.5</td>
<td>9.2</td>
<td>8.0</td>
<td>8.5</td>
</tr>
<tr>
<td><strong>ICT Total</strong></td>
<td><strong>31.6</strong></td>
<td><strong>40.4</strong></td>
<td><strong>26.2</strong></td>
<td><strong>38.3</strong></td>
<td><strong>31.3</strong></td>
<td><strong>33.8</strong></td>
<td><strong>40.9</strong></td>
<td><strong>53.6</strong></td>
<td><strong>41.3</strong></td>
<td><strong>30.3</strong></td>
<td><strong>29.1</strong></td>
<td><strong>33.5</strong></td>
<td><strong>31.3</strong></td>
<td><strong>27.8</strong></td>
<td><strong>29.3</strong></td>
</tr>
</tbody>
</table>

Table 84: ICT capital Expenditure

Key Assumptions, Risks and Uncertainties
In the long term, the continued acceleration of ICT technology development will almost certainly drive changes to our forecast expenditure. Hence, while the forecast expenditure is based on the best information we have today, expenditure beyond 5 years is relatively uncertain and will likely change as newer technologies emerge. Table 85 lists the emerging trends.

<table>
<thead>
<tr>
<th>Trend</th>
<th>What is it about?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Everything as a Service (XaaS)</td>
<td>XaaS envisions business capabilities, services, and processes not as discreet vertical offerings operating individually in silos but, as a collection of horizontal services that can be accessed and leveraged across organizational boundaries to create outcomes of value to consumers. By embracing XaaS, an organisation can focus on nurturing and growing its core capabilities, while consuming services to support enabling capabilities. Examples: Outage Visualisation as a Service, IT as a Service, Cloud delivered services (SaaS, IaaS etc)</td>
</tr>
<tr>
<td>Big Data &amp; Advanced Analytics</td>
<td>Shifting the way businesses uses data and analytics more toward driving business operations and not merely for measuring performance or reporting. Examples: Situational Intelligence, Load Forecasting, Predictive Maintenance</td>
</tr>
<tr>
<td>Real-time Adaptive Security</td>
<td>Real-time adaptive security is an approach to integrating security into service planning, delivery and operations. Adaptive security merges comprehensive activity monitoring, profiling and authentication with advanced analytics to detect and respond to suspicious activity in an automated / dynamic fashion</td>
</tr>
<tr>
<td>DevOps</td>
<td>DevOps is the combination of cultural philosophies, practices, and tools that increases an organization’s ability to deliver applications and services at a higher velocity (compared to traditional delivery models) driving service delivery and operational efficiencies, and reducing time-to-value for business initiatives in the process</td>
</tr>
<tr>
<td>Industrial Internet of Things (IIOT)</td>
<td>IT/OT convergence promotes a single view of an enterprise’s asset information, and management tools to help ensure that every server, machine, sensor, switch, device in an organisation is maintained and operated in a standardised fashion delivering on-going operational efficiencies through consolidation. IIOT is progressively integrating OT technology into IT domain making this alignment possible</td>
</tr>
</tbody>
</table>
## Trend | What is it about?
--- | ---
**Immersive User Experience – Augmented Reality (AR)** | Augmented Reality represents the controlled superimposition of virtual world objects over real world objects to create new environments. AR shifts user engagement patterns, allowing more natural and behavioral interfaces. These interfaces make it possible for users to interact with real world objects guided by digital intelligence generated by sensors and connected assets. This can enhance staff knowledge through contextual information. Examples: Asset Maintenance Operations

**Intelligent Systems** | Machine Intelligence and Deep Learning are helping companies make better decisions by embedding complex analytics into customer interactions and system performance, and automating increasingly difficult tasks. Examples: Situational Intelligence, Predictive Maintenance

**Block-chain for settlements** | Block-chain is a distributed system of record in which value exchange transactions are irrefutably recorded across a peer-to-peer network, using cryptographic trust and assurance mechanisms. Block-chain promises to transform industry operating models and how businesses settle electronic transactions. Examples: Bids and Offers, Energy Dispatch, Final Pricing / Settlement

**Digital Twin** | The growing need to model, monitor and predict the behavior of assets is leading to the creation of a digital twin which provide a dynamic software model of the asset, using sensors and other data to understand its state, handle changes and improve operations. Examples: Asset Predictive Maintenance, Asset Performance Optimisation

**Industrial Digital Platform driving Next Generation Critical Systems** | Technology platforms that support developing and operating Industrial Internet applications will establish a standardised approach to model and control not just one aspect of industrial automation but the entire system (for example, integrating SCADA, APM, OSM). This will enable organisations to achieve better efficiencies and performance as a whole. Examples: Integrating SCADA with Market functions directly from the Digital Platform

**Pervasive Networking** | Flexible, decentralized networks, that connect and integrate different wireless, mobile, terrestrial, and satellite networks into one seamless Internet. Such networks provide the ability to connect remote devices into an Industrial Digital Platform.

### Table 85: ICT emerging trends

**Detailed Portfolio Plans**
The following sections describe our asset management approach for each portfolio.
PORTFOLIO PLANS - ASSET MANAGEMENT SYSTEMS AND TRANSMISSION SYSTEMS

The Asset Management portfolio and Transmission Systems portfolio meet the business requirements for managing and operating the grid.

The primary systems included within our Asset Management Systems portfolio are:

- **Asset Management Planning System (AMPS).** Our asset management planning system provides strategic, long-range asset, risk, and budget planning capability.
- **Maximo.** Our asset management information system contains our operational asset register and maintenance management tool. It forms an integral component of the finance system. Maximo is a standard enterprise asset management product from IBM.
- **Geospatial Systems.** Provide location based intelligence for all our asset management systems including Maximo, SDTF, Asset Map, and CONNECT.
- **Condition Based Risk Management toolset (CBRM).** A risk-based asset health modelling system that provides asset health and criticality that define the risk profile of an asset class and improving the visibility and usability of asset condition and risk information.
- **Transpower integrated project utility (TIPU).** Provides an enterprise-wide planning and project/portfolio management platform.

The primary systems included in our Transmission Systems portfolio are:

- **Supervisory Control and Data Acquisition (SCADA) and Energy Management System (EMS).** SCADA is used for monitoring Grid equipment, measuring the power system, and issuing control signals to equipment in the field to manage the Grid. EMS is a suite of applications that perform engineering calculations to predict power system behaviour and present information to Grid operators.
- **Time Series Plant Information (PI)** – Transpower operates real-time and post-event plant information (PI) systems. In real-time these systems provide enhanced trending, visualisation and prediction of power system behaviour. Post event use cases are broad and include the root cause diagnosis of equipment failures, protection system issues, power system anomalies and electricity market breaches.
- **Outage Planning and Outage Management Systems** – There are 3 integrated outage planning and management systems that work together. The Integrated Outage Notification System (IONS) enables the rolling 12-month outage planning process, the SCADA Outage Scheduler (SOS) and Market Outage Scheduler (MOS) enable the real-time scheduling and coordination of outages within and between the National Grid Operating Centres and the System Operator.
- **MI5 Config Manager** – Is the repository of remote device configuration settings.
- **PowerFactory** – Provides a Grid system modelling and simulation environment that enables Grid engineering design, operations, fault diagnosis and outage management.
- **Stationware** – Is the repository of circuit breaker and protection scheme settings and supports the management of changes to this data across multiple Grid projects.
GRID BUSINESS FUNCTIONS

These systems provide our capability to deliver the 12 grid business functions. Our ICT plans for capability development with each function is described below.

Strategy & Planning

We are seeking to improve the integration between strategy, planning and delivery functions. A key focus is the processes and tools that support asset management planning. During 2017, we are investing in a new AMPS that will provide the foundational platform for implementing improvements in our decision framework, and supporting the optimisation of our asset planning for both Capex and Opex. For the remainder of RCP 2, the focus will be on integrating AMPS with our other asset management and performance systems, including our CBRM, risk and criticality and outage management systems. During RCP 3 real-time asset health data is planned to be added to AMPS and then integrated with a new cost estimation tool, and the digitisation of our asset management strategies and strategic demand modelling systems.

Our cost estimation systems (TEES) will also be reaching end of life around 2020, and will be replaced in the early part of RCP 3.

Asset and Work Planning & Delivery

Outcomes sought for work planning and delivery include improving planning capability, the optimisation of the grid works plan, and service provider engagement. Our current processes are largely manual in nature and the existing ICT tools are customised. This is making them increasingly more difficult to use and costlier to maintain and manage. As a result, we have identified key pre-requisite initiatives that need to be delivered before the full benefits of investment in our programme scheduling and work planning can be realised. These initiatives are:

- Delivery of AMPS to provide a foundation platform
- Integrating the planning and delivery environment. This is planned to commence in 2018, and will provide the process and systems to implement improvements to our work planning and scheduling, bringing our Opex and Capex scheduling together in 2019, and incorporating reliability centred maintenance to our asset planning cycle during RCP 3
- Integration with core systems. During 2017 and 2018 we are investing in the integration of our planning and delivery environments to improve the delivery of volumetric projects. During RCP 3 we are planning to refresh or replace our core delivery tool, TIPU, and extend delivery functionality through further integration with key corporate systems

Asset Operations & Control

The driver for increased capability in our Asset Operations & Control capability is to ensure the safe operation of an increasingly sophisticated grid, that is running closer to it limits. Increased capability also aims to mitigate the risk associated with a retiring workforce of very experienced operators. This impacts on our SCADA/EMS, Operator Call Management, Situational Intelligence, Outage Management and Workforce Roster Management systems. Our planned approach is to enhance the existing system with innovations around the interfaces to provide the required capabilities. We also continue to monitor the progress of technologies in the Big Data, Internet of Things and with IT/OT convergence, as these are likely to bring the stepwise improvements within the next 10 years.

A series of projects is planned across RCP 2 and RCP 3 to refresh our SCADA/EMS product to reduce cyber security and support risks and introduce usability enhancements provided by the vendor.

In 2017, implementation of a more advanced operator call management system will provide the ability to improve the coordination of work within the Operations Centres and reduce the risk of human errors caused by manual processes, distractions and spikes in operator workload.

Workforce & Roster management tools enhancement work has been scheduled for 2020 as it is dependent on the delivery of Situational Intelligence and Outage Management enhancements.
**Power Systems Engineering**

The key focus area for Power Systems Engineering are the tools, processes and testing facilities that enable the provision of fast and accurate (dependable) impact assessments of changes to the Grid. This includes governance, processes, training, standards and the development of guidelines. There is also an opportunity to leverage the tools’ existing functionality (in StationWare & PowerFactory) to automate the transfer of protection settings into our engineering models for improved quality and efficiency. We are also looking to provide further integration with our service providers to ensure that this data is regularly updated, and is in accordance with our standards.

PowerFactory and StationWare are refreshed every two years. In 2018 an improved user interface will be provided to enable service providers to bulk import/export protection system settings into StationWare. This will reduce manual work and ensure the data is updated and integrated more frequently to reduce rework on concurrent projects. In 2020, we will investigate the use of automated protection data transfers between PowerFactory and StationWare to increase the integrity of the data in PowerFactory and reduce some of the manual modelling effort that is currently required.

**Grid Risk & Performance Management**

The outcomes sought for our grid risk & performance management include:

- Consolidation of asset criticality frameworks, systems, and measurement and to improve the integration between our service measures, operational management of risk and assurance across the organisation
- Improving our capability to capture and automate the process of asset feedback information. We also seek to develop a more consistent and efficient approach to asset condition assessments and performance monitoring by using emerging technology to capture near real time asset condition and performance
- Improvements in our management of asset location, hazard, and safety information
- Implement leading practice for inventory management, to maintain optimal stock levels for efficient work management.

Historically this capability has been distributed with separate functional business teams delivering risk management, assurance, issues, investigation, and Control Self-Assessment (CSA) activities. During 2017 and 2018 we are developing systems for site risk reviews that will assist in the discovery, collation, and dissemination of site risks, and implement a solution for the consistent audit, management of incident and event investigations that allows actions to be tracked efficiently. It is planned that these systems will be integrated into our core planning and asset management systems during 2019 and 2020. An ACI system upgrade is planned for RCP 3 with further investments introducing variable line ratings and improved grid capability offers by 2025.

Our asset health and performance systems and processes are still maturing. During 2016 we invested in a tactical implementation of asset feedback. Our plan is to enhance this and integrate it with our AMPS in 2019 and then deployed for real time asset feedback from field staff in 2020.

During 2018, we are also planning to improve our warranty management processes, with small capital investment delivered in 2019 to ensure our warranty systems remain aligned.

CBRM was implemented in 2017 with a phased approach which will implement full condition based risk management for six core asset classes by 2018. During RCP 3 we are looking to invest in asset health management using real-time data to improve the visibility of our assets for improved operational control and planning.

**Outage Planning & Switch Management**

The key outcomes sought are to improve the outage planning process, increase automation, and reduce cost and rework. This will assist in further reducing operational risks and assist in the safe operation of the grid.

In conjunction with our 2016-17 Outage Planning Review investigation some tactical improvements will be made to the existing Outage Planning system (IONS) to trial the agreed process improvements and track the performance of the process through metrics that highlight where further improvements are required. In 2020 a more substantial outage planning improvements programme will build out the required outage planning enhancements, based on the lessons learned from the trial.
In 2018 the use of an emerging Outage Switch Management (OSM) product will be investigated to determine its fitness for replacing paper and telephone based Grid asset switching operations with a digitised system. This capability will integrate with our core SCADA/EMS system to provide a simplified interface that takes the operator through pre-planned digital switching plans and prevents their execution if SCADA/EMS indicates that the Grid is in the wrong state to safely implement the switching sequence.

In 2019 our real-time Outage Scheduling applications will be integrated with the upstream Outage Planning and downstream Outage Switch Management capabilities to enable plan optimisation based on feedback loops. Usability enhancements will also be provided to reduce manual steps so that the operator’s time is freed up to focus on proactive risk identification and event response.

**Asset Management**

Outcomes sought include improvements in our asset management life cycle, asset location information, hazard and safety information, and inventory management. During 2019, we plan to integrate our strategic asset spares management with our procurement and contract management systems. We are looking to invest in updating our Maximo data hierarchy for more efficient analysis and flexibility. We have carried out a mid-life software refresh of Maximo in 2017, and plan a further life cycle refresh in 2020 and in 2024 to ensure our systems remain supported and fit for purpose. During RCP 3 we plan to further improve the Maximo information management to enable Maximo to become a single source of truth for Grid assets, capabilities, location and spares management and improved integration with our environmental systems.

**Situational Intelligence**

Wide Area Situational Intelligence is a capability that we use to combine and present operational status information from our SCADA/EMS with other relevant datasets, such as spatial, weather and lighting information. As the Grid is operated closer to its limits, we will become more reliant on these systems. Our current focus over the RCP 2 period is on providing a much more scalable platform capable of capturing and analysing more data, in real-time, from a larger number of data sources and to ultimately leverage more advanced data analytics and machine learning.

Our thinking around Wide Area Situational Intelligence is well progressed and we have developed the strategy, outcomes, key requirements and target architecture. The Grid operations division will look to migrate to a new platform and build out their required capabilities in the 2019-25 timeframe.

**Mobility Services**

Our Grid related mobility investments are focused on improving the communication and coordination with our field workforce. Field workforce mobility solutions will be provided to support our three core Grid capabilities, including Asset Management, Works and Service Delivery Management, and Grid Operations. This will significantly improve the delivery efficiency of condition assessment, and site risk reviews to better inform our asset planning, delivery, and operations. A programme of Grid Operations mobility investments have been planned from 2019 to 2025.

**Process Automation & Integration**

The driver for increased capability in our process automation and integration will increase the number of service providers and stakeholder’s business processes executed via automated business to business (B2B) services, with improved collaboration for work planning, design and delivery executed through improved electronic exchange of data and information across our systems.

For the remainder of RCP 2, we are investing in an annual programme of work to improve our automated system interfaces with our service providers. 2020 will see investments to integrate our outage management and grid works planning systems with our AMPS for greater visibility and collaboration of our forward plan. During 2022-2025 we are planning further investments to improve the automation between our delivery systems and our corporate services for effective and efficient automated exchange of data and information. Across RCP 2 to RCP 3 we have planned 4 yearly life cycle refreshes for our ESB and B2B systems to maintain their fit for purpose.
Asset Data, Information & Business Intelligence

A key focus over the remaining RCP 2 period is to maintain our asset data and business intelligence systems. During 2017, we are investing in spatial platform life cycle refresh, which will be repeated every two years. During 2018, we plan to invest in improving spatial imagery in support of our Auckland strategy and real-time data capability, for improved situational awareness to our support teams. During RCP 3 we are looking to integrate our video management systems for improved safety and real time operational management.

During 2017 and 2018 we plan investment to replace our grid drawings system to allow the use of richer formats, and more efficient sharing of electronic drawings with our service providers and stakeholders. Life cycle refresh cycles are planned to occur in 2021 and 2024. During RCP 3 we plan to replace our asset photos systems and look to leverage technology innovation to integrate our video and spatial data systems in 2023 and 3D near real time views in 2024.

For our time series systems, activities planned for the remainder of RCP 2 include improvements in data structures and system performance, and standardisation of source Network and Telemetry data in our upstream SCADA/EMS and remote devices. During the RCP 3 timeframe we plan to make more substantive changes to the Time Series system and data architecture to create separate critical and non-critical data streams.

During RCP 2 and RCP 3 we plan to progressively enhance the capability of our Network and telemetry data management systems by using statistical analysis and automated rule based transformations to first analyse and then standardise the remote systems and SCADA/EMS data. The key outcomes we are seeking is to deliver improvements in the efficiency and quality of the secondary systems configuration management, and to simplify and standardise the telemetry data and alarms. In RCP 3 we plan to extend the reach of this capability to ensure the effective end-to-end management of our operational data streams through our core Grid operations systems.

Support Services

We are planning to improve our service delivery and reporting. This includes improving operations resilience and contingency management, root cause analysis, revenue meter management and fleet car management.

During 2018 we will undertake a life cycle refresh of the Meter Data Repository (MDR) and Billing Preparation System (BPS) which share the same underlying ICT platform. Further life cycle investment in this ICT platform as part of RCP 3 will ensure continuation of support. In addition, the revenue metre management capability related systems EMS MV90, GMMS (Grid Meter Data Management System), MDR (Meter Data Repository), PI Corp (Corporate Plant Information) and PQView (Power Quality View) will receive life cycle upgrades consistent with the relevant 3-5 yearly cycles.

In 2020, we plan to investigate moving TM1 from an on-premise Capex model to a Software as a Service (SaaS) Opex based model using a cloud offering. Finally, FMIS, which was upgraded in October 2016, will receive new functionality and enhancements via periodic updates using Oracle’s continuous delivery model, resulting in bi-annual upgrades starting in 2019 and progressing well into RCP 3.
ASSET MANAGEMENT AND TRANSMISISON SYSTEMS
INVESTMENT SUMMARY

Asset Management Systems

In summary, our approach to Grid Asset Management systems is to mature, consolidate and integrate our systems to align with grid capabilities and outcomes during the remainder of RCP 2. The emphasis is on implementing new core platform systems that will provide a step change improvement in our planning capability, and integrating data from our current systems to provide a coherent delivery pipeline from strategy through to operations, supported by improved feedback from asset condition and risk.

During RCP 3 we are required to implement major life cycle refreshes of some key systems (TIPU, TEES, Maximo), along with leveraging new technology enhancements to implement near real-time asset condition monitoring and data collection. We are also looking to improve our asset capability information and modelling. The primary planned ICT investments are:

- **2017** - investment in a new AMPS for efficient asset investment planning, and a replacement system for managing our grid drawings
- **2018** - integration of CBRM systems and asset risk and assurance programs with AMPS to provide an improved risk based approach to Asset investment planning. We are also investing in improving our Project delivery systems and processes to provide a more repeatable and efficient delivery of our Grid Projects
- **2019** - continued investment in integration of our asset management systems, with inputs from our outage management systems and CAT, whilst also improving reporting both regulatory and operational measures. Begin modelling of Asset Capability Information
- **2020 to 2022** - investment in technology refreshes for our TIPU, TEES and drawing management systems as they will have reached end of life. Capture and use of near-real-time asset condition data to understand our asset performance for improved operational and planning decision making
- **2023** - investment in integrating our environmental and consent systems into our delivery systems and invest in improved reliability centred maintenance programs
- **2023 to 2025** - investment in refreshing our Maximo systems for asset management. Looking to improving our asset capability information for variable line ratings and introducing an improved Grid capability offer. We also plan to invest in integrating improved video management systems with our spatial systems.

Transmission Systems

Our approach for Transmission Systems is to standardise and integrate operational data, enable more sophisticated situational awareness and decision support, and streamlining processes and tools. The primary planned ICT Transmission Systems investments are:

- **2016-18** statistics based remote systems configuration data analytics and a more automated change management process to safely standardise our critical Network and Telemetry data
- **2017** our existing SCADA/EMS system will be refreshed to maintain appropriate cyber security risk profile and ensure that we remain on a supported platform
- **2017** we will investigate the SCADA/EMS product landscape and future technology trends and use this information to develop a SCADA/EMS strategy, target architecture and roadmap that informs the future development of our Asset Operations & Control capability.
- **2017** tactical improvements to our outage planning system to align the system to our new process; and process metrics will be captured to help identify remaining areas for improvement
2018 a digitised and more automated Outage Switch Management process will be implemented to reduce the risk of human errors and improve the grid operating centres ability to coordinate work within the team and more effectively management Grid events.

2019-20 continue to develop our Grid Operations data quality and ensure that our data management processes and tools provide sustainable end-to-end data management across our core Operational data systems (primarily Remote Systems, SCADA/EMS and PI Historian). These tools need to take industry trends such as Internet of Things (IoT) and IT/OT convergence into account so that data continuity is achieved as we transition over to newer device technologies.

2019-25 migration to a more advanced situational intelligence platform that can ingest real-time data from a wide variety of data sources and provide more sophisticated overviews of the Grid that highlight impending issues.

2019-25 outage switch management and situational intelligence capabilities will be extended out to the field workforce through investments in B2B interfaces and mobility solutions to improve two way communications with our service providers and customers.

2020 more advanced Workforce & Roster Management tools provided to proactively identify competency risks and address them through training and supervised experience on the desk. This capability will also enable the integration of outage planning, competency metrics and workforce fatigue indicators to ensure that the right skills are available on each shift.

2020 more substantive changes to (or potential replacement of) our outage planning & management systems will be undertaken to provide the outage plan optimisation, feedback loops and usability enhancements that are needed to streamline the outage management process.

2020-21 improved integration will be provided between the core protection system engineering systems (PowerFactory, StationWare, PI Historian and REA) to provide efficiencies for protection systems management and ensure that protection systems faults can be diagnosed and corrected quickly.

2021 our Time Series Plant Information (PI) solution architecture will be reviewed to ensure alignment with desired service levels and to meet competing demands for critical (keeps the lights on) and non-critical (important, but doesn’t keep the lights on) data streams.

### Expenditure Summary

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Table 86: Forecast capital expenditure
PORTFOLIO PLAN – CORPORATE SYSTEMS

The Corporate Systems portfolio describes the business requirements for managing and operating our day to day corporate operations. The primary systems involved in our Corporate Systems portfolio are:

- **Financial Management System (FMIS).** Used for our financial management and reporting requirements.
- **Enterprise Data Warehouse (EDW).** Repository of corporate and operational data. Data is gathered using ETL tools (primarily Oracle Data Integrator - ODI) from various systems, including Market DB, Maximo, FMIS, and IONS.
- **Contract Management System (CMS).** Enables full contract life cycle management from contract creation to its termination or expiry.
- **Risk View.** A Software as a Service (SaaS) solution, provides risk visualisation and analysis supporting an enterprise wide risk management capability for bow-tie and SQRA.
- **Maximo HSE (Health, Safety and Environment).** A module within Maximo that integrates health, safety and environment processes with work and asset management.
- **Billing Preparation System (BPS).** Delivers the billing preparation, ancillary services reporting, and invoicing associated with transmission charges.

Along with these primary systems, there are many other smaller systems that support our corporate environment. Examples include systems supporting ancillary services reporting, and invoicing for our regulated services, Grid skills implementation of the Learning Management System (LMS), supporting service provider access to Transpower approved courses, property management containing leases, rentals and archived historical property information.

CORPORATE SHARED FUNCTIONS

Together our corporate systems support seven shared business functions. These are:

- Financial Management
- Customer and Stakeholder Management
- Risk, Assurance, and Compliance
- Procurement and Supplier/Contractor Management
- Business Change and Training
- Health and Safety Management
- Environment and Property

The planned ICT investment to support the business capability required for each function is described below.

**Financial Management**

Transpower financial systems are core support systems enabling the integration between strategy, planning, delivery functions and regulatory reporting for efficient financial planning and management.

Our financial systems are mature, and fit for purpose. With the upgrade of our FMIS system in 2017, we will move to a smaller but more frequent bi-annual refresh cycle for cost efficiency. In 2018, we will undertake a life cycle refresh of the Billing Preparation System (BPS) which shares the same underlying ICT platform with Meter Data Repository (MDR). Zemindar, which is used to calculate grid charges, will receive life cycle upgrades in 2019 and 2024.

**Customer and Stakeholder Management**

Our customer and stakeholder management functions are supported by our Customer Relationship Management system (Microsoft Dynamics CRM) and ENVi, our environmental consents and compliance database. All our supporting ICT systems for customers and stakeholders were updated in 2016, and we plan for life cycle refreshes during RCP 2 and RCP 3.
Risk, Assurance and Compliance
We are looking to improve our risk, assurance, and compliance systems to provide a consistent view of risk and assurance management activities and effectiveness of controls across the business. To achieve this, during 2017 – 2018, investment in an integrated technology solution will be undertaken. In 2019, we plan to integrate assurance management with Risk View (SaaS) which provides our corporate view of risk management.

Procurement and Supplier/Contractor Management
Outcomes sought include improving the capability for efficient contract life cycle management. Key focus areas are:
- streamlined end to end process for procurement
- visibility of supplier & procurement activity
- service provider arrangements deliver enhanced value
- effective and efficient strategic sourcing framework

In 2017, we will complete an investigation into a process optimisation of the procurement and supplier/contractor management capability, which is aimed at improving stakeholder visibility of supplier tendering and procurement, as well as contract life cycle management. The output of the investigation will be used to inform the initiatives to be undertaken, including the acquisition of ICT systems.

Business Change and Training
We are looking to deliver effective outcomes that will provide accredited resources with access to the toolsets and supporting processes, and providing an efficient process for initiating changes to grid functional processes, delivering high employee engagement and well-motivated commitment to delivery.

The planned acquisition of additional training modules for the SaaS solution MySkills in 2017, will enable greater collaboration and reduce travel costs through provision of a virtual learning environment. In 2018 an investigation will be undertaken into an operational change management tool to ensure that stakeholders are identified and engaged early in the operational change life cycle and that the extent and context of operational changes are clearly communicated ensuring better governance and more successful outcomes. A new operational change management tool is planned to be implemented in 2019.

Health and Safety Management
We are looking to further enhance our health and safety management through efficiency and efficacy improvements in our safety performance reporting. Key focus areas are:
- centralised view of all site hazards
- stakeholder visibility of corrective actions
- effective control of all safety and health risks
- central "source of truth" for health and safety data

During 2017-2018 we will enable the recording of site hazards from physical hazard boards in Maximo HSE. This will ensure informed decisions can be made as to site specific hazards service providers are sent to a site. Electronic site hazard boards will also be considered as part of the project. In 2017, we will also complete an investigation into how to improve the interface for service providers to expedite monthly health and safety performance reporting. In 2018, we will enable integration between Maximo HSE and safety processes enabling more effective tracking of observations regarding controls and any subsequent actions raised to resolve deficiencies. In 2019, we will further consolidate Maximo HSE with the integrated technology solution further enhancing our end to end management of health and safety issues and investigations.
Environment and Property
We are looking to deliver effective outcomes that support improved property management decisions.
During 2017 an investigation will be undertaken into the remediation of PROP (property database). The investigation will address the criticality of data held with the property database, the constraints associated with the current underlying technology and options that enable more dynamic reporting for users. The resulting solution from the investigation will be implemented in 2018.

CORPORATE SYSTEMS PORTFOLIO INVESTMENT SUMMARY
- 2017 - Our TM1 and Oracle Business Intelligence Enterprise Edition (OBIEE) systems will be upgraded and we will investigate the process optimisation of the procurement and supplier/contractor management capability, which will inform future investments. There will be investment to improve the interface for Transpower’s stakeholders for improved monthly health and safety performance reporting.
- 2018 - Investment to upgrade our property management system (PROP), and plan to invest in a solution for the recording of site hazards from physical hazard boards in to Maximo HSE. This will be enhanced during 2019 to support the effective end to end management of health and safety issues and investigations with an improved data quality feedback and resolution process and tool.
- 2019 – we plan for a life cycle upgrade of our FMIS system to maintain its fit for purpose, which will be on a bi-annual basis out to the end of RCP 3. There will be investment to improve our reporting to provide quantitative evidence of data quality improvement progress for core asset data sets.
- By 2020 a life cycle refresh will have considered moving TM1 from an on-premise Capex model to a Software as a Service (SaaS) Opex based model using a cloud offering.
- By 2021 we will have enabled an integrated view of real-time time series data (including asset health indexes or modelling) and other related data captured in the data warehouse including Maximo, ACI, CBRM, APT, PI etc.
- By 2024 we will have reviewed our Business Intelligence and data warehouse (BI/DW) outcomes to ensure ongoing alignment to our business strategy and priorities and that our software delivery methodology results in quality outcomes.

EXPENDITURE SUMMARY

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Table 87: Forecast capital expenditure
PORTFOLIO PLAN – SHARED SERVICES

The Shared Systems portfolio describes the enabling ICT platforms for business solutions to be delivered, along with the development and oversight of corporate information management. This includes the design, build and maintenance of hardware, operating systems, middleware technologies, and our Northern and Southern data centres. The primary systems involved in our Shared Services portfolio are:

The primary systems involved in our Shared Services portfolio are:

- **Microsoft Exchange** - We currently use an on-premises implementation of Microsoft Exchange 2013 running on dedicated hardware across both datacentres to provide a highly available email solution.
- **VMware** - Provides the key virtualisation capability across our infrastructure and enables us to consolidate hardware to reduce costs and improve efficiencies.
- **Windows Server** - The server operating system used predominantly across Transpower’s server fleet. Currently running a mix of supported versions which are typically refreshed with the system that the infrastructure is supporting.
- **BMC Remedy** - Supports our Service Management capabilities. We use its change management and configuration management components, although the system itself provides a full range of service management features.
- **SharePoint Server** - Used for document management, workflow and collaboration services. It is also used as an application development and publishing solution.
- **Active Directory** - This is the Directory Service and related services built into the Windows Server operating system which provides authentication and authorisation services as well as assigning and enforcing security policies.

ICT SHARED SERVICES FUNCTIONS

The Shared Services systems provides the underlying capability required for our business units to operate. This is split into specific business requirements for IST to operate, and the requirements for wider business operations.

**IST Strategy, Architecture & Planning**

Our key focus in this area is on establishing standardised frameworks by adopting industry standards and implementing tools, systems and processes to support them. Most of the required capabilities are currently supported only by our document management solution which we are looking to upgrade and move to the cloud in 2018.

**IST Design, Develop & Build Management**

Key outcomes include improving the management of business requirements throughout the project life cycle, and improving the design to build life cycle to include new methodologies such as Agile and DevOps.

Our capabilities in the Requirements Management area all need improvement with specific investment in systems needed to support the validation and traceability of requirements. In the testing area, we need to invest in systems to support the automation of testing which, in turn, supports a DevOps and continuous integration methodologies. In the project management space, we need to investigate and recommend a solution to help with resource and time management capabilities.

**IST Transition & Delivery Management**

Key outcomes in these areas are focused mainly on improving capabilities of existing systems and refining processes related to environment and change management including Service, Asset & Configuration Management (SACM) which needs improving in the software licensing management, and the release to operations processes which need process improvements to facilitate more efficient and higher quality production releases.
IST Operations
Key outcomes in this section revolve around improving our problem management capabilities, as well as extending and improving our automation & orchestration to improve efficiencies. We need to invest in our Problem Management capabilities by either implementing new systems or extending existing systems’ functionality. We will also be looking to invest in a solution to uplift our password management capabilities which would increase our security posture significantly.

Shared Services
Key outcomes in this area include ensuring key hardware and software infrastructure components are refreshed effectively to remain on a supported and secure platform. Some of our key systems require refreshing over the next few years, including VMware, SharePoint, Exchange, BMC Remedy, and SQL Server.

We will put more focus on delivering strategies over the next few years to provide direction for our Shared Services team. Some areas that require new strategies to be documented are personal devices, recoverability and archiving. As a result of these strategies we will be looking to align our investments in these areas in future years. Our patching and cryptography capabilities are both key Shared Services enablers to our Cyber Security capabilities but both require improvement to lift them to an acceptable level. “SOE (Servers)” is a capability that was rated poorly and is also a key Cyber Security enabler as it ensures that the Standard Operating Environment (SOE) on our server fleet is secure and up to date. Remote Access is a key enabler to several business capabilities but has been assessed as needing a lift in effectiveness to meet modern demands of mobile working.

Information Management
The key outcomes in this area that became apparent through the capability assessment are that we need to improve our architecture and governance processes, as well as update and improve the core systems that house our document management libraries. This will be covered mostly by refreshing the document management systems but also through reviewing and improving the information management architecture and governance.
ICT SHARED SERVICES INVESTMENT SUMMARY

For the remainder of RCP 2, the primary areas of focus in the Shared Services portfolio are life cycle refreshes of key systems and enhancing our infrastructure security. Where it makes sense, we are moving systems to the cloud as part of their life cycle refresh.

2017 – Our on-premise Exchange environment is due to be refreshed towards the end of RCP 2 but we are bringing this forward to move corporate mailboxes to the cloud-based Office 365 solution from Microsoft. We will also ensure that Exchange continues to support on-premises critical systems where necessary.

2017 – We will refresh our VMware platform with the latest version to remain on a supported and stable platform. As part of this project we will be looking to utilise new features and implement better roles and responsibilities to enhance the security of the environment.

2018 – Our SharePoint platforms will need to be refreshed in 2018 but we will move our document management and collaboration capabilities to Office 365 instead while keeping the bare minimum on-premise SharePoint infrastructure operating for critical systems if necessary.

2018 – Our Microsoft SQL Server database platform will require a life cycle refresh in 2018 and as part of this initiative we will also be investigating improvements to our infrastructure using new automation and cloud-based technologies.

2019 – We will refresh our Oracle platform in 2019 to remain supported and will be looking to adopt new features where they make sense.

2020 – In 2016 we refreshed our Citrix platform and introduced a new architecture to ensure that future refreshes are more efficient and lower risk. The refresh in 2020 will be the first scheduled refresh to utilise this new architecture.

Expenditure Summary

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<th></th>
<th>RCP 2</th>
<th>RCP 3</th>
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<tr>
<td>Shared Services</td>
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Table 88: Forecast capital expenditure
PORTFOLIO PLAN – TELECOMMUNICATIONS, NETWORK, AND SECURITY SERVICES

The Telecommunications, Network and Security Services portfolio incorporates the TransGO network, which is Transpower’s national wide area network (WAN), our network and security operations.

The TransGO network, is a high capacity, fibre optic national communications network allowing telecommunication between all our sites and locations that support grid operations, critical switching and the grid protection functions.

The primary assets and systems involved in our Telecommunications, Networks and Security portfolio are:

- **Fibre** – The physical fibre cables that carry the network buried under the ground, running below the ocean, or strung between our high voltage towers.
- **TransGO WAN** – The national data network linking all Transpower sites including data centres, substations, and corporate offices.
- **TransGO LAN** – The network infrastructure located at our Transpower sites connecting our services to the TransGO WAN.
- **Security** – The systems and processes providing security controls which keep us safe by reducing our risk exposure to cyber security threats.
- **TransGO Voice & Enterprise Collaboration** - The systems that provide person-to-person communications within Transpower and to the outside world. Includes voice, video, instant messaging, screen sharing and presentations.
- **Management Services** – The systems and processes used to maintain the network and security infrastructure.
- **Supporting Services** – The additional shared services delivered over the networks and security infrastructure.

TELECOMMUNICATIONS, NETWORKS AND SECURITY FUNCTIONS

The Telecommunications, Networks and Security portfolio covers three enabling capability groups:

- Networks, Telco and Site Made Ready (SMR)
- Shared Communication Services
- Security

Each of the capability areas are described below.

**Networks, Telco and SMR**

This consists of our key network infrastructure capabilities, wireless and wired local area networks, our network labs, network management tools, and Site Make Ready (SMR). SMR is the process of ensuring a site is ready by installing the relevant batteries, cabling and racking equipment. Overall, our investments in this area are working well and are of high quality. We have identified some areas requiring investment including our network analytics capability and our battery analytics systems.

Our TransGO network is the single biggest IST asset. We have a planned technology refresh every 10 years to ensure the capacity of the network meets the growing demand. Where possible we use strategic sourcing to extend the life cycle through acquiring extended support agreements and purchasing spare parts in advance.

When TransGO programme was launched 10 years ago, the network capacity offered by TransGO was a major step change. With the continued deployment of IP services we’ve seen a year on year increase in network capacity that if continues may start to constrain the business if not addressed within the next few years. In 2005, our core network requirement was just 6Mb/s. By 2015 this had exceeded 600Mb/s – a 100-fold increase. With the development of our two data centres and the requirements for replication and failover, it is reasonable to expect that will we need to augment our core capacity by 2025.

The current asset management plan includes a cost for a like for like refresh of the TransGO network at an estimated cost of $60m. However, there is a project currently underway to determine the range of feasible options which would provide the level of functionality and security required to run the national grid.

Our fibre network consists of over 7,500km of fibre cable, of which Transpower owns about 1,355km. Our forecast for over the next 15 years, incorporates an expected replacement of the Cook Strait fibre cables as well as the OPGW which is the overhead cables running between Christchurch and Culverdon.
For our TransGO LAN we aim to continue with our seven-year replacement strategy, with the aim of refreshing one-seventh of our network infrastructure each year.

**Shared Communication Services**

The shared communications services incorporates our communications platforms both in our corporate and critical environments. It includes our enterprise voice platform which is in the process of being migrated from fixed desk Cisco phones to a software phone solution using Skype for Business which also introduces new collaboration and mobility capabilities. In addition, it covers our critical voice platform, satellite phones, two-way radios, as well as our video conferencing systems.

We still also use fax technology throughout the business and we have identified some opportunities to investigate our usage of fax lines and look to reduce our dependencies on these by using more modern solutions in their place.

**Security**

The systems and processes providing security controls are rated on their capability to effectively reduce risk (i.e. reduce the likelihood of threats occurring and mitigate consequences of events that do occur). We have developed a process based on our bow-tie risk models to identify opportunities to improve or implement new security controls.

Each new security initiative will be prioritised based on its alignment to meet our ICT Strategy, it’s effect on the overall cyber risk reduction, it’s budgeted cost and what can reasonably be achieved in each financial year of an RCP period. This process will be run as an ongoing annual basis using an updated threat profile and the effectiveness results of our operational security controls. This investment modelling approach is consistent, unbiased, scalable and directly based on our risk based approach to managing cyber security.

![Figure 66 - Long term anticipated investment to risk levels](image)

The primary Security Controls and Systems involved in our Security portfolio are:

- **Network Controls** – Check Point Firewalls & Intrusion Prevention Systems (IPS) and Qualys Vulnerability Management
- **Application Controls** – Symantec Secure Web Gateway, Cisco Email Security and F5 Application Policy Manager
- **Endpoint Controls** – Symantec Anti-Malware
- **Detect and Respond Controls** – Riverbed Network Packet Capture, Elastic Central Logging Services and RSA Security Incident and Event Management (SIEM)
TELECOMMUNICATIONS, NETWORKS AND SECURITY INVESTMENT SUMMARY

- 2017-18 The West Coast to TransGO Phase 2 project completes the TransGO WAN build to the remaining sites on the West Coast of the South Island, and the Northland to TransGO Phase 2 project completes the TransGO WAN build in the Northland Region. An acceleration of planned investment is required to setup the networks infrastructure for the new Wellington office in Boulcott Street.

- 2017-18 For our security investment, we will continue our improvements in security controls which will assist in detecting previous undetectable security incidents and reducing the time to respond and recover from them. Through the Network and Security Services RFP process we are selecting new partners to assist us in operating our existing systems and present new opportunities to leverage their managed services to improve or supplement our network services and security controls. The establish of cloud based security controls will allow us to leverages new security capabilities and governance over Everything as a Service (XaaS).

- 2018-20 Several firewalls and security appliances will require life cycle refreshes and our strategy will be to use virtualisation or Security as a Service when recommended to reduce future life cycle expenses. Work will continue to improve our maturity to get the full benefit of our existing security investments. Our endpoints such as laptops and tablets will have the same security controls applied whether they are in a Transpower office or working remotely at home or in a public place.

- 2019 - Several of the Networks Management systems require life cycle refresh including the 5620 Service Aware Manager (SAM), the 1350 management system, the Comtel Network Management System Next Generation system, and the Netcool system.

- 2020 - A life cycle refresh of the Cisco Prime network management system.

- 2020-26 We will continue to invest in security initiatives which reduce our risks based on the current threat landscape of the period. We expect with the networking of our substation assets maintaining network segregation between our IT/OT networks will continue to be a key security control in reducing the risks to which our critical systems are exposed to. Additionally, the move towards Everything as a Service in the IT/Enterprise space will mean that we transform existing onsite security controls to be Cloud focused and aware.

- 2021 - We will need to refresh our Datacentre LAN, based on Cisco Nexus technology. The estimated cost is $2m.

EXPENDITURE SUMMARY

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<td>Network, and Security</td>
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Table 89: Forecast capital expenditure
8. BUSINESS SUPPORT ASSET PORTFOLIO

This chapter describes the management of our Business Support Assets and forecast expenditure. It covers:

- Non-critical substation buildings and land
- Office buildings and facilities
- Vehicles
- Office Equipment
- Forecast RCP 2 expenditure

Our business support assets include assets not otherwise included in other asset classes. They are diverse in nature, and as such are managed individually, dependant on the type and nature of asset involved. Table 89 provides a summary of the assets included.

<table>
<thead>
<tr>
<th>Asset category</th>
<th>Overview</th>
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<tbody>
<tr>
<td>Non-critical substation buildings</td>
<td>Transpower owns and operates 137 GXPs and 32 grid injection points (GIPs). The majority of GXPs have an area of non-critical substation land and many have non-critical buildings</td>
</tr>
<tr>
<td>Office buildings and facilities</td>
<td>3 leased offices, 2 owned offices, 3 owned warehouses and 3 owned training facilities</td>
</tr>
<tr>
<td>Vehicles</td>
<td>91 passenger vehicles</td>
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<tr>
<td>Office equipment</td>
<td>Office desks, chairs and meeting room furniture</td>
</tr>
</tbody>
</table>

Table 90: Business support assets

Each of these are described below.

NON-CRITICAL SUBSTATION BUILDINGS AND LAND

We have both non-critical buildings and land. The characteristics of these are:

- Non-critical substation buildings—generally these consist of storage buildings and several current and former depots. These buildings were built at our older substations and remain at a significant number. Typically, these buildings are in a fair to good condition. There are also a small number of non-critical buildings and land that are not directly associated with a substation (for example, the Evans Bay cable store, the Bog Roy earthing station and the Molesworth depot).

- Non-critical substation land—land surrounding or abutting substation switchyards. The purpose of this land is to enable future development and to ensure the operational integrity (the safety, security and ability to operate) of the station by providing a visual, sound and security buffer and to contain earth potential rise effects.

Planning

Non-critical buildings and land are managed by our regional service managers and may be used by connected customers for feeder access or associated connections equipment.

Operations and maintenance

Where possible and appropriate, we license non-critical buildings and lands to cover holding costs and where practicable provide a return. Generally, tenants are responsible for maintenance of land and improvements. In the absence of a tenancy or where we need to carry out maintenance over and above the tenants’ obligations, these costs are met under the regional facilities Maintenance contracts.
Disposal and divestment
In 2014/15, we reviewed all our land holdings to identify any that were not directly necessary for the safe and secure operation of the grid. As a result, we identified several properties for disposal and approved a three-year disposal programme starting in 2015/16 to sell surplus land subject to all necessary internal and regulatory approvals. For the year 2015/16 22 properties have been sold with gross proceeds of over $7 million. The disposal programme for 2016/17 covers a further 14 properties which could yield over $4.5 million in gross proceeds. One final tranche of properties is earmarked for sale at an estimated value of $6 million.

OFFICE BUILDINGS AND FACILITIES
We have corporate offices in Auckland, Wellington (two), Palmerston North and Christchurch. We also have warehouses at Otahuhu, Bunnythorpe and Addington substations, plus linesman training facilities at Western Road substation, Omaka (Blenheim) and Bunnythorpe substation. The Auckland office, Christchurch office, all the warehouses and training facilities are on sites owned by Transpower, so the maintenance of these sites is included as part of ACS buildings and grounds asset management. The Wellington and Palmerston North offices are leased. All the offices, warehouses and training facilities are in good condition and regularly maintained.

Planning
The following office projects are planned for RCP2, RCP3 and RCP4:
- Consolidation of our two Wellington offices to a redeveloped site at 22 Boulcott Street, due to be completed in October 2017
- Minor refurbishment works at our Auckland (Otahuhu) office. Various works planned from 2019/20 to 2034/35
- Minor refurbishment works at our Christchurch (Islington) office. Various works planned from 2019/20 to 2034/35
- Refurbishment/relocation of our Palmerston North office in 2019/20
- Upgrade of our warehouse facilities (various works planned from 2015/16 to 2017/18).

Operations and maintenance
We have agreements with suppliers to maintain the office buildings and facilities. These are regularly reviewed.

Disposal and divestment
We will be terminating the leases of our two Wellington offices on 31/10/17 when we relocate to our new head office at 22 Boulcott Street.

VEHICLES
Our vehicles are predominantly located at the Auckland, Palmerston North, and Christchurch offices. They are either allocated to staff that regularly visit our sites, landowners and customers or used as pool vehicles. The vehicle fleet is predominantly made up of diesel vehicles, which are more cost effective to run than petrol vehicles.

Planning
We are planning to replace vehicles during RCP 2 when they meet our replacement criteria. We have committed to changing 30% of our fleet to hybrid or electric vehicles by 2019. So far we have purchased 7 hybrids and plan to purchase another 13 by 2019. We participate in the All of Government contract for the supply of motor vehicles, which is regarded as the best available price offered in the market. A similar approach is planned for RCP3 and RCP4.
Operations and maintenance
The vehicle fleet is managed by an external provider who takes a consistent and cost-effective approach to maintenance based on manufacturer’s guidelines. GPS is fitted to vehicles to ensure they are operated efficiently and safely. We also participate in the Ministry of Defence syndicated fuel contract with BP, which has reduced our annual fuel bill by 15 per cent.

Disposal and divestment
We use a condition based assessment to determine when vehicles should be replaced. We usually sell vehicles through established auction houses.

OFFICE EQUIPMENT
Our office equipment is modern and ergonomic.

Planning
We have budgeted to replace all Wellington office furniture when we relocate in 2017.

Operations and maintenance
Office equipment is repaired or replaced as required.

Disposal and divestment
We sell redundant office equipment or donate it to charities.

EXPENDITURE SUMMARY

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<th>RCP 2</th>
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Table 91: Forecast capital expenditure