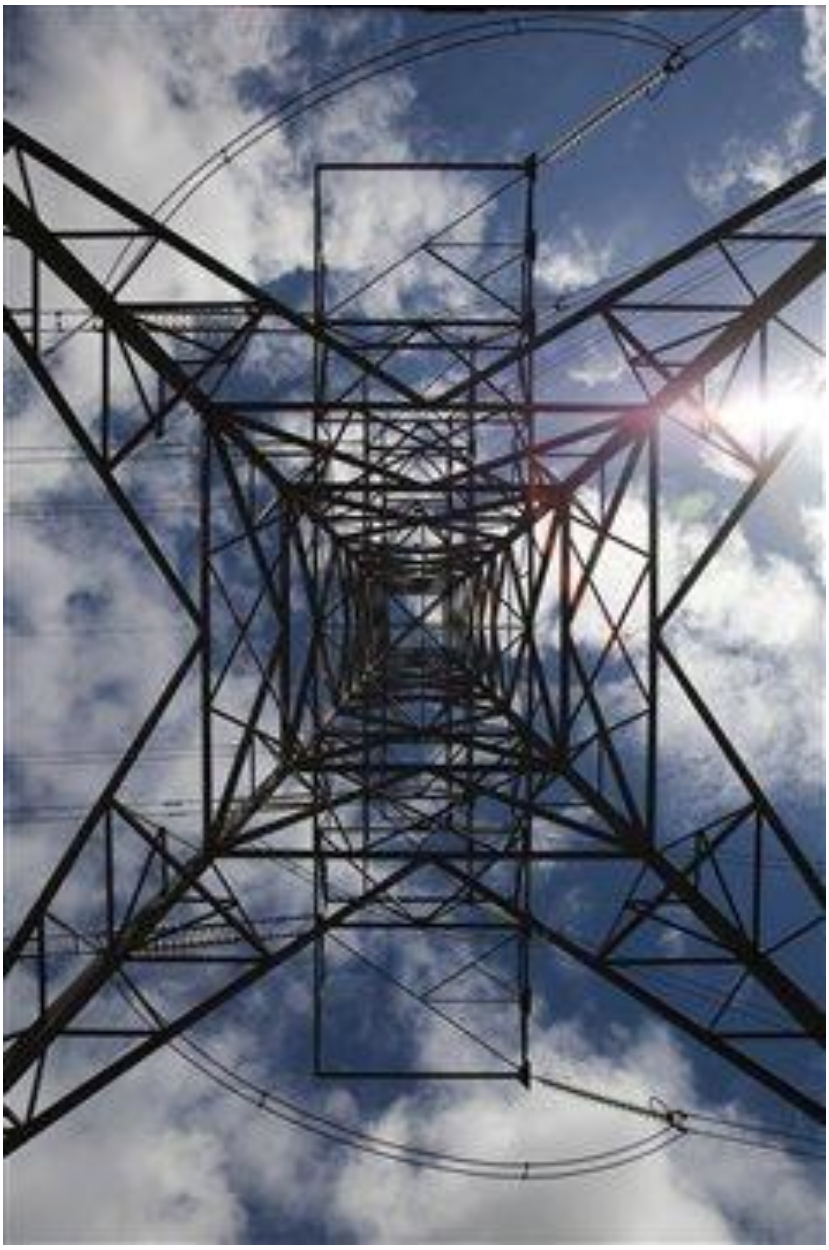
ELECTRICITY TRANSMISSION

NETWORK OUTPUT MEASURES METHODOLOGY

National Grid, SP Transmission PLC, Scottish Hydro Electric Transmission Limited



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1.0 PURPOSE AND SCOPE

1.1 Network Output Measures Principles

1. RIIO (Revenue = Incentives + Innovation + Outputs) is a new regulatory framework. It places emphasis on incentives and outputs to drive the innovation that is needed to deliver a sustainable energy network to consumers.

2. Outputs are a fundamental element of the RIIO framework. The primary outputs monitor each onshore Transmission Owner's (TO) performance for the delivery of end services to consumers. The Network Output Measures (NOMs) are binding secondary outputs which show that the TOs are providing consumers with long-term value for money through a set of early warning measures or lead indicators. These assess the underlying performance of the transmission system.

3. The NOMs are designed to demonstrate that the TOs are targeting investment in the right areas to manage network risk effectively, ensuring that the TO will continue to deliver primary outputs in the future.

4. As network investment takes place over the longer term, there would be a time lag before any under investment in the assets would impact the primary outputs. Using the NOMs, the TOs can identify the work needed to manage assets to deliver a known level of network risk, thus providing assurance that performance is maintained in future price control periods.

5. The TOs have developed a set of principles relating to these metrics which will enable Ofgem to evaluate each TO's performance and achieve the NOMs objectives.

The NOMs methodology is based on the following key principles:

1. Compliance: Ensuring that the measures comply with the law.

    a. The NOMs outputs must be compatible with existing legal obligations, ensuring that statutory duties are not compromised.

2. Measurable: Enable the Authority to assess whether the NOMs objectives have been achieved and whether the targets have been met.

    a. The methodology will demonstrate how the NOMs objectives are achieved.
    b. Allow the Authority to assess the TOs' performance in relation to the development, maintenance and operation of our networks and in assessing future network expenditure.
    c. Develop a framework for the evaluation of the NOMs targets:
        i. Independent assessment of the TOs' performance
        ii. Determine whether over or under-delivery is justifiable
    d. Develop network risk trade-off mechanism
        i. Incorporate health, criticality, risk and overall network risk
        ii. Describe current asset deterioration as well as future expected deterioration
        iii. Include Probability of Failure (state requiring replacement) with respect to asset condition
        iv. Explore options such as monetisation of criticality and utility function
    e. Describe how levels of redundancy/backup are incorporated into criticality assessments

    f. Devise method for assessing impact of load related investment
    g. Develop testing mechanism for independent assessment of NOMs objectives, principles and against targets
    h. Consider framework for next price control period

3. Consistency: Develop a common approach to ensure that the measures are consistent and comparable.

    a. Common approach to NOMs developed by all TOs
    b. Ensure consistency as far as practicable between UK regulated sectors (DNO, GDN)
    c. Engagement with GDNs and DNOs to ensure concepts of health, criticality, risks are common across all sectors
    d. Common terminology (definitions of health, risk, criticality, intervention)
    e. Commentary and analysis of practices in other industries and internationally

4. Transparency to Stakeholders: Ensure that consumers are getting value for money – minimising the burden on current customers without creating unnecessary costs for future customers.

    a. To provide a known level of network risk for consumers, demonstrating that the TOs are investing consumers' money wisely in our networks
    b. To provide transparency that the TOs are investing in our existing assets appropriately
    c. Stakeholder engagement

5. Applicability: Ensure that the TOs' stewardship of our assets is appropriate and proportionate.

    a. Used internally within each business to enhance current asset management processes
    b. Understanding business drivers
    c. TO should have full control over performance against the NOMs outputs
    d. Methodology should ensure that the TOs can innovate

6. Objectivity: Providing data/information for the Authority to enable evaluation of performance and for TOs to manage our assets.

    a. Specify details about the type and quantity of data held by each TO
    b. Data assumptions/limitations, the level of confidence and how uncertainties can be quantified

1.2 Methodology Purpose

6. For the price control period (RIIO-T1) which covers the eight years from 1 April 2013 to 31 March 2021, special licence condition 2L sets out the requirements for the NOMs for each of the TOs.

7. Special Licence Condition 2L requires that the TOs have in place a methodology for a set of NOMs which are designed to enable the evaluation of:

   1. Network Asset Condition
   2. Network Risk
   3. Network Performance
   4. Network Capability
   5. Network Replacement Outputs

8. This NOMs methodology describes:

   a. The requirements in the Licence Conditions
   b. The common framework describing how the NOMs are calculated
   c. Comparisons of the NOMs with measures produced by other asset management organisations
   d. Communication of information about the TOs' systems to Ofgem, including confidentiality issues surrounding publishing the content of this Network Output Measures methodology to external (outside Ofgem) parties
   e. How the NOMs will be regulatory reviewed and continuously improved by the TOs

9. This methodology will also form the working document that fulfils the two stage approach agreed with Ofgem in December 2015. There are sections identified throughout the methodology which require further work during stage 2. The two stage approach is described in detail in section 2.4.3.

1.3 Glossary of Terms

Asset Health Indices	Lists of assets, grouped by equipment type, that prioritise the technical requirement for replacement based on relevant performance and condition criteria
Average Circuit Unreliability	Network unavailability as a result of asset unreliability
Black start	The procedure to recover from a total or partial shutdown of the transmission system which has caused an extensive loss of supplies. This entails isolated power stations being started individually and gradually being reconnected to each other in order to form an interconnected system again.
Boundary Transfer Capability	The maximum amount of power flow across specific transmission circuits following the most onerous secured event of a fault outage without exceeding the thermal rating of any asset forming part of the National Electricity Transmission System, without any unacceptable voltage conditions or insufficient voltage performance and without any transient or dynamic instability of the electrical plant, equipment and systems directly or indirectly connected to the National Electricity Transmission System.
Capability	The existing and future transmission capacity being provided

	by the Transmission Operators on the main interconnected transmission system
Capital Plan	A list of proposed asset replacement or refurbishment schemes
COMAH	Control of Major Accidents Hazards
Criticality	A representation of the impact of potential failure on the stakeholders and has three elements: Safety Criticality, System Criticality, Environmental Criticality
Distribution Network Operator (DNO)	Distribution Network Operators own and operate the distribution network of towers and cables that bring electricity from our national transmission network to homes and businesses
EKP	Economic key Point: an element of system criticality
Electricity Ten Year Statement	A statement produced by National Grid in the role as National Electricity Transmission System Operator (NETSO) with contribution from the GB Transmission Owners including National Grid, Scottish Hydro Electric Transmission and SP Transmission. It aims to provide clarity and transparency on the potential development of the GB Transmission system for a range of scenarios. The document considers this development through strategic network modelling and design capability, while trying to capture future uncertainty with regards to the generation mix, operation of the network and technology development.
Environmental Criticality	Impact of asset unreliability or failure taking into account the sensitivity of the geographical area local to the asset
Functional Failure	An asset which has been removed from service (on a temporary basis) as a result of an unreliability related event
Gas Distribution Network (GDN)	Gas Distribution Network
Intervention - Maintain	Activities to achieve asset life and ensure asset performance. Maintenance would not be expected to improve the asset's Health Index and will not extend its asset life.
Intervention - Refurbish	Interventions that will change asset condition and/or extend asset life which also have the effect of improving the asset's Health Index.
Intervention - Replace	Interventions to replace an asset in its entirety that is in a state requiring replacement. The asset's Health Index will be reset or improved.
Long Term	>10 years
National Electricity Transmission System	The system consisting (wholly or mainly) of high voltage electric lines owned or operated by transmission licensees within Great Britain, in the territorial sea adjacent to Great Britain and in any Renewable Energy Zone and used for the transmission of electricity from one generating station to a substation or to another generating station or between sub-stations or to or from any interconnector and includes any electrical plant or meters owned or operated by any transmission licensee within Great Britain, in the territorial sea adjacent to Great Britain and in any Renewable Energy Zone in connection with the transmission of electricity but shall not include any remote transmission assets.

Network Asset Condition Measure	The current condition of the Network Assets, their reliability and the predicted rate of deterioration.
Network Assets	The assets that collectively form the licensee's Transmission System, and includes the principal components of those assets.
Network Capability Measure	The level of the capability and utilisation of the Licensee's Transmission System at entry and exit points
Network Output Measures	The measures defined in paragraph 2L.4 of Special Condition 2L (Methodology for Network Output Measures).
Network Performance Measure	The aspects of the technical performance of the TO's transmission system that have a direct impact on the reliability and cost of services.
Network Replacement Outputs	The Replacement Priority profile that the TO is required to deliver on its Transmission System by 31 March 2021 that has been approved as part of the Price Control Review and funded in its Opening Base Revenue Allowance, as measured by the Network Output Measures. Specified in Special Licence Condition 2M
NETS SQSS	The National Electricity Transmission System Security and Quality of Supply Standards (NETS SQSS) establish a coordinated set of criteria and methodologies that Transmission Licensees use in the planning and operation of the National Electricity Transmission System.
Network Risk Measure	The overall level of network risk to the reliability of the TO's Transmission System that results from the condition of the assets and the interdependence between the assets.
Network Utilisation	Substation demand expressed as a percentage of Capacity
Network Wide Risk	The likelihood and consequence of a potential negative impact to the network, as a result of a potential future event.
Ofgem	The Office of Gas and Electricity Markets, a non-ministerial government department and an independent National Regulatory Authority, recognised by EU Directives and governed by the Gas and Electricity Markets Authority
Replacement Priorities	Lists of assets, grouped by equipment type, that prioritise the requirement actions (replace, refurbish) based on the Asset Health Index and Criticality in terms of consequence of the failure
RIGS	Regulatory Instructions and Guidance are published by the Authority and are the primary means by which the Authority directs the licensee to collect and provide the information to the Authority
RIIO	Revenue = Incentives+ Innovation+ Outputs; Current Regulatory Price Control Framework
Safety Criticality	Impact of direct harm to public/personnel as a result of asset failure
Short/Medium Term	Short term = 0-5 years, medium term = 5-10 years.
Stakeholder	The general body of persons (including customers or other actual users of the TO's network) who are affected by or have an interest in the TO's operations.
State Requiring Replacement	The point at which it is expected that equipment condition will have an unacceptable impact on performance or capability, and repair is either not possible or uneconomic
System Criticality	Impact of transmission system not delivering services to

	customers
System Security	A coordinated set of criteria and methodologies that transmission licensees use in the planning and operation of the national electricity transmission system of Great Britain
The Authority	The Gas and Electricity Markets Authority established under section 1 of the Utilities Act 2000.
Transmission Licensee	The holder of a transmission licence.
Transmission Owner (TO)	The holder of a transmission licence in relation to which licence the Authority has issued a Section D (transmission owner standard conditions) Direction and where Section D remains in effect (whether or not subject to any terms included in a Section D (transmission owner standard conditions) Direction or to any subsequent variation of its terms to which the TO may be subject).
Utility Function	A measure of preferences. The utility function approach is a way of assigning a number to each element being compared such that a higher number represents a greater preference for the option under consideration.

2.0 APPLICATION OF NETWORK OUTPUT MEASURES

2.1 Licence Requirements

10. Special Licence Condition 2L requires that each licensee must at all times have in place and maintain a methodology for Network Output Measures ("the NOMs methodology") that:

   a. Facilitates the achievement of the NOMs methodology objectives
   b. Enables the objective evaluation of the NOMs
   c. Is implemented by the licensee to provide information (whether historic, current, or forward looking) about the NOMs. This may be supported by such relevant other data and examples of network modelling as specified in any Regulatory Instructions and Guidance (RIGs) issued by the Authority in accordance with the provisions of Standard Licence Condition B15 of the Transmission Licence for the purpose of this condition
   d. Can be modified in accordance with specific provisions (described in section 2.4.2 of this document).

11. The NOMs methodology objectives are designed to facilitate the evaluation of:

   a. The monitoring of the licensee's performance in relation to the development, maintenance and operation of an efficient, co-ordinated and economical system of electricity transmission
   b. The assessment of historical and forecast network expenditure on the licensee's Transmission System
   c. The comparative analysis over time between GB transmission and distribution and with international networks
   d. The communication of relevant information about the licensee's Transmission System to the Authority and other interested parties in an accessible and transparent manner
   e. The assessment of customer satisfaction derived from the services provided by the licensee as part of its Transmission business

12. The NOMs methodology is designed to enable the evaluation of:

   a. The Network Asset Condition measure, which relates to the current condition of the network assets, the reliability of the network assets, and the predicted rate of deterioration in the condition of the network assets, which is relevant to assessing the present and future ability of the network assets to perform their function
   b. The Network Risk measure, which relates to the overall level of risk to the reliability of the licensee's Transmission system that results from the condition of the network assets and the interdependence between the network assets
   c. The Network Performance measure, which relates to those aspects of the technical performance of the licensee's Transmission system that have a direct impact on the reliability and cost of services provided by the licensee as part of its Transmission business
   d. The Network Capability measure, which relates to the level of the capability and utilisation of the licensee's Transmission system at entry and exit points and to other network capability and utilisation factors
   e. The Network Replacement Outputs measure, which are used to measure the licensee's asset management performance as required in Special Licence Condition 2M (Specification of Network Replacement Outputs)

13. This methodology is designed to enable the evaluation of all five NOMs. Each measure is reported to the Authority annually to facilitate the ongoing assessment of each TO's performance, through the regulatory reporting process.

2.2 Using the Network Output Measures

14. The TOs' NOMs are used internally to enhance current asset management processes and understanding of business drivers. This is especially in relation to the development, maintenance and operation of our networks and in assessing future network expenditure.

15. In addition to the joint methodology statement, the TOs have developed specific appendices which describe how they use the NOMs within our respective businesses. These specific appendices are confidential.

16. Under RIIO-T1, the TOs have each developed integrated business plans which are supported by a suite of mechanisms designed to help manage the uncertainty that the electricity industry faces over the next decade. Non-load related activities are the capital and direct operating elements of the plan which are focused on maintaining performance of our assets through replacement, refurbishment and maintenance.

17. Through these activities, the TOs' intention is to improve our safety and environmental performance whilst maintaining reliability (in terms of Energy Not Supplied) at current levels. These activities are targeted at delivering stakeholders' requirements, from connecting new supplies to providing a safe, reliable service.

18. The TOs' business plans are designed to manage the ongoing safety, reliability and environmental performance of our networks. The potential customer impact associated with the deteriorating performance of assets towards the end of their useful life continues to drive a programme of interventions on our transmission network assets.

19. The TOs manage interventions on our equipment to ensure that:

    a. The number, severity and criticality of equipment failures are acceptable to the TOs and our stakeholders
    b. Long term replacement plans can be achieved without having an unacceptable impact on reliability, availability, quality of supply, health, safety and environmental performance, and transmission constraints
    c. Long term capital forecasts are within acceptable levels for efficient deliverability, procurement and financing requirements

20. The available interventions for managing the performance of assets range from routine maintenance to full replacement. At the highest level, there are three options for intervention for each lead plant type which have definitions agreed with Ofgem:

    a. Maintenance
    b. Refurbishment
    c. Replacement

2.2.1 Maintenance

21. The purpose of asset maintenance is to ensure that relevant statutory and legal requirements are met, such as those relating to safety and environmental performance, as well as allowing the TOs to gather condition information so that performance risks are better understood and mitigated.

22. Maintenance is a fundamental tool in the TOs' management of network reliability, safety and environmental performance (and hence customer satisfaction). Reducing maintenance to zero, or reducing levels without undertaking impact assessments, would lead to a decline in the condition of assets (this effect is seen more rapidly than for under-investment in replacement), leading to increased unplanned events and in some cases bringing forward the need for asset replacement or increasing refurbishment activities.

23. Maintenance policy evolves as processes and practice are periodically reviewed. The TOs reassess maintenance policy and interval decisions on an ongoing basis using the latest information available in order to ensure our assets can achieve their anticipated asset lives and reduce the potential for unplanned disruption. Maintenance activity can uncover developing trends for defects, ensure rectification of unforeseen functional failure modes and can enable innovation.

24. When developing maintenance content and undertaking frequency reviews, the TOs have a systematic, structured method for cost/benefit evaluation. This includes understanding the asset's reliability for known failure modes, taking account of how the operating costs would be expected to increase during the time between maintenance tasks, identifying potential changes in performance and consideration of the impact that a change to the maintenance task frequency might have on the life of the asset. As part of the planning process, maintenance is bundled into efficient packages to optimise access to the network and the assets.

25. Through maintenance activities the TOs can manage the natural deterioration of asset condition so that the assets remain operable throughout their anticipated technical life, reducing unplanned outages on the network as well as monitoring the condition of assets to improve understand of their performance. This then feeds into future asset intervention plans.

(See glossary (1.3) for definition of intervention - maintain).

2.2.2 Refurbishment

26. The decision to refurbish instead of replace an asset follows careful consideration of a number of criteria. For refurbishment to be technically feasible and cost-effective, the asset population size must be sufficiently large because the costs associated with developing the technical content of a refurbishment procedure, and the set-up costs to undertake the work, mean that it is difficult to make refurbishment of small populations cost-effective.

27. The ongoing lifetime cost of supporting a refurbished asset family must also be considered. It may be more cost-effective to replace highly complex units that require frequent intervention.

28. Continuing spares support must be considered. Whilst some spares can be re-engineered without significant risk, this is not appropriate for performance critical

components. If such components are unavailable (or not available cost-effectively), refurbishment is unlikely to be a realistic option.

29. Additionally, the condition and deterioration mechanisms of the asset class must be well understood. If these criteria are met, and it is considered that refurbishment is a viable option, it would be expected that refurbishment activities would change the asset's condition and/or extend asset life which also has the effect of improving the asset's Health Index.

(See glossary (1.3) for definition of intervention - refurbishment intervention).

2.2.3 Replacement

30. Individual assets or families which are deemed to be a priority given their risk and criticality trigger the need for replacement and capital investment. To facilitate the development of an optimised replacement plan, priority ranked lists for replacement are created for each lead equipment type. The priority ranking is achieved by applying both technical and specific business criteria to develop Asset Health Indices (AHI) and Replacement Priorities.

31. AHIs define the requirement to replace based on condition and performance of the asset whilst Replacement Priorities also include criticality in terms of the safety, environmental and system consequences of asset failure. This distinction recognises that two assets, both with the same AHI can have a different Replacement Priority because of the consequence of failure. Following replacement, an asset's AHI will be reset or improved.

(See glossary (1.3) for definition of replacement intervention).

2.2.4 Decision Making

32. These three activities are undertaken to ensure the longevity and performance of the TOs' networks. Without effective management of these activities, and understanding the related interactions between them, the TOs would, in time, experience deterioration of network outputs which would have a significant detrimental impact on the capability of the network.

33. Figure 1 shows how the process by which elements of NOMs feed into an investment plan. Health criteria (e.g. condition, performance) categorised into AHIs represent the Network Asset Condition. These AHIs are combined with information about Criticality to determine Replacement Priorities. These Replacement Priorities are combined with other factors (e.g. outages, resources) to determine scheme priority which is used to determine the investment plan.

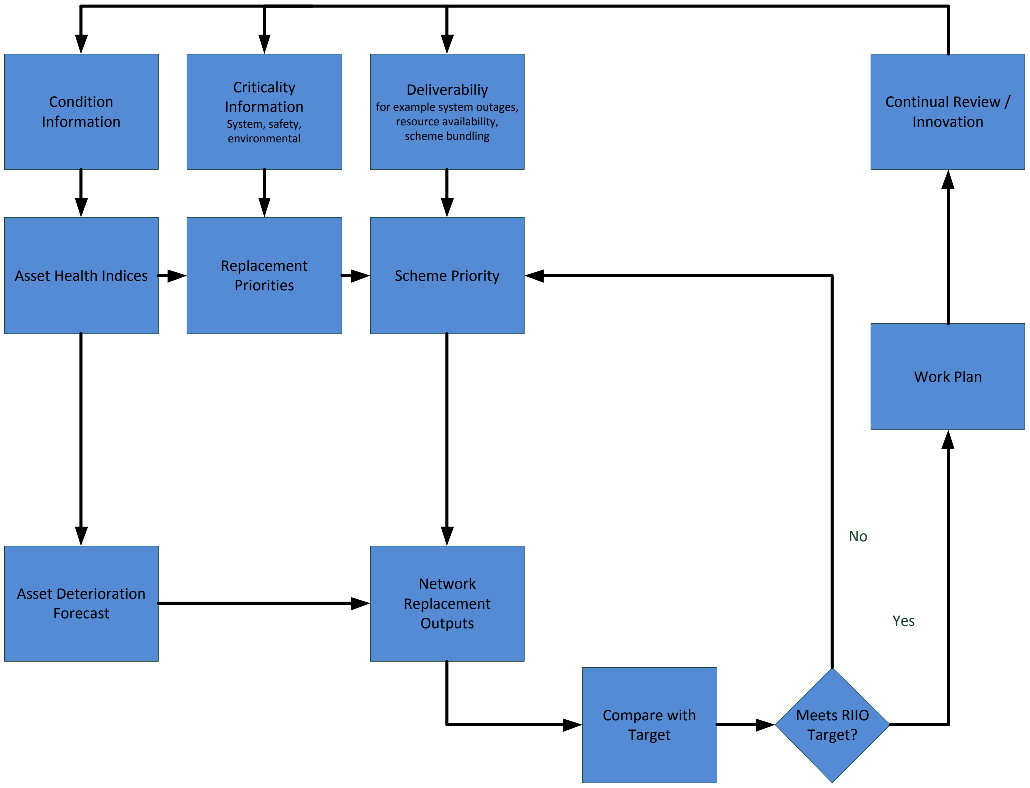

Figure 1: Investment Process

34. The Replacement Priorities represent the level of Network Risk held on the system and have been developed in a way that ensures a consistent understanding of risk across all asset types. They take into account changes to asset populations, including load and non-load related replacement volumes.

35. The Replacement Priorities determine the Network Replacement Outputs, providing Ofgem with the ability to monitor and assess the TOs' asset management performance. The non-load related targets for the Network Replacement Outputs are coded into the respective licences for each TO in Special Licence Condition 2M. The process for setting the targets is discussed in section 2.3 and illustrated in Figure 3.

36. Network Performance is currently monitored through the Average Circuit Unreliability (ACU) metric, which represents network unavailability as a result of asset unreliability. This metric records the impact of Functional Failures and is used to understand the impact of unreliability on the TOs' networks.

37. Work has been undertaken to further understand the relationship between asset condition and network performance. The ACU is presented in a format that disaggregates the metric by equipment group and then by asset condition. Figure 2 shows the conceptual relationship between Energy Not Supplied events and other network performance metrics. The TOs are continuously developing their understanding of the relationship between Asset Health and Network Performance.

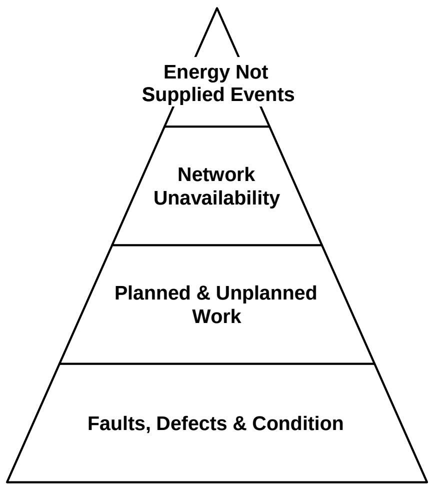

Figure 2: Network Performance Triangle

38. Network Capability is used to understand the localised demand driven need for developing Transmission infrastructure. Utilisation is represented as demand or generation as a percentage of capacity. The Capability measure records the impact of specific schemes on the capability for each boundary, using thermal, voltage and stability incremental capability across each boundary.

2.3 How the RIIO-T1 Network Replacement Output Targets were set

39. Figure 3 shows the process for setting the RIIO-T1 network replacement output targets. It is described in detail in section 4.5.2.

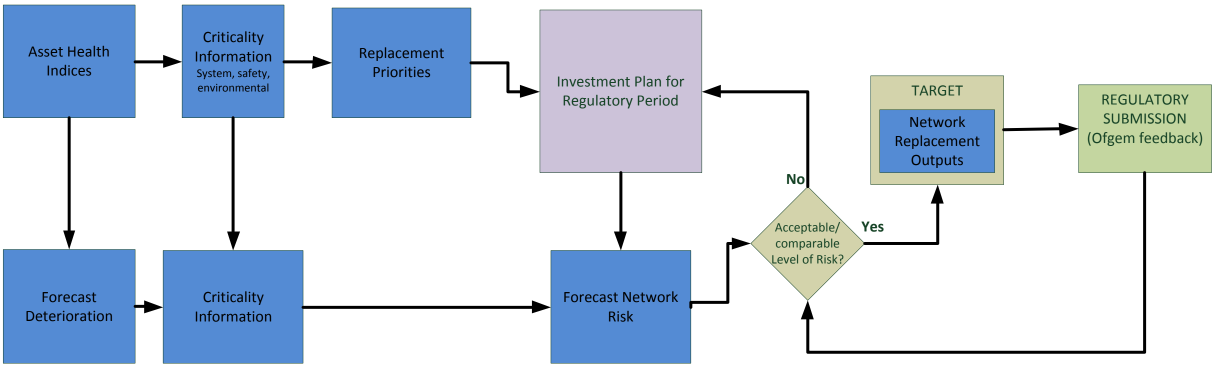

Figure 3: Process to Set Network Replacement Output Targets

40. The TOs actively develop their asset management capabilities. The risk and criticality approach targets asset interventions on assets in poorest condition with the highest consequences of failures. One of the fundamental parts of this approach is the TOs' ability to forecast asset degradation, supported by extensive knowledge of the assets informed through innovation, failure investigations, forensic investigations, condition monitoring and assessment, family history, international experience and asset performance data.

41. For the RIIO-T1 submission, the network replacement output targets encoded into Condition 2M of the Transmission Licence were set based on the forecast of expected asset Replacement Priorities (Network Risk) at 31 March 2021. To generate this forecast of expected Replacement Priorities the TOs used forecast asset deterioration and their forecast investment plans for the RIIO-T1 period. As part of the RIIO-T1 price control review, Ofgem and their consultants assessed the TOs forecast asset deterioration and forecast investment plans and based on this assessment adopted the asset Replacement Priorities at 31 March 2021 as the basis of the network replacement output targets.

42. To align with the stated intent to maintain reliability at historic levels, the forecast investment plans were developed to keep the network risk at a similar level at the end of RIIO-T1, as it was at the beginning of RIIO-T1.

43. There are two principle sources of uncertainty around forecast network risk. These are:

(a) Uncertainty associated with the forecasting of asset degradation;
(b) Uncertainty associated with unexpected type faults.

44. Asset degradation is inherently uncertain and probabilistic modelling techniques are used to forecast future condition. This is combined with information on asset Criticality to calculate a forecast of Replacement Priority.

45. The forecast Replacement Priorities at 31 March 2021 were based on a 50% percentile, giving the median value and thus expected forecast of network risk. To ensure the uncertainty in future asset condition was included in the assessment of forecast network risk by Ofgem and their consultants, confidence levels at 25% and

75% to were additionally provided to Ofgem to provide an understanding of distribution of uncertainty around the expected Replacement Priorities.

46. Unexpected type faults cannot be forecast but can have a significant impact on network risk, cause significant costs and lead to disruption of the capital programme. It would not be sensible to model this risk probabilistically so these were not included in the forecast of Replacement Priorities.

47. Throughout the eight year RIIO-T1 period, the TOs are learning more about their assets as they age and experience new duty cycles. Further assets will enter the wear-out period of life which will allow collection of new condition information. In addition it is likely failures will occur which reveal new deterioration mechanisms which are currently unknown.

48. This new condition information and new deterioration mechanisms will feed into the deterioration modelling and asset technical lives. In addition, the TOs continue to seek new cost-beneficial intervention options to manage the evolving condition of the assets. In some cases this will allow some life extension and in other cases this will cause life reductions.

2.4 Ongoing Review and Development of the Network Output Measures

2.4.1 Licence Requirements

49. Part E of Special Licence Condition 2L requires that each licensee must, from time to time, and at least once every year, review the NOMs methodology to ensure that it facilitates the achievement of the methodology objectives.

50. The methodology is jointly review by all TOs. The TOs regularly discuss the methodology as well as the development of the NOMs. The terms of reference for these review meetings are: *The TOs will meet to discuss the appropriateness of the current NOMs in meeting the requirements of Special Licence Condition 2L; share information to ensure consistency and calibration across the TOs; discuss and resolve common issues with the implementation of NOMs*

51. Outside of the annual review, if a TO determines that a modification is need to the NOMs methodology that TO will call for a joint review with the other TOs.

52. When it is agreed that changes should be made to better facilitate the achievement of the objectives, the TOs follow the process for consulting stakeholders, as defined in the Licence. Changes to the NOMs methodology and specific appendices will follow the process outlined below.

2.4.2 Process to Modify the Network Output Measures Methodology

53. Licence conditions 2L.10 and 2L.11 state that the licensee may make a modification to the NOMs methodology after:

   a. Consulting with other Transmission Licensees to which this condition applies and with any other interested parties, allowing them a period of at least 28 days within which to make written representations with respect to the TO's modification proposal.

   b. Submitting to the Authority a report that contains all of the matters that are listed below:

      i. A statement of the proposed modification to the NOMs methodology
      ii. A full and fair summary of any representations that were made to the licensee pursuant to paragraph 2L.10(a) and were not withdrawn
      iii. An explanation of any changes that the TO has made to its modification proposal as a consequence of representations
      iv. An explanation of how, in the licensee's opinion, the proposed modification, if made, would better facilitate the achievement of the NOMs methodology objectives
      v. A presentation of the data and other relevant information (including historical data, which should be provide, where reasonably practicable, for a period of at least ten years prior to the data of the modification proposal) that the licensee has used for the purpose of developing the proposed modification
      vi. A presentation of any changes to the Network Replacement Outputs, as set out in the tables in Special Licence Condition 2M (Specification of Network Replacement Outputs) that are necessary as a result of the proposed modification to the NOMs methodology
      vii. A timetable for the implementation of the proposed modification, including an implementation date

2.4.3 Development of the Methodology

54. The TOs have committed to developing a method to enable Ofgem to assess risk trade-offs for the Network Replacement Outputs in order to determine whether each TO has met or exceeded its targets at the end of the RIIO-T1 period. The aim is to develop a consistent approach of assessing risk across different asset categories and is proposed in section 4.5.2.

55. During the period July 2014 to December 2015 the TOs further developed the NOMs methodology according to a programme agreed with Ofgem (Stage 1). This document has been updated to incorporate the work that was undertaken. It proposes a mechanism to allow trade-off between asset classes based on converting the existing targets to Monetised Risk.

56. Following a stakeholder consultation that was undertaken in October 2015, comments received from stakeholders have also been incorporated into this methodology. In particular further explanation has been added on how uncertainty is treated and a commitment has been made on further work that will be undertaken to assess the monetary values to apply to Environmental Criticality (the general consensus from the stakeholder consultation being the Environmental Criticality monetary values were too low).

57. Following this consultation, Ofgem identified additional work they wanted the TOs to undertake on the methodology. This included work to complete Stage 1 and a Stage 2 programme of work which extends until end March 2017. To complete the Stage 1 work, the TOs have added in an explanation of how the TOs make investment decisions, and how the RIIO-T1 network replacement output targets were set as well as restructuring the document and adding more explanation about how redundancy is treated in the criticality calculation, adding information on how calibration, validation and testing will be performed and introducing more diagrams and process maps to explain how the methodology works.

58. The following work programme, in Table 1, shows the further development work required and the associated timescales for achieving this work. Where the Stage 2 work is a development of this Stage 1 methodology, the commitment to the further work that will be undertaken is included in the relevant section (see Methodology Reference). Where the Stage 2 work introduces whole new sections no Methodology Reference is shown. This will be determined in the first deliverable in the Stage 2 work.

Action	Milestone	Methodology Reference
Stage 1: Updated methodology, sent to Authority for approval, with commitment to further work	End Jan-16	N/A
Stage 2: Develop 'working copy' of methodology with new structure and placeholders for new sections – sent to Ofgem for comment	End Feb-16	N/A
Stage 2: Update Ofgem with understanding of common elements between TOs' processes (identify what is common, what is specific but can go into public domain, and what is confidential	End Mar-16	To be determined
Stage 2: Bring common elements from specific appendices into methodology	End Jun-16	4.1.2
Stage 2: Develop justification for trade-offs	End Jun-16	4.5.2
Stage 2: Detailed explanation of process for managing assets and trade-off with monetised risk	End Jun-16	4.5.2
Stage 2: Further work on redundancy	End Jun-16	4.2.2
Stage 2: Further work on High Impact, Low Probability events (in conjunction with other sectors)	End Sep-16	4.2.2 4.5.2
Stage 2: Testing of trade-off mechanism with real data	End Sep-16	5.1, 5.2, 5.3
Methodology submitted to Ofgem for approval to conduct stakeholder consultation	End Dec-16	N/A
Stakeholder consultation completed (start process in Jan-17)	End Mar-17	N/A
Methodology submitted to Ofgem for approval including stakeholder feedback	End Mar-17	N/A

Table 1: NOMs Development Programme

3.0 REPORTING TO THE AUTHORITY

3.1 Licence Requirements

59. The NOMs will be reported to Ofgem as part of the annual Transmission Regulatory Reporting Packs (RRP) as required in Standard Licence Condition B15: Regulatory Instructions and Guidance (RIGs).

60. Licence Condition 2L.6 requires that the TOs provide information (whether historic, current or forward-looking) about the NOMs supported by such relevant other data and examples of network modelling, as may be specified for the purposes of this condition in any RIGs that have been issued by the Authority in accordance with the provisions of Standard Licence Condition B15.

Network Output Measure	Reported in RRP Table
Network Asset Condition	6.15.1_NOMs_detail
Network Risk	6.15.2_NOMs_RP
Network Performance	5.10_ACU
Network Capability	5.3_Boundary_Tran_Requirements 5.4_Bound_Capab_Dev 5.5_Demand_&_Supply_Sub
Network Replacement Outputs	6.15.2_NOMs_RP

Table 2: NOMs RRP Tables

In addition to the submitted tables, the TOs provide a narrative which explains changes to the outputs from the previous year.

3.2 Reporting Timescales

61. The reporting year for the provision of information is from 1 April to 31 March the following calendar year. The information required under the RIGs will be provided not later than 31 July following the end of the relevant reporting year.

62. For the RIIO-T1 period, the first reporting period was 1 April 2013 to 31 March 2014.

3.3 Data Assurance

63. Licence Condition B23 requires each TO to undertake processes and activities for the purpose of reducing the risk, and subsequent impact and consequences, of any inaccurate or incomplete reporting, or any misreporting, of information to the Authority.

64. To ensure compliance with this licence condition, each TO carries out risk assessments to understand the implications of reporting inaccurate, inconsistent or incomplete data. Each NOM table reported in the RRP has undergone such a risk assessment. Where improvements can be made to data systems or processes, actions are planned that are proportionate to the risk of a submission in order to reduce the impact of inaccuracies in the submissions.

65. In providing data the TOs have developed work instructions for each table to be submitted to ensure a consistent approach.

66. Data concerning the asset inventory, condition scoring and criticality information is specific to each TO. Details about the type and quantity of data are described in each Specific Appendix.

67. Specifically, these describe the data that informs health indices and how it is used for specific assets. They indicate the volume of available data and whether any data has to be inferred. They explain whether there is any blanket replacement of certain assets and associated reasons. These also describe how any limitations in the data affect the confidence in scoring for health and criticality and how any uncertainties can be quantified.

4.0 NETWORK OUTPUT MEASURES METHODOLOGY

4.1 Network Asset Condition

4.1.1 Licence Requirements

68. Paragraph 2L.4(a) of the Special Licence Condition requires the TOs to enable the evaluation of:

    a. The Network Asset Condition measure, which relates to the current condition of the Network Assets, the reliability of the Network Assets, and the predicted rate of deterioration in the condition of the Network Assets, which is relevant to assessing the present and future ability of the Network Assets to perform their function

69. The key elements from this Special Licence Condition are:

    a. Current condition of the assets
    b. Reliability of network assets
    c. Predicted rate of deterioration in condition
    d. Present/future ability of network assets to perform their function

4.1.2 Methodology

70. The Licence Condition requirement can be summarised as the need to enable the evaluation of the Asset Health of the TO's assets. Figure 1 illustrates how Asset Health prioritisation feeds into the assessment of the investment plan.

Assessing Asset Condition

71. Asset condition is the main factor in determining the health of an asset. AHIs are categorised below in Table 3.

AH 1	New or as new
AH 2	Good or serviceable condition
AH 3	Deterioration, requires assessment or condition monitoring
AH 4	Material deterioration, intervention required
AH 5	End of serviceable life, intervention required

Table 3: Asset Health Indices

72. The asset would not be expected to adequately perform its function beyond its end of serviceable life.

73. The AHIs do not represent a requirement for routine intervention options such as maintenance, repair or inspection.

74. The above categorisation gives a common and consistent definition that the TOs are using to describe Network Asset Condition

75. AHIs are produced for the following lead assets:

    a. Circuit Breakers

b. Transformers
c. Reactors
d. Overhead Lines – *split into the following three categories*
   i. Line conductors
   ii. Line fittings
   iii. Towers (SP Transmission and SHE Transmission only)
e. Underground Cables

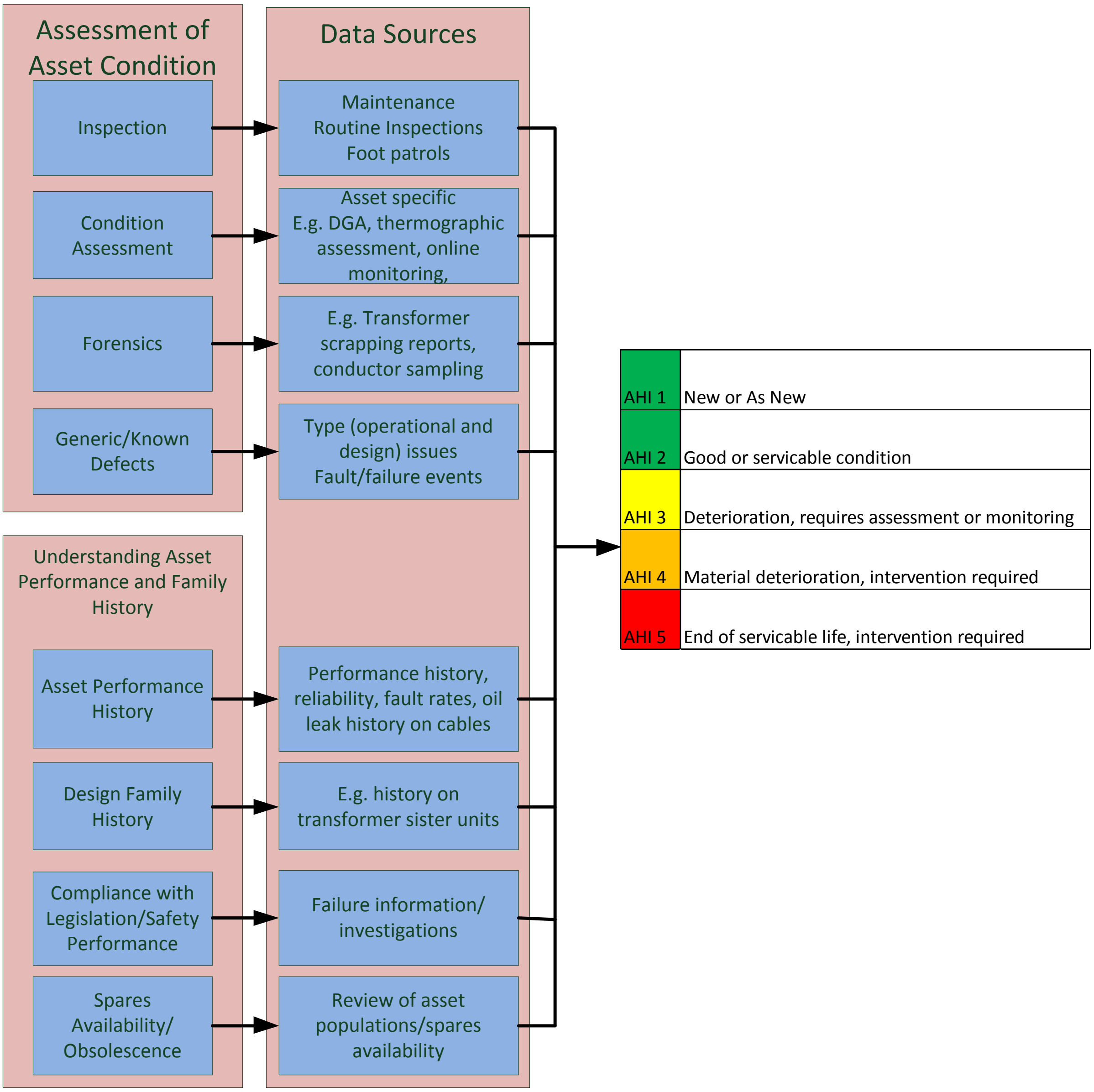

Figure 4: Process for Assessing Asset Condition

76. Figure 4 shows the process for assessing asset condition. It indicates the type of information available to monitor asset condition and performance, and the sources of this data. Examples of specific factors that the TOs use to assess condition for each asset group can be found in Table 4. As well as assessing condition, asset performance information (e.g. fault rate, failure information) provides a measure of the reliability of network assets and is factored into derivation of the AHIs.

77. Due to the differing asset portfolios, operating histories and asset management strategies adopted by the TOs, there will be differences in the assessment of asset health priorities.

78. In Stage 2 significant further work will be undertaken by the TOs to determine exactly what is common and what is specific in terms of assessing asset condition.

Equipment Type	Factors to determine AHI	Additional Factors
Overhead Lines	Condition assessment score - including conductor condition Environmental – including galloping, sub-conductor oscillation, industrial environment, % of route 150m above sea level, coastal location (distance from coast) Conductor corrosion and forensic results	Service experience of other circuits of similar design/age in similar environment Historic and projected defects
Cables	Historic and projected environmental performance Risk of tape corrosion Risk of sheath failure	Historic unreliability Results of condition assessment where applicable Service experience of cable systems
Switchgear	Forensic evidence from targeted condition assessment and known deterioration modes Historic number of defects and significant NEDERS (National Equipment Defect Reporting Scheme) issues pointing to safety or environmental issues. Likelihood of failure – trends for individual and family type	Unplanned revenue costs Technical sustainability – evaluation of original equipment manufacturers' or National Grid support in terms of technical knowledge and availability of spares.
Transformers	Condition assessment Design family performance Chemical analysis of oil for dissolved gas or other ageing tests Site testing and/or continuous monitoring Scrapping Reports of replaced transformers Condition scores: Dielectric condition assessed using DGA (dissolved gas analysis Thermal condition assessed using DGA Mechanical condition assessed using FRA (frequency response analysis) External condition of transformer (e.g. corrosion)	Oil quality – acidity, breakdown voltage and resistivity

Table 4: Factors used in determining AHIs

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Assessing Asset Deterioration.

79. Determining asset deterioration requires an understanding of the rate of deterioration of asset health.

80. Table 5 shows the deterioration mechanism and factors affecting the deterioration mechanism consistent across the TOs:

81. In Stage 2 significant further work will be undertaken by the TOs to determine exactly what is common and what is specific in terms of assessing asset deterioration.

Equipment Type	Deterioration Mechanism	Factors Affecting Mechanism
Transformers	Thermal Ageing of Paper Insulation	Transformer operating temperature, moisture content of the insulation and acidity of the insulating oil
	Localised Overheating due to induced currents flowing in the transformer core bolts and steel	Integrity of core bolt and core to frame insulation
	Thermal Fault	High resistance winding connections or restricted oil flow in windings due to poor thermal design or deterioration of the dielectric resulting in restricted oil flow
	Winding Movement	Vibration associated with normal operation or forces within the winding resulting from through fault conditions
	Dielectric Fault	High moisture content of the dielectric or transient overvoltages
	Corrosive Oil – dielectric failure due to deposition of copper sulphide in the paper insulation.	High operating temperature combined with insulating oil containing corrosive compounds
Cables	Tape corrosion	Family design weakness Installation environment
	Sheath failure	Often associated with installation (cables cleated in air) where cable subject to thermal cycling and bending
	Environmental performance (oil leaks)	Numerous factors – weak joint plumbs, tape corrosion, lead sheath failure
	Failure of old-style link boxes (refurbishment)	Ingress of water Design
	Failure of old-style SVLs (refurbishment)	Ingress of water Design
	Condition of joint plumbs (refurbishment)	Design – weak plumbs lead to oil leaks

Switchgear	Seals	Loss of elasticity giving moisture/water ingress and/or oil leakage Pressure induced deformation and wear Loss of sealing ability Wear and Tear O-Ring Embrittlement
	Porcelain to metal joints - cement	Frost/Oxide Jacking Loss of mechanical strength Chemical ageing of cement, weakening flange joints
	Drive Rods, Glassfibre rods	Shearing or bending Age related shearing of glass fibre rods Separation of end pieces Bearing wear
	Tension Components	Relaxation of tension tubes, increased vibration and loosening of assemblies
	Mechanisms, Linkages and Air Cubicle Components	Mechanism linkage weakness (duralloy) Torsion springs Dash pot – Poor design Pressure Switches deterioration Piston corrosion/wear Poor settings, loss of adjustment
	Contacts and PTFE Nozzles	Poor settings, loss of adjustment Duty related wear
	Grading Capacitors	Capacitor pack punctures Corrosion leading to water ingress or oil leakage
	Resistors	Corrosion leading to moisture ingress
	Electronic Control & Monitoring Systems	Sub-component failure
	Oil filled Bushings	Water ingress Poor oil quality
	OCB Tanks	Corrosion leading to water ingress
	Steel housing of drive mechanism	Corrosion leading to water ingress
	Paint/Coatings	Corrosion
Overhead Lines	Conductor corrosion	Local pollution levels (coastal/industrial)
	Conductor fatigue	Topography, wind induced vibration (i.e. Aeolian vibration, sub-conductor oscillation, galloping, ice-loading)
	Conductor fittings	Topography, local pollution levels (coastal/industrial), wind induced vibration
	Conductor joints	Poorly cleaned installation of new to old conductor, inadequately compressed joint
	Dowel pins	Corrosion of split pin leading to dowel pin migration
	Insulators (Glass)	Corrosion of steel pin caused by local pollution levels (coastal/industrial)

	Insulators (Porcelain)	Expansive corrosion of steel pin at the air-cement-steel interface caused by local pollution levels (coastal/industrial)
	Spacers	Vibration fatigue
	Dampers	Vibration fatigue
	Tower steelwork corrosion	Topography, local pollution levels (coastal/industrial), painting quality at first installation
	Tower foundations	Construction quality, soil type, ground water level/change in level
	Tower foundation muffs	Corrosion at foundation/muff interface due to construction quality

Table 5: Asset Deterioration and Factors affecting Asset Deterioration

82. The TOs define the rate of deterioration by the age of which a typical asset will be at a particular AHI. An example of the minimum information required to define this rate of deterioration is shown in Table 6.

Health Index	AH 1	AH 2	AH 3	AH 4	AH 5
Average Age	New	5 years	30 years	42 years	50 years

Table 6: Example of minimum information provide for AHI progression

83. This rate of deterioration can then be used to predict future AHIs at a particular asset age using the current AHI.

84. The rate of deterioration assumptions and modelling undertaken to predict the AHIs is documented in the individual TOs' Specific Appendices.

85. In developing the rate of deterioration, the TOs have shared information in how AHIs will change with time.

86. The forecast Replacement Priorities are based on a 50% percentile, giving the median value and thus expected forecast of network risk.

87. For the RIIO-T1 submission to ensure the uncertainty in future asset condition was included in the assessment of forecast network risk undertaken by Ofgem and their consultants, confidence levels at 25% and 75% were additionally reported to provide an understanding of distribution of uncertainty around the expected Replacement Priorities. Whilst these confidence levels are not reported to Ofgem annually, the information is available within the TO businesses to ensure the uncertainty around deterioration of condition is understood.

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4.1.3 Ensuring Consistency

88. TOs have, through regular development meetings, shared relevant internal documentation including the TOs' Specific Appendices regarding processes for assessing AHIs.

89. The TOs have shared information on the derivation of AHIs and asset deterioration and have agreed a consistent set of factors which is contained within Table 4. This information is reviewed as part of the annual review of the NOMs methodology as required in Special Licence Condition 2L.

90. Table 5 lists the deterioration mechanisms for each equipment group which have been agreed by the TOs. These are the mechanisms which result in changes in condition and thus the AHIs. This information will continue to be reviewed on an ongoing basis as part of the annual review of the NOMs methodology as required in Special Licence Condition 2L.

4.1.4 Reporting

91. The AHIs are reviewed each year and reported to Ofgem in Table 6.15 of the Transmission RRP. This information is reported for the 400 kV, 275 kV, and 132 kV Transmission networks. The information is further split into criticality and replacement prioritisation (see section 4.2.2).

4.1.5 Continuous Improvement

92. The TOs will continue to develop our understanding of the health, performance and condition of our Transmission assets and consequently the methods for determining AHIs and rates of deterioration. These enhancements will be reflected in reissues of the NOMs methodology as required in Special Licence Condition 2L.

93. As part of this annual review, the TOs will continue to share information about the processes and factors which feed into the assessment of Network Asset Condition to ensure that the NOMs are consistent and comparable across the TOs.

4.1.6 External Publication

94. There are no confidentiality issues associated with the external publication of the proposed methodology for Network Asset Condition. However, the summary tables that form part of the Transmission RRP should not be published externally. In addition, the Specific Appendices should not be published.

4.2 Network Risk

4.2.1 Licence Requirements

95. Paragraph 2L.4(b) of the Special Licence Condition requires the TOs to enable the evaluation of:

   a. The overall level of risk to the reliability of the TO's Transmission system as a result of Network Asset Condition and the interdependence between network assets (Network Risk)

96. The key elements from this Special Licence Condition are:

   a. Overall level of risk
   b. Inclusion of Network Asset Condition
   c. Interdependence between network assets

97. The TOs carefully considered this Special Licence Condition and in the development of the proposed measures used the following definition for Network Risk:

The likelihood and consequence of a possible negative impact to the network, as a result of a potential future event.

4.2.2 Methodology

98. When developing our investment plans, prioritised candidates for asset replacement or refurbishment are produced for the Lead Assets.

99. Replacement Priorities provide the prioritised replacement or refurbishment candidates Figure 1 shows how Replacement Priorities feed into the development of the investment plan.

100. Replacement Priorities allow the TOs to consider:

   a. The operation of the Transmission system and the impacts of asset unavailability
   b. The impact on the business and its stakeholders of asset management decisions across the whole life-cycle (short, medium, and long term)

101. This allows the TOs to target the assets, economically and efficiently, which represent the greatest Network Risk and thus manage the impact of Network Risk upon the customer.

102. Replacement Priorities are determined through three activities:

   a. Assessment of AHIs – as defined in section 4.1 (Network Asset Condition).
   b. Assessment of Criticality
   c. Derivation of Replacement Priorities

103. There are four categories of replacement priority:

   a. RP 1 (highest risk)
   b. RP 2

c. RP 3
d. RP 4 (lowest risk)

104. Table 7 shows the expected timescales for intervention for each Replacement Priority.

RP 1	0-2 years
RP 2	2-5 years
RP 3	5-10 years
RP 4	10+ years

Table 7: Replacement Priorities

105. Criticality is a representation of the consequence to stakeholders and has three elements:

a. Safety Criticality
b. Environmental Criticality
c. System Criticality

Safety Criticality

106. Safety Criticality is based on the consequence of direct harm to personnel/public as a result of asset failure (e.g. conductor drop, asset fire, explosion).

107. Safety Criticality is scored using a consistent methodology (Very High, High, Medium, Low) which considers the impact of failure/unreliability and the location of the asset.

108. The high level criteria for determining Safety Criticality are described in Table 8 below.

Safety Criteria	Very High	High	Medium	Low
Location	Constant personnel/ public activity within vicinity of asset.	High levels of personnel/ public activity within vicinity of asset.	Regular personnel/ public activity within vicinity of asset.	Limited personnel access. No likely public access.
Impact of Failure/ unreliability	Failure of asset may result in fatality.	Failure of asset may result in permanently incapacitating injury.	Failure of asset may result in reportable injury.	Failure of asset results in minor injury or no consequence.

Table 8: High Level Criteria for determining Safety Criticality

Environmental Criticality

109. Environmental Criticality is based on the environmental impact caused by asset unreliability or failure, taking into account the sensitivity of the geographical area local to the asset.

110. The high level criteria for determining Environmental Criticality are described in Table 9 below. Criteria are not included for the Very High category for Environmental Criticality to ensure comparability with Safety Criticality.

Environmental Criteria	Very High	High	Medium	Low
Location	n/a	Asset located within proximity of environmentally sensitive area	Asset located in controlled area which may be close to an environmentally sensitive area or distributed asset not within proximity of sensitive environment	Asset located in controlled area
Impact of Failure/ Unreliability	n/a	Failure of asset may lead to reportable environmental incident which may result in prosecution.	Failure of asset may lead to significant environmental incident with agency visibility.	Failure of asset may lead to minor environmental incident (without agency visibility) that can be managed locally or no environmental consequence.

Table 9: High Level Criteria for determining Environmental Criticality

111. Both Safety and Environmental Criticality need to be assessed on an asset basis as the safety or environmental impact of asset failure or unreliability will depend on the asset type and its location. For this reason, whilst Safety Criticality and Environmental Criticality are categorised using a consistent scale (Very High, High, Medium, Low), the assessment of Safety Criticality and Environmental Criticality are documented separately for each TO in the Specific Appendices.

112. In Stage 2 significant further work will be undertaken by the TOs to determine exactly what is common and what is specific in terms of assessing safety and Environmental Criticality.

113. Safety Criticality and Environmental Criticality scoring depends upon the asset type and the failure mode. For a circuit comprising several asset types (e.g. Overhead Line and Cable), each asset is scored individually. The impact of unreliability or failure will vary form asset type to asset type and a safety or environmental consequence may not apply for some assets.

114. Table 10 shows where Safety Criticality and Environmental Criticality affects equipment groups.

	Safety Impact?	Environmental Impact?
Overhead Line	✓	X
Cable	✓ *	✓
Switchgear	✓	X
Transformer	✓	✓ (minor)

Table 10: Safety Criticality and Environmental Criticality Impact by Equipment Type

✓ Significant impact from failure of equipment (* applies to cables with specific ancillaries/accessories)
✓ Minor impact from failure of equipment
X No impact from failure of equipment (where equipment considered in isolation)

115. In Stage 2 significant further work will be undertaken by the TOs to re-examine the Safety and Environmental Criticality assessment across the TOs to determine exactly what is common and what is TO specific.

System Criticality

116. System Criticality covers the impact of the Transmission system not delivering services to the customers of the TOs and any indirect impact to the safety to the public (through Energy Not Supplied) or the smooth operation of GB infrastructure and economy.

117. System Criticality specifically includes:

a. Nuclear power station connection sites, with reference to the Nuclear Site Licence Provisions Agreement (NSLPA) and Scottish NSLPA in place
b. Control of Major Accidents and Hazards (COMAH) sites
c. Infrastructure that supports Black Start sites
d. Infrastructure that supports key transport links
e. Infrastructure that supports key sites of economic activity within the UK
f. Impact on customers
g. System security

118. The TOs held discussions with the GB System Operator to determine a System Criticality methodology. The proposals have been developed by the System Operator ensuring sign-on from the TOs.

119. System Criticality combines the elements of vital infrastructure, impact on customers and system security to determine an overall System Criticality category. A high level representation of the building blocks which make up the assessment of System Criticality is included in Figure 5.

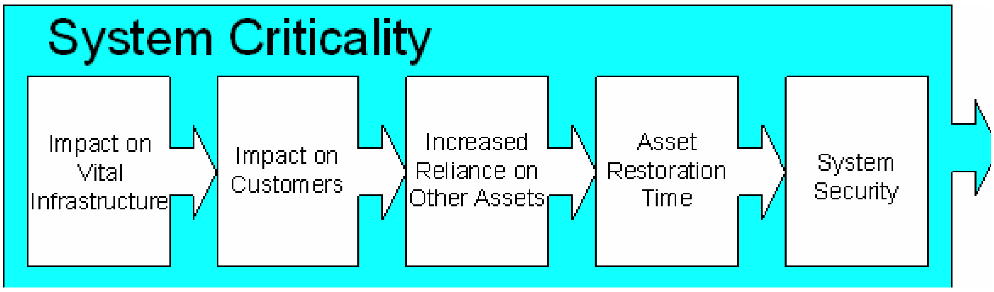

Figure 5: High Level View of System Criticality

120. System Criticality can be defined at both a circuit and a substation level. It is built up of a number of elements with specific examples (not exhaustive) highlighted in Figure 6.

Impact on Vital Infrastructure	• Directly connected customers which impact on public safety • Directly connected suppliers providing key services to the public	• Transport issues • Support Nuclear Generation Safety • Economic key points • COMAH • Black start
Impact on Customers	• Deliverability of electricity to areas in order of density (numbers of customers)	• MWs at risk
System Security	• Delivery of electricity to consumers • Delivery of the most flexible network to the electricity market (accessibility of maximum generation)	• Infrastructure essential for transport of power or voltage stability reasons

Figure 6: Elements of System Criticality

121. System Criticality is scored using a consistent methodology (High, Medium, Low). Criteria are not included for the Very High category to ensure comparability with Safety Criticality.

122. The methodology used for System Criticality is shown in Figure 7.The x and y parameters which are defined by the individual TOs reflect the differing sizes of our Transmission networks.

	Criteria				
Criticality	Vital Infrastructure		Impact on Customers		System Security
C1 Very High	N/A	OR	N/A	OR	N/A
IF NONE OF THE ABOVE ARE APPLICABLE					
C2 High	Vital Infrastructure: {Economic Key Point; Supporting Major Traffic Hub; COMAH Site; Black Start Site; Supports Nuclear Generation}	OR	Substation Demand ≥ [x] MW+	OR	System Security = High
IF NONE OF THE ABOVE ARE APPLICABLE					
C3 Medium	N/A	OR	Substation Demand > [y] and <[x] MW	OR	System Security = Medium
IF NONE OF THE ABOVE ARE APPLICABLE					
C4 Low	N/A	AND	Substation Demand ≤[y]MW-	AND	System Security = Low

Figure 7: Definition of System Criticality

Vital Infrastructure Criticality Criteria

123. Vital infrastructure represents five elements of infrastructure which is crucial to our stakeholders:

a. Infrastructure that supports nuclear power station connection sites

The TOs entered into the NSPLA (National Grid) and Scottish NSLPA (SP Transmission and SHE Transmission) with the nuclear generators to assist with ensuring that a satisfactory safety case could be put in place.

Part of the safety case for nuclear sites includes the availability of power to operate critical pumps, fans, instrumentation, and other systems. The normal source of supply is a connection with the Transmission system with on-site generation acting as back-up supplies.

The NSLPA places obligations on the TOs with regard to planning, operation and maintenance of the Transmission network where it may affect the reliability of the connection to any nuclear power station.

The NSLPA states that a TO shall not do, or omit or cause to be done, anything that would cause the TO to infringe the provision of the nuclear site licence. This provides a further driver to replace assets before failure for these parts of the network.

Those sites or circuits defined within National Grid's Transmission Procedure TP120 (Nuclear Sites Licence Provision) are referred to 'coloured circuits'. Within TP120 there are Appendices A-C which lists, by nuclear generator, the substations, circuits or particular Transmission assets which are required to maintain reliability of the connections. The Scottish NSLPA includes a schedule which lists all relevant plant and equipment required to maintain reliability of the connections and these are reflected into the relevant generator Site Responsibility Schedule. Within Scotland, the System Operator also identifies 'coloured circuits'.

b. COMAH sites

This information is provided at substation level. These are sites which are defined by the Health & Safety Executive and whose unavailability may result in a major safety issue. COMAH applies mainly to the chemical industry but also to some storage activities, explosives, nuclear sites and other industries where threshold quantities of dangerous substances identified in the COMAH Regulations are kept or used.

Further information on COMAH sites is available via the Health & Safety Executive website (http://www.hse.gov.uk/comah/).

c. Black Start sites

The System Operator has an obligation under the Grid Code (CC6.3.5) to ensure that the National Electricity Transmission System can be re-energised in the event of total or partial system shutdown. This Black Start requirement is met through the procurement of Black Start service capability at a number of strategically located power stations across Great Britain and is agreed via bilateral contracts between the System Operator and the relevant power station.

In accordance with its licence conditions, the System Operator aims to procure a black start service economically and efficiently on an ongoing basis. Black Start criticality information is provided at a substation level. Black Start sites are those where generators are able to generate using back-up fuel resources. These are vital when the system has had a major incident and the system has crashed or parts of the system are 'islanded'. The substations are also determined to be vital.

d. Infrastructure that supports key transport links

This information is provided at a substation based level. This information is kept up to date by the System Operator. Given the nature of these sites, they do not change frequently.

These sites are available to the Electricity Transmission control room via the Control Room Advice and Information Guide (CRAIG) within the Sensitive Demand Sites categorised as Transport – Major Airports, Transports – Rail, Other Infrastructure.

e. Infrastructure that supports key sites of economic activity within the UK

These sites support economic activity within the UK and their unavailability will result in areas of economic activity being heavily impacted. These sites are defined by the government and are provided to the TOs. The location of these sites is highly confidential and cannot be included in this methodology.

124. The Criticality scores for sites and substations are reviewed each year and reported as part of the Transmission RRP.

125. If any of the vital infrastructure criteria apply, then the System Criticality is assigned as high.

Impact on Customers Criticality Criteria

126. Substation demand is taken from the submissions from customers. Substation demand is defined as the required demand at the yearly peak as submitted by customers as part of the B/07 and P2/6 processes.

127. This demand data is reported in the Electricity Ten Year Statement. Using the customer submitted demand ensures customer requirements are being taken into account in defining System Criticality. Due to the different scales of the TOs' respective networks, the system demand criteria (i.e. the x and y parameters from Figure 7) for High, Medium and Low Criticality are specific to each TO and defined in the respective Specific Appendix.

System Security Criticality Criteria

128. The principle of redundancy is embedded in the system security element of the Criticality scoring. This treatment takes into account constraints on the system based on the Security and Quality of Supply Standards (NETS SQSS). Redundancy and backup are inherently taken into account in these constraints.

129. The System Operator expects a level of redundancy because outages are needed for interventions (e.g. maintenance, replacement) and redundancy is needed to cover unplanned outages.

130. The System Operator is obliged to ensure security of supply according to section 5.8 of the NETS SQSS which states:

Following the occurrence of a secured event on the onshore transmission system, measures shall be taken to re-secure the system to the above [as described in the NETS SQSS] operational criteria as soon reasonably practicable. To this end, it is permissible to put operational measures in place pre-fault to facilitate the speedy restoration of system security.

131. The NETS SQSS sets out the n-2 criteria used in the system security criticality assessment. Appendix C of this document outlines some of the processes that the System Operator has available in order to re-secure the transmission system in the event of asset failure.

132. The TOs have adopted a consistent approach to deriving the system security element of System Criticality based on the criteria outlined in this methodology, with variations to accommodate the different configurations and sizes of their respective networks.

133. For example, National Grid's method to determine system security is based on:

a. Local Group Demand Criteria

The criticality of circuits feeding a demand group are determined by the unsupplied demand at peak for a n-2 loss taking into account the demand transfer capability within switching time (30 minutes assumed) and a contribution from embedded generation.

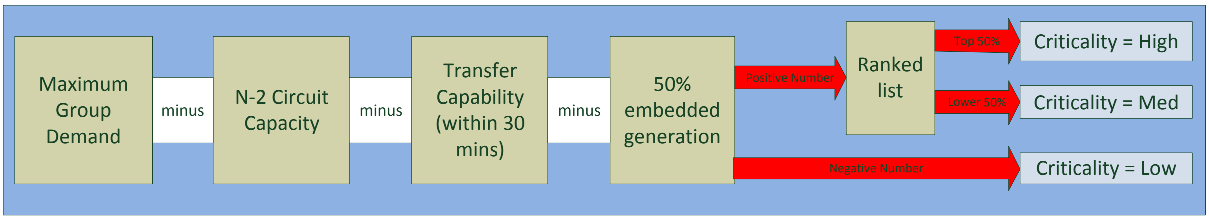

Figure 8: Process to determine criticality of sites/circuits feeding demand group

The greater the unsupplied demand on the system, the greater the assigned System Criticality score for the substation. If the resulting demand is a zero or a negative number, this means that all demand at this site can be supported after the switching time. This would result in an assigned Criticality score of Low. The remaining sites are ranked such that the circuits feeding the higher 50% of this ranking have a Criticality score of High, and the remaining 50% of this ranking have a Criticality score of Medium. Hence, the site/circuit with a greater level of redundancy is assigned a lower Criticality score.

Maximum group demand is taken from the B/07 and P2/6 submissions. n-2 circuit capacity is taken form circuit loading schedules. Transfer capability is taken from the B/07 and P2/6 submissions, qualified by expert operational knowledge of the relevant networks. Embedded generation is a summation of the generation registered capacities.

b. For the Main Interconnected Transmission System, which is categorised as strongly meshed, used for bulk transfer of power from power stations to the centres of demand, the MITS is designed to N-2 and operated to N-D. The Criticality of MITS circuits is assessed using three criteria sets (generation concentration, demand concentration and zonal/boundary issues) each with three resulting Criticality outcomes – across the criteria sets the results are considered to comparable:

Generation Concentration: Areas where there is high concentration of net generation and little supporting infrastructure to transport the energy away to demand centres. High Criticality - The criteria are where there are only four or less transmission circuits connecting generation groups in excess of 2.3GW.

Demand Concentration: Areas where there is a high concentration of net demand and little supporting infrastructure to transport the energy required to meet demand.

The higher the concentration relative to the supporting infrastructure, the higher the assigned Criticality. High Criticality - The criteria are where there are only four transmission circuits connecting demand groups in excess of 1.5GW with little supporting generation.

Zonal/Boundary issues: These are generally constraint boundaries where for the intact system, or the first outage, there may be a significant volume of generation constrained and/or a significant cost. The higher the expectation of constrained volume/cost, the higher the assigned Criticality. High and Medium Criticality -

Constraint boundaries where for an intact system or first outage there is a significant volume of constrained plant or a significant BSIS cost. This is assessed primarily using 'experts' and graded such that approximately the first 50% will be High Criticality and the second 50% will be Medium Criticality. The remaining circuits (those that are not constrained) are Low Criticality.

134. In Stage 2 significant further work will be undertaken with the TOs working in conjunction with the SO to determine what elements of System Criticality are common and what are specific to the TO in terms of criticality assessments, particularly in the context of the treatment of redundancy.

Deriving an Overall Criticality Score

135. In addition to the immediate consequences (e.g. loss of life, pollution of water courses), a breach of the law may result in wider impacts than just financial penalties (where for some offences there is no upper limit on the fine) including individual prosecution and damage to company reputation. As such, the Very High Criticality scoring is only attributable to the Safety elements of Criticality to reflect the safety statutory duties specifically concerning fatalities.

136. The data sources and process used to derive Criticality scores are detailed in Figure 9.

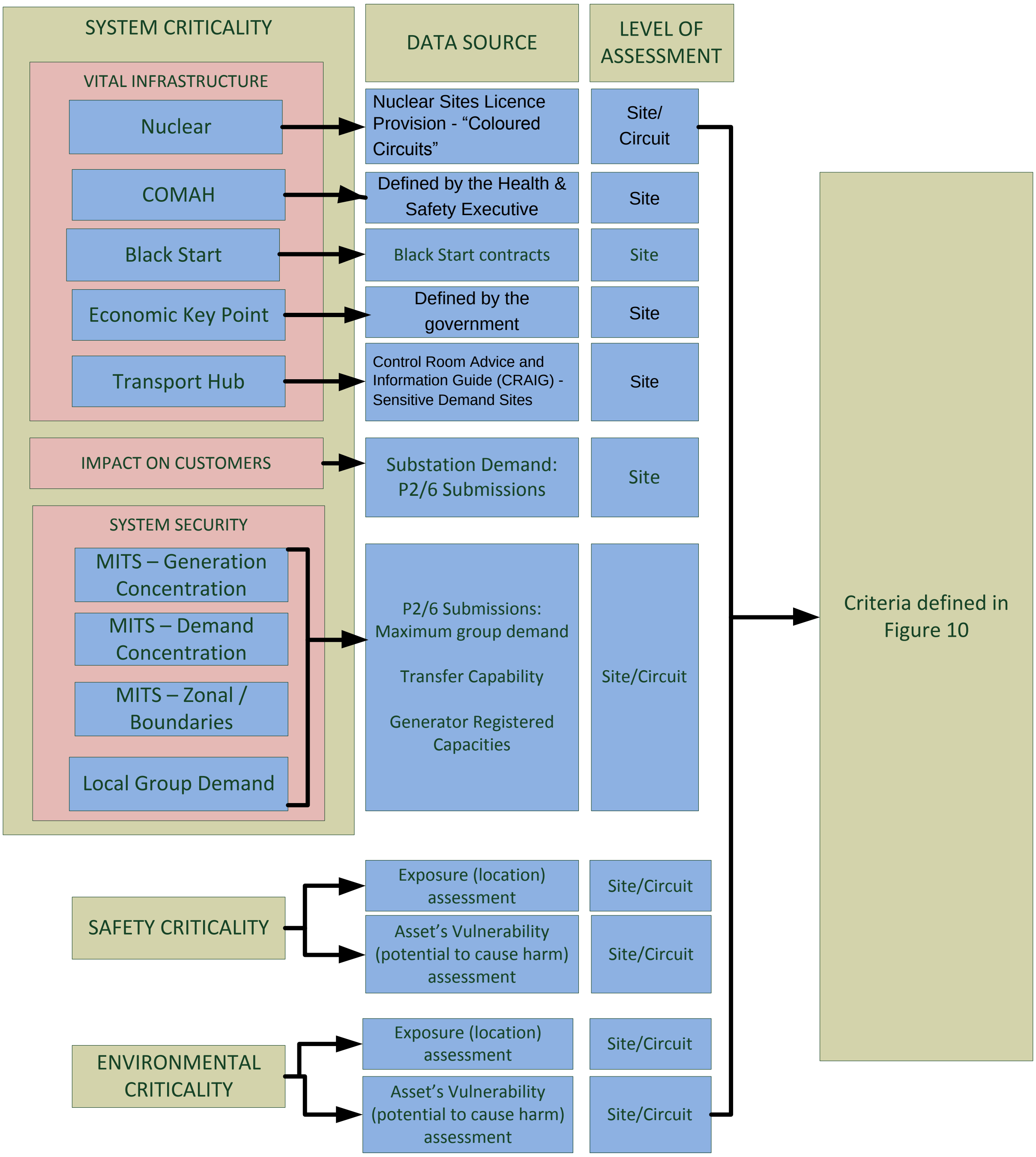

Figure 9: Process for derivation of criticality scores

137. Figure 10 shows how the System, Safety and Environmental Criticality elements map against each other to determine the overall Criticality score.

Criticality	Criteria: System		Criteria: Safety		Criteria: Environment
C1 Very High	N/A	**OR**	Failure of asset may result in fatality. Constant personnel/public activity within vicinity of asset	**OR**	N/A
IF NONE OF THE ABOVE CRITERIA ARE APPLICABLE					
C2 High	Vital Infrastructure: {Economic Key Point; Supporting Major Traffic Hub; COMAH Site; Black Start Site; Supports Nuclear Generation} or Substation Demand ≥[x] MW; System Security = High	**OR**	Failure of asset may result in permanently incapacitating injury. High levels of personnel/public activity within vicinity of asset	**OR**	Failure of asset may lead to reportable environmental incident which may result in prosecution. Asset located within proximity of environmentally sensitive area
IF NONE OF THE ABOVE CRITERIA ARE APPLICABLE					
C3 Medium	Substation Demand = > [y] and <[x] MW or System Security = Medium	**OR**	Failure of asset may result in reportable injury. Regular personnel/public activity within vicinity of asset.	**OR**	Failure of asset may lead to significant environmental incident with agency visibility. Asset located in controlled area or distributed asset not within proximity of
IF NONE OF THE ABOVE CRITERIA ARE APPLICABLE					
C4 Low	Substation Demand ≤[y] MW and System Security = Low	**AND**	Failure of asset results in minor injury or no consequence. Limited personnel access. No likely public access.	**AND**	Failure of asset may lead to minor environmental incident (without agency visibility) that can be managed locally or no environmental consequence. Asset located in controlled area

Figure 10: Criticality Criteria and Mapping for System, Safety and Environmental Scoring

138. Figure 10 shows that the overall Criticality score is derived from the greatest impact identified from the three individual Criticality scores. This ensures that assets with a High score in just one Criticality category can be equally assessed with those containing High scores in two or three categories.

139. A method of weighting and combining Criticalities was considered and rejected on the basis that there was a possibility that the combination process might result in the cancelling out of Criticality scores, potentially resulting in an important Criticality element being overlooked.

140. Criticality is scored for each asset at a substation and circuit level. Safety and Environmental Criticality are location specific (i.e. where they have the potential to cause harm). For example, all Transformers at a substation will have the same Criticality and all Circuit Breakers at that substation will have the same Criticality but it may be different to the Criticality of the Transformers.

141. System Criticality is also scored at a site or circuit level because demand levels at the site are identical and the failure of any asset on a circuit would be covered by the same security criteria.

142. Figure 11 shows how AHIs and Criticalities are mapped to obtain a Replacement Priority.

	AH1	AH2	AH3	AH4	AH5
C1	10+	10+	10+	0-2	0-2
C2	10+	10+	10+	2-5	0-2
C3	10+	10+	10+	5-10	2-5
C4	10+	10+	10+	5-10	2-5

Figure 11: Mapping of Replacement Priorities

4.2.2 Ensuring Consistency

143. To ensure the Network Risk outputs are consistent and comparable across the TOs, as part of the annual review of the NOMs methodology as required in Special Licence Condition 2L, the TOs will continue to share information about:

a. The processes and factors which feed into the assessment of the Replacement Priorities
b. Experiences with delivering the Network Risk measure

144. The TOs undertook other activities to ensure consistency and calibration of the NOMs methodology:

a. The Specific Appendices to the NOMs methodology have been shared at each stage of the process
b. The TOs shared relevant internal documentation regarding processes for determining Replacement Priorities
c. Technical experts from the TOs attended a three-day session to share the information used in the assessment of network expenditure.

4.2.4 Reporting

145. The Replacement Priorities are summarised and included within the Transmission RRP (Table 6.15) as agreed with Ofgem. This allows the TOs to show the overall level of Network Risk and the potential impact of not delivering services to our customers in terms of reliability, safety performance and environmental performance.

146. It is proposed that Table 6.15 reports both actual Replacement Priorities (including the effect of asset replacement or refurbishment performed under both load and non-load schemes) as well as the Replacement Priorities comparable against the

Network Replacement Outputs (section 4.5), the targets for which are defined Table 1 of Special Licence Condition 2M.

147. Actual Network Risk is used by the TOs for both asset management purposes (i.e. how we manage our respective networks) and will be essential to set the correct starting position for the asset base for RIIO-T2.

148. The TOs report the constituent elements of Criticality on a circuit and substation basis in the annual regulatory reporting pack in Table 6.16.

4.2.5 Continuous Improvement

149. The TOs will develop our understanding of the Criticality of our Transmission assets and consequently further enhancements will be made to the Replacement Priorities.

4.2.6 External Publication

150. The information on System Criticality at a site and circuit level is highly sensitive in terms of physical security. Information on the methodology used to derive the categories or any of the outputs from applying this methodology should not be published.

151. In addition, the methodology used to drive Safety or Environmental Criticality or any of the outputs from applying this methodology should not be published as this information could cause public concern if taken out of context.

152. The summary tables that form part of the Transmission RRP should not be published externally.

4.3 Network Performance

4.3.1 Licence Requirements

153. Paragraph 2L.4(c) of Special Licence Condition requires the TOs to enable the evaluation of:

a. Those aspects of the technical performance of the TO's Transmission system which have a direct impact on the reliability and cost of services provided the TO as part of its Transmission business (Network Performance)

154. The key elements from this Special Licence Condition are:

a. Performance of the TO's Transmission system
b. Direct impact on the reliability and cost of the services

4.3.2 Methodology

155. Network Performance is a key output for the customers of the TOs.

156. To provide a full picture on Network Performance, it is necessary to consider a number of complementary performance measures. This is because some measures consider events only and some consider a combination of event and duration.

157. Reduced reliability of the Transmission network increases the risk of loss of supply for directly connected customers and increased costs to market participants which impact the consumer. An increased number of loss of supply events creates a cost of inconvenience to the general consumer and in extreme cases will result in a significant impact upon the economy.

158. Average Circuit Unreliability (ACU) is derived from the unavailability of the network due to outages occurring as a result of unreliability events which cannot be deferred until the next planned intervention and is defined in Equation 1 below.

$$\frac{\text{Total Duration of Repair (cumulative across circuits)}}{\text{Number of Circuits * Duration of reported time period}}$$

Equation 1: Average Circuit Unreliability

159. Duration in the context of ACU is a continuous number and is not rounded or truncated at any stage of the calculation, thus no errors are introduced into the calculation.

160. The monthly duration is calculated using a differing number of days in a month and so any calculation to derive a yearly number will require a suitable weighting of monthly values to account for this.

161. The outages which are classified as being included within the definition of ACU are:

a. Enforced unreliability outages taken at less than 24 hours' notice (otherwise known as unplanned unavailability)
b. Planned unreliability outages taken after 24 hours' notice

162. All unreliability related outages are included within the definition of ACU. The definition above assumes that no outages are planned with less than 24 hours' notice as any such outage would fall into part a. in the definition above.

163. The TOs have investigated whether the Fault and Failure data provides a statistically significant dataset to derive correlations with asset condition. The actual number of Faults and Failures is very small across all the TOs. This is a result of:

a. Actual population sizes of the assets. The population is not large enough to experience a great number of reliability related Faults and Failures
b. Asset management approach within the business. The TOs maintain assets to manage the number of faults experienced an aim to replace before failure using AHI and Criticality to prioritise asset replacement candidates. This means many Faults and Failures that might occur are avoided.

164. The number of Faults and Failures has proven insufficient to enable accurate correlations with asset condition. Details of the investigations undertaken by each TO are included in the respective TOs' Specific Appendices.

165. By looking at Functional Failures, there is a greater set of data which can be used for correlation with asset condition. Functional Failures include those unreliability related outages which are used to determine ACU.

166. Each TO has varying historical datasets with which to produce correlation of asset unreliability with asset condition. In addition, given the introduction of AHIs on a consistent basis across the TOs, there is limited historical condition information to provide correlation with Functional Failures. These historical datasets will grow with time and thus the accuracy of the correlations will improve.

167. The investigations undertaken by each TO include the analysis undertaken to identify correlations between asset unreliability and asset condition are detailed in the TOs' Specific Appendices.

4.3.3 Ensuring Consistency

168. The ACU is calculated consistently using the same definitions in line with the RIGs for all TOs.

169. The calculation to determine Energy Not Supplied for incentivised loss of supply events according to transmission licence condition 3C is based upon a joint methodology statement. This was developed jointly between all transmission TOs and is therefore applied consistently.

4.3.4 Reporting

170. The TOs report a comprehensive set of Network Performance measures in the form of Energy Not Supplied (Table 6.3), Average Circuit Unavailability (Table 5.10) as well as Faults and Failures information (Table 5.2) with associated commentary through the Transmission RRP.

171. For ACU, the total number of circuits used in this calculation varies by TO and will vary from year to year as the networks are modified. For this reason, the number of circuits used as part of the ACU calculation is reported as at 31 March each year.

4.3.5 Continuous Improvement

172. The TOs will continue to assess the performance of their assets and, through monitoring these metrics, will use them to develop strategies to manage asset unreliability.

4.3.6 External Publication

173. There are no issues with the external publication of the NOMs methodology for Network Performance. The summary tables as reported in the Transmission RRP should not be published externally.

4.4 Network Capability

4.4.1 Licence Requirements

174. Paragraph 2L.4(d) of the Special Licence Condition requires the TOs to enable the evaluation of:

   a. The Network Capability measure, which relates to the level of the capability and utilisation of the TO's Transmission system at entry and exit points and to other network capability and utilisation factors

175. The key elements from this Special Licence Condition are:

   a. Information about Transmission system capability
   b. Information about Transmission system utilisation

4.4.2 Methodology

176. The TOs report on Transmission system capability as part of the Transmission RRP which monitors the existing Transmission capacity being provided by the TOs on the NETS.

177. Likewise, the Transmission RRP requires the individual TOs to collect information relating to more localised demand driven needs for developing transmission infrastructure. This is presented in Table 5.5 with utilisation being represented as demand as a percentage of capacity. This shows the relationship between localised demand and capacity and hence provides a proxy measure for utilisation.

178. Adopting these measures ensures consistency in reporting and interpretation of requirements across all TOs.

Provision of information on Voltage and Stability (Thermal)

179. Information is reported in the ETYS at a boundary level. This boundary capability is calculated based on the most onerous limitation whether this is thermal or voltage.

180. Where stability constrains boundary capability this data will be provided where it is available.

181. Transmission RRP Table 5.4 reports present year boundary capability and incremental capability for the reinforcement completed in the present year.

4.4.3 Ensuring Consistency

182. Capability and utilisation is reported by the TOs in a consistent manner according to the RIGS. As described earlier, demand is represented as a percentage of capacity, hence ensuring a consistency of reporting despite the differing scales of the respective TOs' networks.

4.4.4 Reporting

183. Tables 5.3 and 5.4 of the Transmission RRP reflect the capability requirement and boundary capability for all RIIO boundaries. Table 5.5 reflects the utilisation requirement.

184. Table 5.3 collects information on Transmission capacity against required transfer levels at key parts of the Transmission system.

185. Actual capability information is provided in Table 5.4 and reflects the impact of specific schemes on the capability for each boundary. For each scheme the thermal, voltage and stability incremental capability across each boundary is given. In addition, the Table shows the capabilities at the start of the reporting period and the final overall capability (based on all schemes). The RIGs provide the rules for creating Table 5.4.

186. The rules for creating Table 5.5 are also taken form the RIGs. Information will be used from the most recent business planning studies. Further rules are as follows:

   a. Peak Demand: the maximum demand of the demand group at the substation
   b. Maintenance Period Demand: as defined in the NETS SQSS
   c. n-1 Capacity: the first circuit outage condition as defined in the NETS SQSS
   d. n-2 Capacity (300 MW demand groups only): the second circuit outage condition as set out in the NETS SQSS. This is only applicable for substations where the peak group demand is greater than 300 MW.

4.4.5 Continuous Improvement

187. The TOs will continue to review the submitted information for Network Capability.

4.4.6 External Publication

188. There are no issues with the external publication of the proposed NOMs methodology for Network Capability. The summary tables which form part of the Transmission RRP should not be published externally. The Specific Appendices should not be published.

4.5 Network Replacement Outputs

4.5.1 Licence Requirements

189. Special Licence Condition 2M specifies the Network Replacement Outputs the TOs must achieve by the end of the price control period and the principles associated with material over- or under-delivery against those outputs.

190. The actual Network Replacement Outputs at the end of the price control will be assessed by Ofgem to determine whether adjustments should be made to expenditure allowances in the next price control period, RIIO-T2, which commences on 1 April 2021.

191. The TOs are permitted to make trade-offs between asset categories in order to achieve an equivalent or better level of Network Risk.

4.5.2 Methodology

192. The TOs submitted forecast Network Risk Replacement Priorities at 31 March 2021 as part of our RIIO-T1 submissions.

193. Over the RIIO-T1 period, the assets will continue to deteriorate and the TOs' modelling calculates how assets move from one Replacement Priority to another having taken replaced assets into account. The output of this modelling provides both a future view of Network Risk and also a forecast of the work required in the next ten years. An example of this forecasting using dummy data is shown in Figure 12.

194. This forecast of work required along with forecasts of the other interventions (e.g. load related works, maintenance) provides the TOs with the opportunity to smooth volumes of interventions so that system access, internal and external resource, and capital and operational expenditure can be used efficiently.

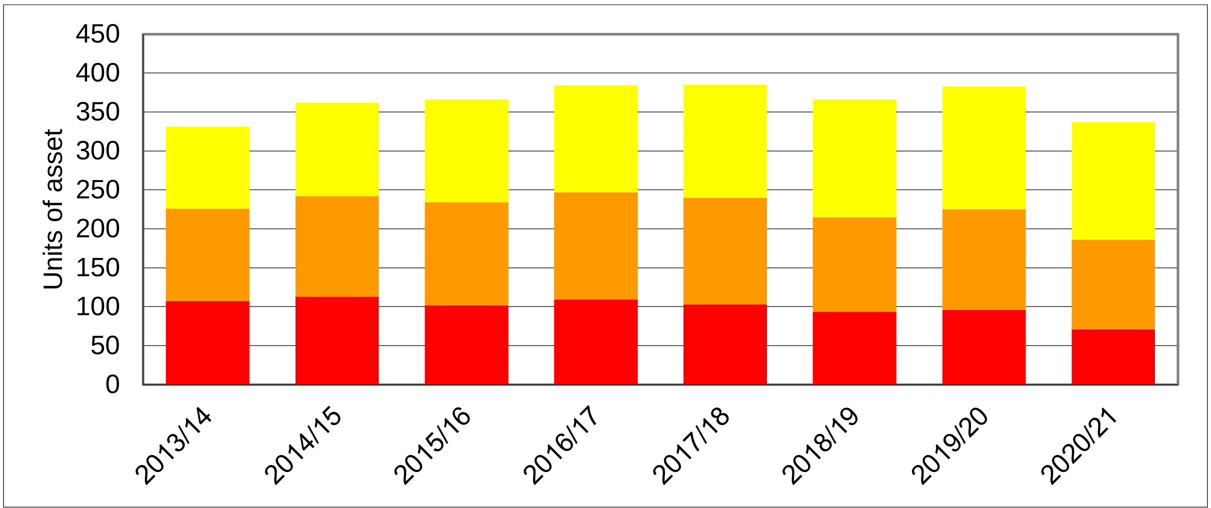

Figure 12: Year-end Replacement Priorities

195. Figure 12 shows the Replacement Priority volumes at 31 March (i.e. at the end of each financial year) for a lead asset. The overall Network Risk is shown by the RP 1, RP 2 and RP 3 categories for each year. The volumes of assets in the RP 1 and RP

2 categories indicate the assets in the poorest condition but the RP 3 category also indicates the number of assets coming up for asset replacement or refurbishment in future years.

196. Figure 12 also summates the effect of replacement or refurbishment over the period as well as the impact of asset degradation. The forecast can be compared with current volume of Replacement Priorities. A high volume of assets in the RP 1 category may reflect the fact that all the assets that were intended for replacement or refurbishment during the RIIO-T1 period may not have been replaced or refurbished, or it may indicate that there is a larger volume of assets which are RP 4 or RP3 today that will have degraded to RP 1 over the period.

197. If there is a large population of assets commissioned in a short time window (such as the roll out of the 400 kV network in the late 1960s and early 1970s) these may all be coming due for replacement in the RIIO-T2 period. This graph will therefore indicate the need for volume management strategies to ensure that future volumes remain economically deliverable.

198. The forecast of Replacement Priorities at 31 March 2021 represents the Network Replacement Outputs, the level of Network Risk at the end of the RIIO-T1 period. Table 1 in Special Licence Condition 2M of each TO's licence details the expected Network Replacement Outputs for each asset category, at each voltage level, and this table is specific to each TO. The process for setting these targets is described in Figure 13.

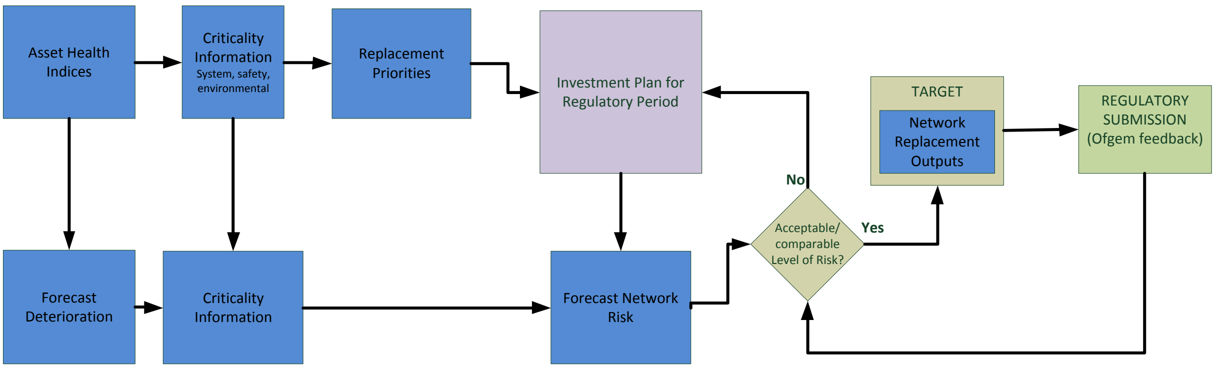

Figure 13: Process for Setting Network Replacement Output Targets

199. In order to achieve these targets, the forecast takes into account the deterioration of the assets and any interventions that will have the effect of improving Asset Health Index. These interventions are defined, as agreed with Ofgem, in the glossary (section 1.3) and repeated in Table 11 for clarity.

	Intervention	Definition
NOMs	Replace	Interventions to replace an asset in its entirety that is in a state requiring replacement. The asset's Health Index will be reset or improved.
	Refurbish	Interventions that will change asset condition and/or extend asset life which also have the effect of improving the asset's Health Index.
Non-NOMs	Maintain	Activities to achieve asset life and ensure asset performance. Maintenance would not be expected to improve the asset's Health Index and will not extend its asset life.

Table 11: Definition of Interventions

Treatment of load related investment

200. The target for the Network Replacement Outputs is the level of Network Risk based on investment in non-load related (NLR) schemes only. Any replacement of assets that fall into the window of replacement that is achieved from load related (LR) investment must be excluded from the overall level of Network Risk when determining whether the targets have been met and how the TOs have performed at the end of RIIO-T1.

201. As the impact of LR investment is excluded, the Network Risk reported against the target does not reflect actual Network Risk on the system. To this end, the TOs will report both NLR Network Risk and actual Network Risk for each reporting year.

202. It is particularly important for the TOs to understand the actual level of Network Risk to appropriately manage our assets and to plan investments going into the future. For RIIO-T2 it is very important that the investments and outputs are derived from actual Network Risk.

203. Figure 14shows the difference between actual Network Risk with no investment, actual Network Risk with both LR and NLR investment, and Network Risk with NLR investment only. The Network Replacement Outputs target is based upon the Network Risk position with NLR investment only.

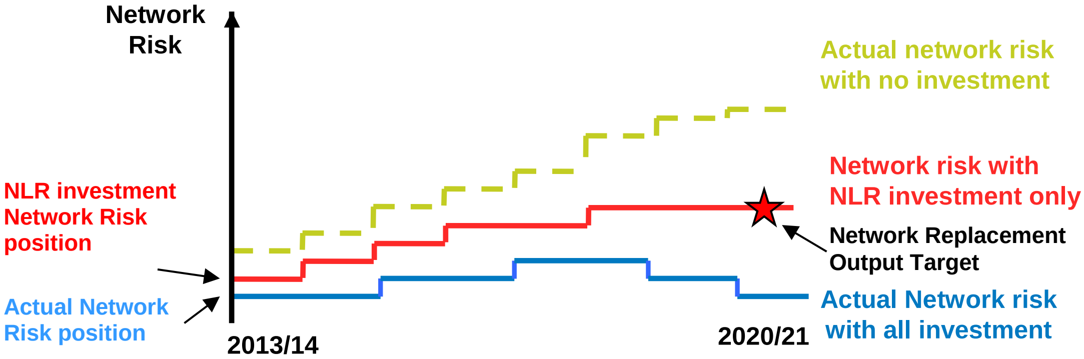

Figure 14: Network Risk Position Showing Different Types of Investment

204. The TOs report the asset additions and disposals and the type of investment (whether LR or NLR) year on year in the RRP.

205. In order to convert the actual Network Risk value into one that is only based on NLR investment, the impact of all LR investment within the specific time period being reported needs to be removed. The NLR only Network Risk is obtained by assuming the LR investments had not occurred.

206. NLR only Network Risk is calculated by adding the unit (e.g. Transformer) or length (e.g. Cable) that was removed on the LR scheme back into the inventory and subtracting the LR unit or length that was added from the respective Replacement Priority categories. This creates a ‘ghost asset’. The waterfall chart in Figure 15 illustrates this conversion from actual Network Risk (stacked column on the far left) to NLR only Network Risk (stacked column on the far right) by showing the asset removed as a positive number and the asset added as a negative number for a reporting year.

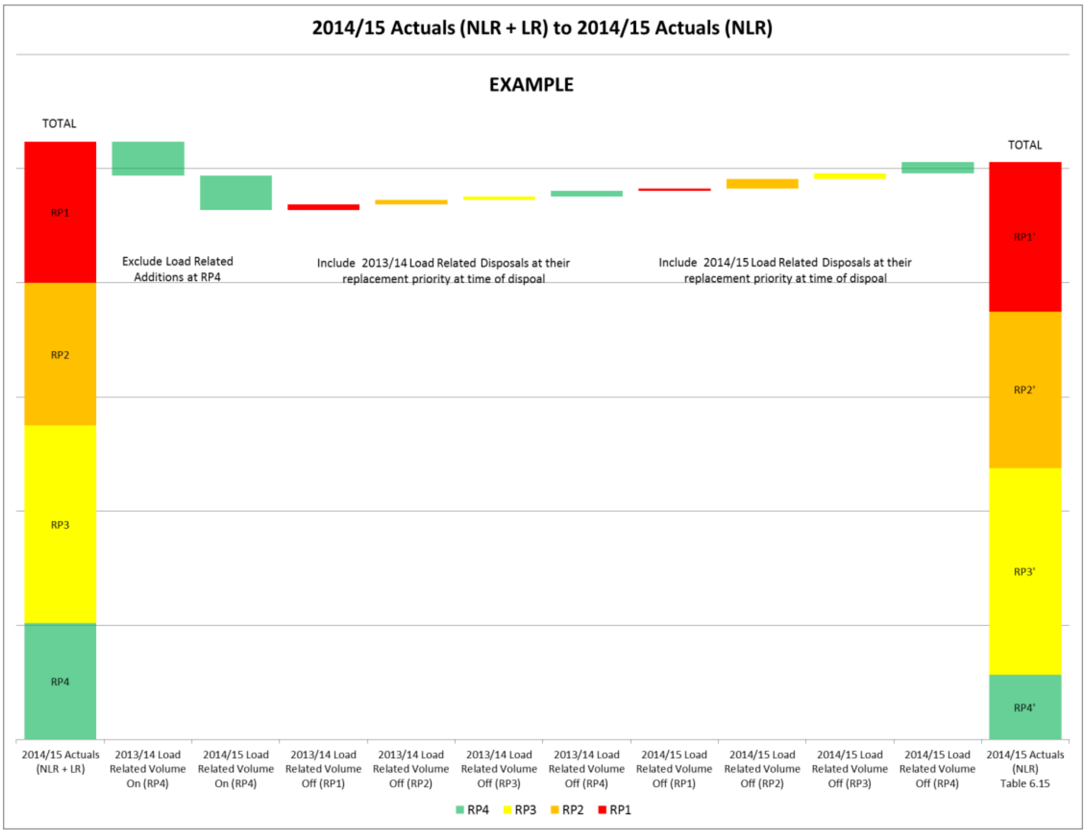

Figure 15: Waterfall Chart Showing How NLR Network Risk is Derived from Actual Network Risk

207. There may be instances where an asset replaced under a LR investment suffers an early life failure. Special treatment is required for such failures because NLR only Network Risk does not take LR investment into account. Therefore an early life failure of an asset commissioned under a LR investment cannot be simply represented because the asset that has failed has previously been excluded from the NLR only Network Risk.

208. If an asset replaced under a LR investment (‘ghost asset’) fails, the effect of replacing the ghost asset should be same as the effect of a NLR replacement:

209.When the LR investment replaces an existing asset on the system:

a. If the LR investment asset is replaced after failure, the NLR only Network Risk will first be decreased by the volume associated with the asset that is replaced by the LR investment (with corresponding Replacement Priority), and secondly increased by the volume associated with subsequent NLR volume on (with corresponding Replacement Priority)
b. If the LR investment asset is decommissioned after failure (i.e. not replaced) the NLR only Network Risk will be decreased by the volume associated with the asset that is replaced by the LR investment (with corresponding Replacement Priority)

210.Figure 16describes the scenario when a LR investment replaces an existing asset (e.g. a demand reinforcement requiring TO network reconfiguration involving the replacement of existing assets, assumed to be RP 3 for the purpose of illustration) and then this asset fails and is subsequently replaced under a NLR replacement.

211.Figure 16 shows the movement of the NLR only Network Risk for this scenario. Before failure of the asset, there is no impact on the NLR only Network Risk because the investment is LR. After the failure of the LR asset, the asset is treated as if the original asset that was replaced is taken off the NLR only Network Risk. The NLR only Network Risk will be decreased by the original volume off but with the Replacement Priority of the asset that was originally replaced by the LR investment. The subsequent NLR volume on will increase the NLR only Network Risk with the corresponding Replacement Priority.

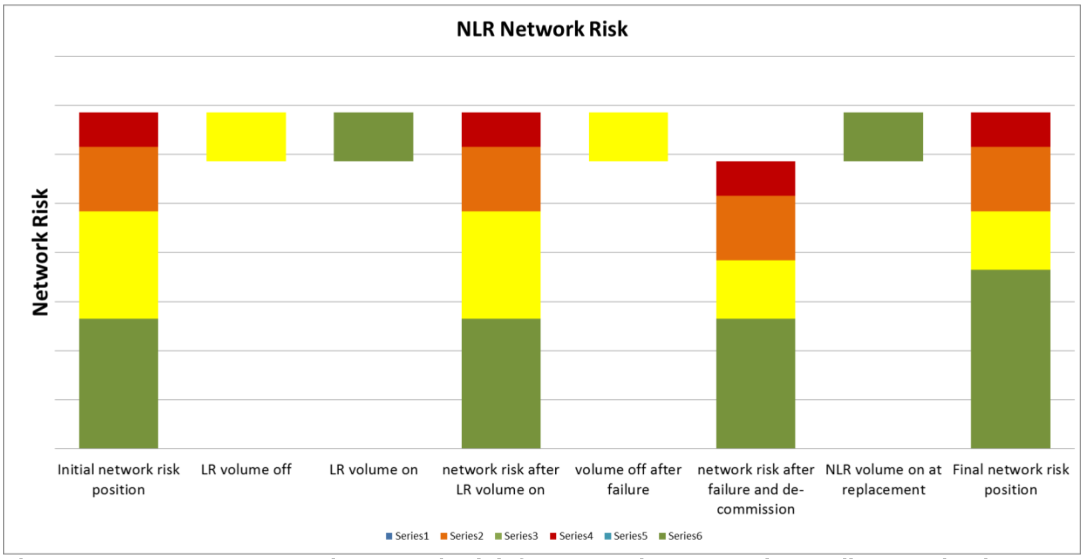

Figure 16: Impact on NLR only Network Risk for LR Replacement, then Failure, and subsequent NLR Replacement

212.When the LR investment introduces an additional asset on the system:

a. If the LR investment asset is replaced after failure, the NLR only Network Risk will be increased by the volume associated with the NLR volume on and corresponding Replacement Priority
b. If the LR invest asset is decommissioned after failure (i.e. not replaced) the NLR only Network Risk will not be affected

213.Figure 17 describes a scenario when as asset is commissioned (e.g. a new generation connection requiring new Transmission assets on a greenfield site) under a LR investment, and then fails and is replaced under a NLR investment. For the NLR only Network Risk, a LR volume on will not change the NLR only Network Risk.

214. After the failure, a NLR volume off is not applicable to the NLR only Network Risk as the asset is not included in the NLR only Network Risk. The subsequent NLR volume on will increase the NLR only Network Risk associated with corresponding Replacement Priority.

215. As illustrated in Figure 17, it is most likely that the asset being added will be RP 4. There may be circumstances that TOs decide not to replace the failed asset and simply decommission it. In this case there will be no impact on NLR only Network Risk.

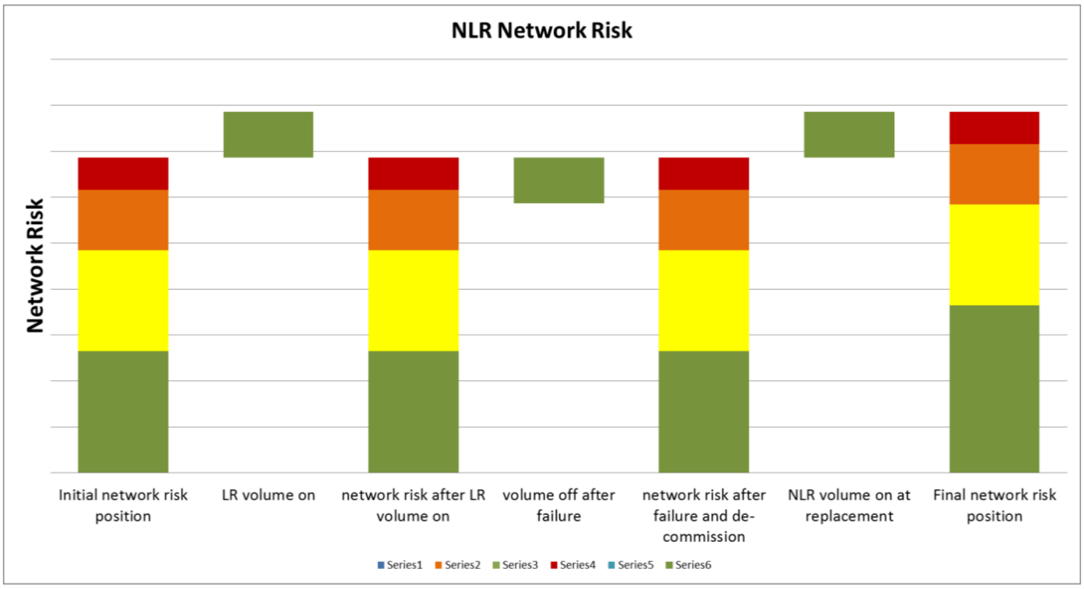

Figure 17: Impact on NLR only Network Risk for LR Volume on, then failure, and subsequent NLR Replacement

Impact of changes to Criticality

216. Although Criticality is not expected to change greatly over the RIIO-T1 price control period, there may be instance where Criticality scores may be revised. This may include an asset replaced by a different asset type removing a risk (e.g. replacing an oil filled cable with an XLPE cable removes the environmental risk) or demand levels changing, which would necessitate a review of the System Criticality.

217. In practice, these changes are small and are not expected to have a significant impact on Network Risk. However, in order to account for changes in Criticality, the effect of the Criticality change on Replacement Priorities is monitored and the net difference is reported year on year in the RRP narrative. Figure 18 demonstrates an example of the impact of Criticality changes on Network Risk.

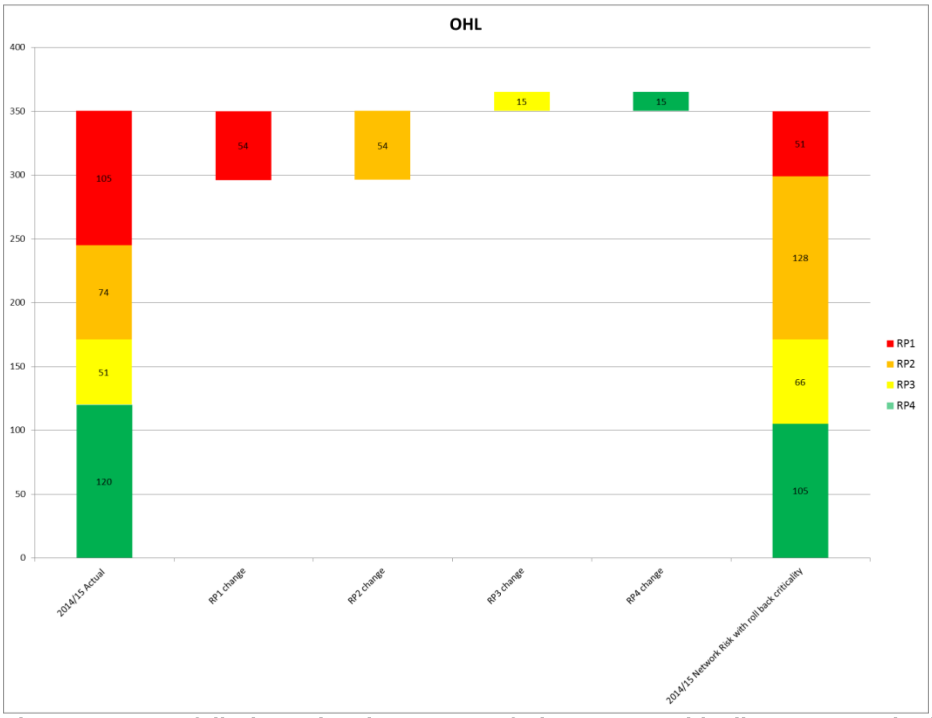

Figure 18: Waterfall Chart Showing Impact of Changes to Criticality on Network Risk

Network Risk trade-off mechanism

218. In assessing the TOs' performance at the end of RIIO-T1, Special Licence Condition 2M.5 includes provision for a trade-off mechanism which allows the TOs to trade between asset types in order to demonstrate an equivalent or better level of Network Risk. The Special Licence Condition states:

In assessing whether the licensee should be deemed to have delivered a particular Network Replacement Output under paragraph 2M.3 of this condition the Authority will, amongst other things, take account of any trade-offs between asset categories which the licensee is able to demonstrate has or are likely to deliver an equivalent or better set of Network Outputs to those specified in Table 1 of this condition.

219. In determining whether the TOs have met the targets for the Network Replacement Outputs, Special Licence Condition 2M.9 describes the treated of under- or over-delivery according to Table 12.

Incentives	Justified	Unjustified
Over-delivery	Cost of over-delivery shall be included in the second price control period allowances The financing cost incurred by the licensee in advancing investment shall be reimbursed Reward of 2.5 per cent of the additional costs associated with the material over-delivery	Cost of over-delivery shall be included in the second price control period allowances The licensee shall incur the financing cost of earlier investment
Under-delivery	Cost of under delivery shall be excluded from the second price control period allowances The licensee shall benefit from the financing cost of delayed investment	Cost of under delivery shall be excluded from the second price control period allowances The benefit arising to the licensee from the financing cost of delayed investment shall be clawed back Penalty of 2.5 per cent of the avoided costs associated with the material under-delivery

Table 12: Treatment of under- and over-delivery of Network Replacement Outputs (2M.9)

220. In Stage 2 further work will be undertaken to define what reasons will be accepted as justified and unjustified under- and over- delivery.

221. In order to be able to compare Network Risk between the different asset classes, risk needs to be expressed in a ‘common currency’, Monetised Network Risk. Monetised risk is a utility function, a measure of preferences. The utility function is a way of assigning a number, in this instance a risk cost, to each asset such that a high risk cost asset holds a greater level of Network Risk.

222. This ensures a consistent approach in comparing the relative importance of the assets and enables scenarios that can allow trade-off between the different asset classes.

223. It is important to note the monetised values represent a risk cost associated with the consequence of assets failing. This risk cost does not represent the cost of investment to replace the assets.

224. Monetised Network Risk is composed of three elements:

a. Probability of Failure
b. Monetised Criticality
c. Financial Consequence

The trade-off converts the Network Replacement Outputs into Monetised Network Risk target, £, as shown in Figure 19.

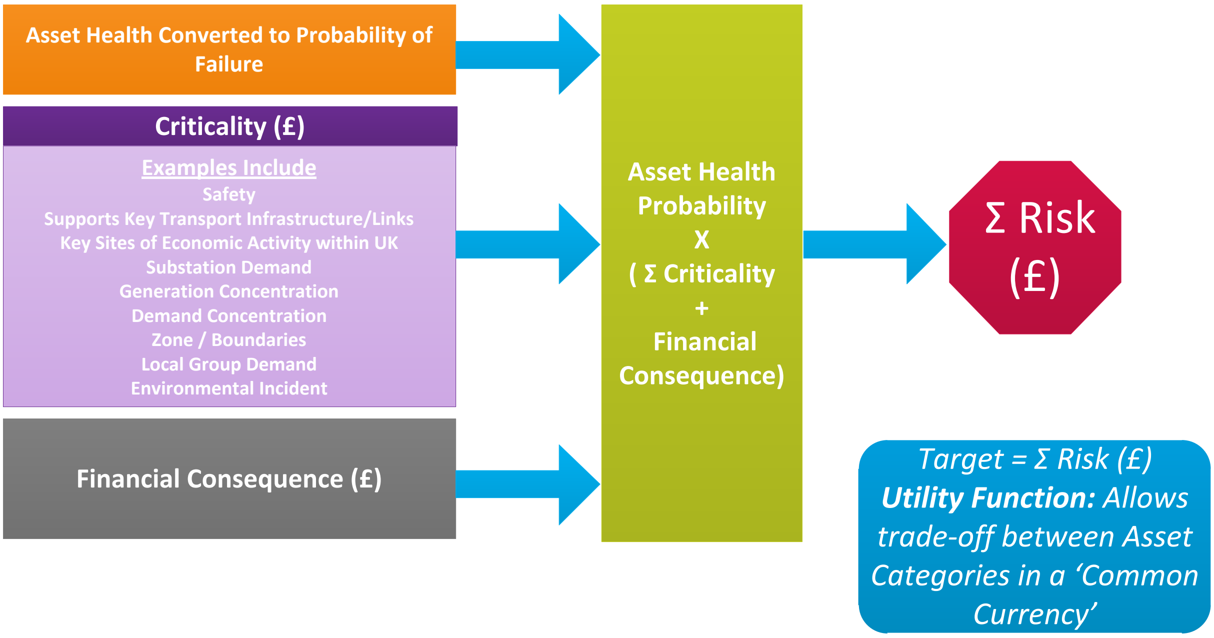

Figure 19: Derivation of Monetised Risk

Probability of Failure

225. Probability of Failure represents the likelihood that an asset fails.

226. Figure 20 illustrates the Probability of Failure as a function of asset condition. It is dependent on asset type, current AHI and expected future AHI. It is derived from the asset deterioration curves using an equivalent age approach.

227. The equivalent age approach can be understood in a similar way to calculating human 'health age' by adding health related factors such as BMI, smoking history, dietary and exercise habits, etc. (See appendix E)

228. The Probability of Failure is based upon catastrophic failure because this is the type of failure that the TOs are trying to avoid with asset replacement or refurbishment interventions. The adoption of this failure type is consistent with trading Network Replacement Outputs.

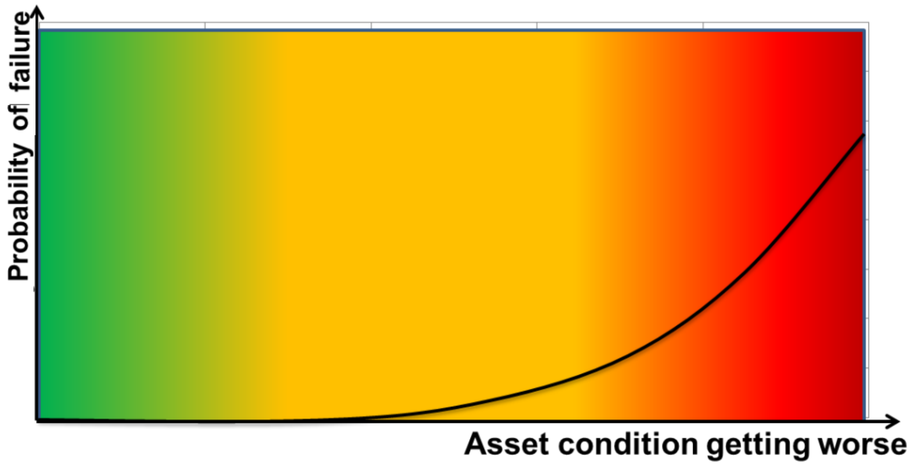

Figure 20: Probability of Failure

229. The Probabilities of Failure for each asset group (and sub-groups depending on asset design) are specific to each TO.

a. Transmission asset populations are small and vary between TOs
b. Assets are located in different environments
c. There will be differences in the way that the assets have been operated or maintained throughout their lives.

230. In Stage 2 significant further work will be undertaken by the TOs to determine exactly what is common and what is specific in terms of defining probabilities of failure.

231. A methodology of calculating the Probability of Failure is described.

232. The Probability of Failure is a conditional probability function based on the asset still being in service at the point of observation. See Appendix E for references on probability theory. It is derived as follows:

a. The deterioration models are taken for each asset group (and sub-groups) as derived in section 4.1
b. An equivalent age is derived for assets with different AHI using the deterioration model
c. As described in section 4.1.2, the deterioration model establishes links between AHI and asset age
d. The equivalent age can be therefore expressed as a function of both the AHI and the real age of the asset
e. The Conditional Probability of Failure according to its equivalent age can be calculated through the standard asset life approach which combines a probability of failure density function and cumulative probability of failure function

$$\text{Conditional Probability of Failure} = \frac{\text{Probability of Failure Density Function}}{1 - \text{Cumulative Probability of Failure Function}}.$$

Equation 2: Probability of Failure

233. It should be noted that Probability of Failure is defined over a 1 year period and assumes a constant value of probability over this period.

a. The Probability of Failure density function and Cumulative Probability of Failure function are illustrated in Figure 21 and the Conditional Probability of Failure can be calculated using Equation 2.
b. The equivalent age is mapped onto the Conditional Probability of Failure curve for each AHI to obtain the Conditional Probability of Failure as a function of AHIs. This is shown in Figure 22

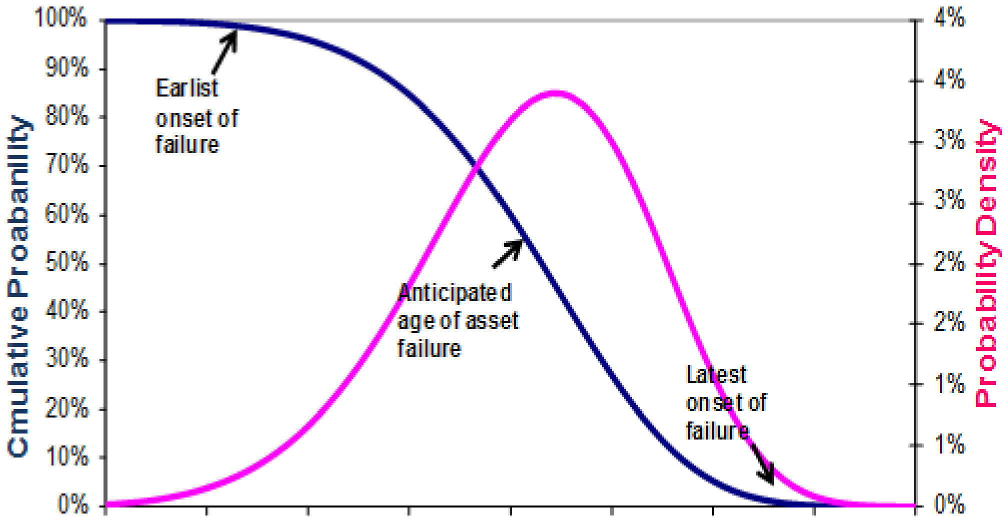

Figure 21: Probability of Failure Density Function and Cumulative Probability of Failure Function with regard to Asset Life

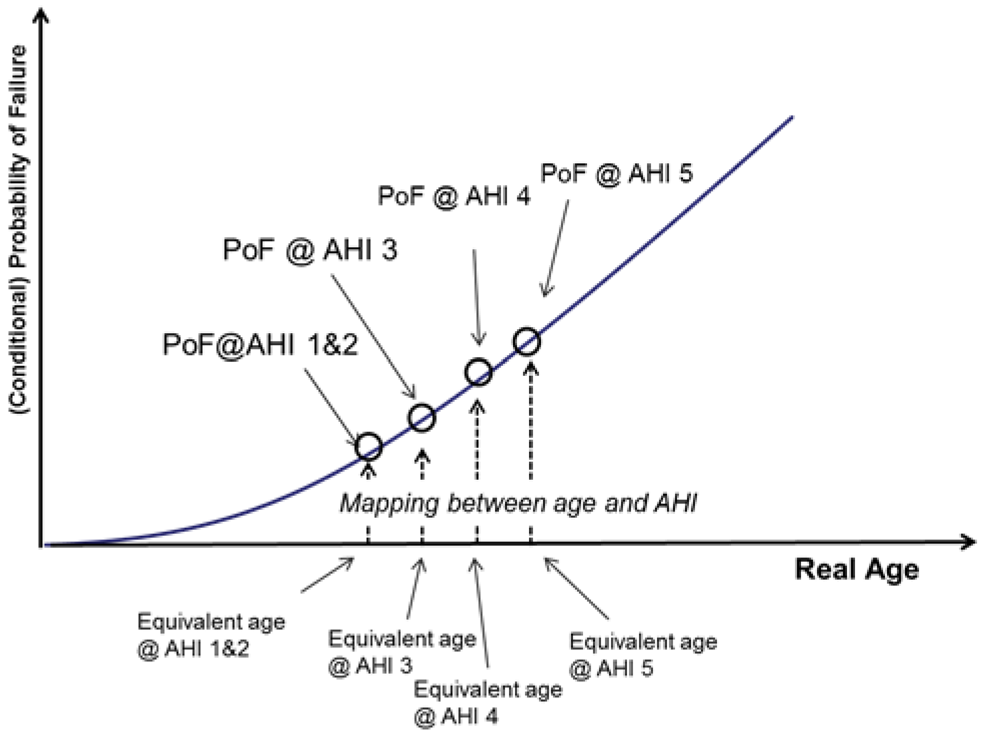

Figure 22:Calculating (conditional) Probability of Failure using the equivalent age to obtain (conditional) Probability of Failure as a function of AHIs

234. An average value is used for Probability of Failure at a particular AHI for each asset type (or sub-groups). An example of Probability of Failure for different asset groups, using dummy data, is shown in Figure 23.

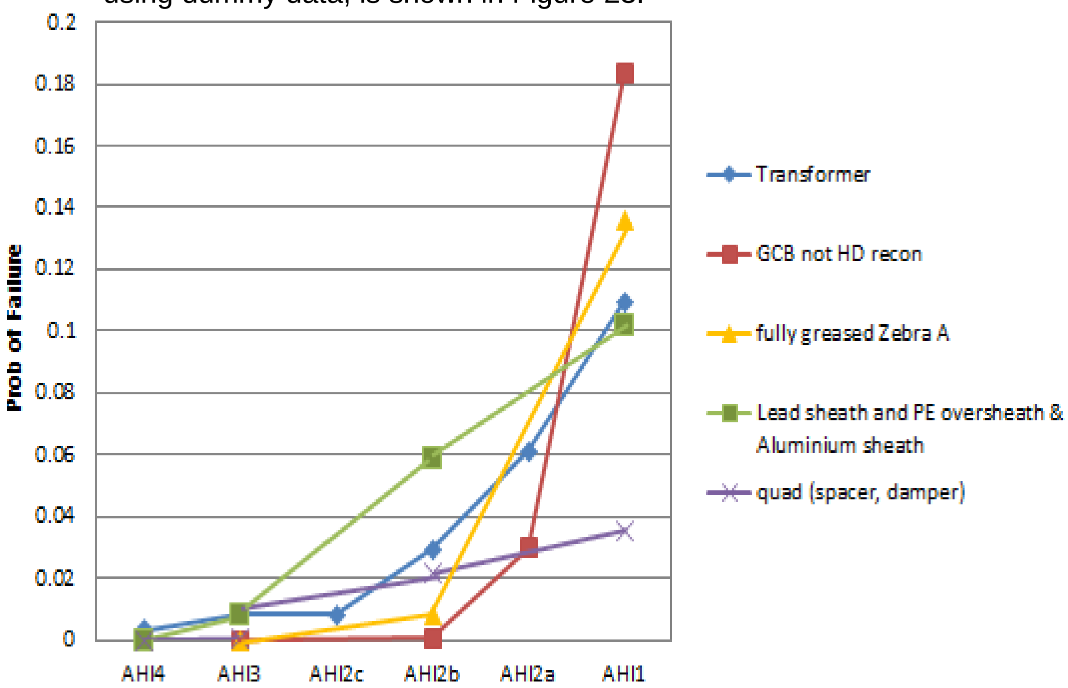

Figure 23: Probability of Failure as a function of AHI

235. In order to address uncertainties around the Probability of Failure, the TOs acknowledge that there are potentially uncertainties due to “hazard censoring”. This occurs because assets are generally removed from the system before failure, hence

detailed information about in-service failures is limited for transmission system assets. There might also be other uncertainties generated when the average Probability of Failure is used for an asset group or sub-group. This treatment is generally regarded as sufficient to be used to trade-off between different asset types and health indices. The framework of using a unique Probability of Failure assigned to each Asset Health Index provides a suitable balance between complexity and practicality.

236. The process of testing, described in Section 5.3, will provide assurance that the Probabilities of Failure are consistent with actual asset performance.

Monetisation of Criticality and High Impact, Low Probability events

237. Financial consequences of significant international events have been examined, focussing on the social impact of asset failure in order to derive monetary values for each element of Criticality. Focussing on the social impact of asset failure, financial consequences of events that have occurred across the world have been examined.

238. The monetary values have been derived from events that have occurred in western economies and have been converted to £GBP and inflated to 2015 prices. These are shown in Figure 24. The references for the derived values can be found in Appendix A and the TOs are particularly interested to gather any additional information which can be used to inform this work from stakeholders and interested parties. The explanation of how the particular values were chosen for the different Criticality values (shown as red stars in Figure 24) is given in Table 14.

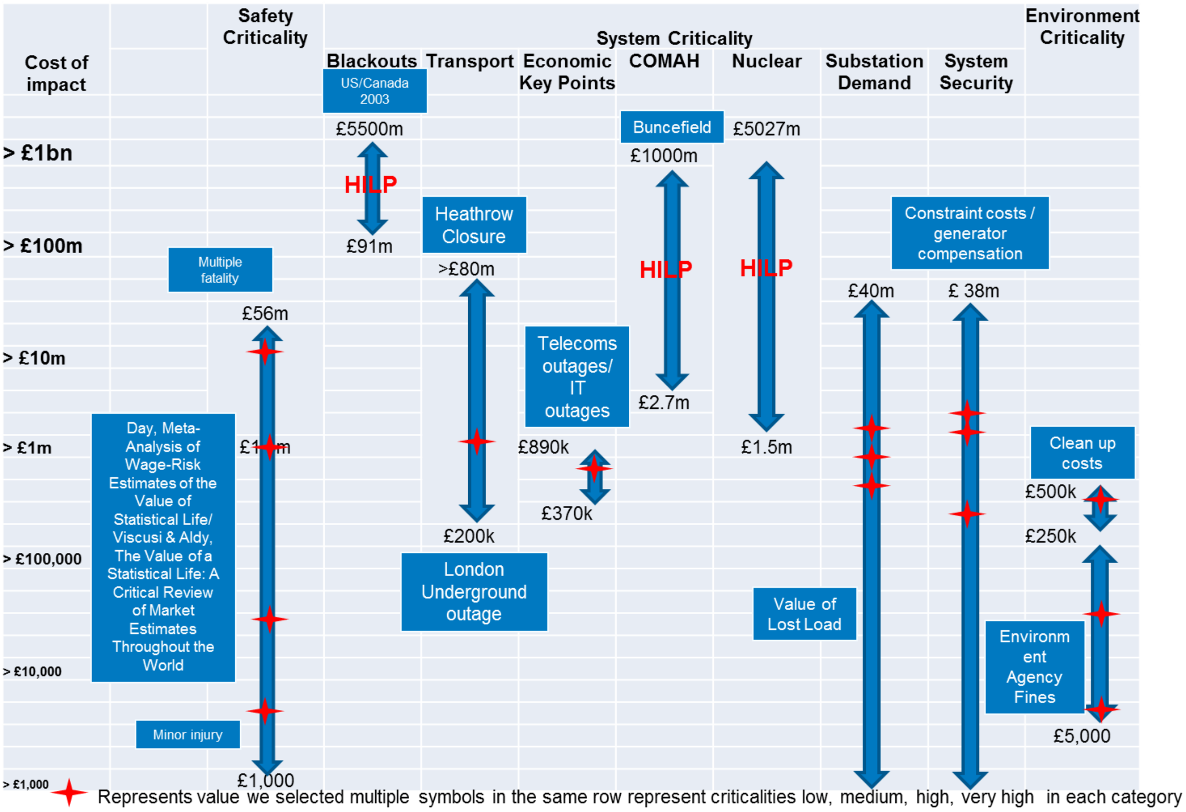

Figure 24: Referenced work showing financial impact of events

239. Some Transmission assets are also exposed to High Impact, Low Probability (HILP) events. These events are difficult to predict and occur infrequently so are less well understood. When multiplying a probability by a consequence for these sorts of events, the outcome looks very reasonable, but businesses need to treat assets exposed to these sorts of events differently.

240. Examples of sites/circuits which may be regarded as HILP include those supporting some vital infrastructure, such as NSLPA, COMAH and Black Start sites, which are all incorporated into System Criticality (see section 4.2.2).

241. Designation of assets to HILP sites/circuits is consistent with the process of assigning Criticality scores. The data sources for these sites/circuits are defined in Figure 25.

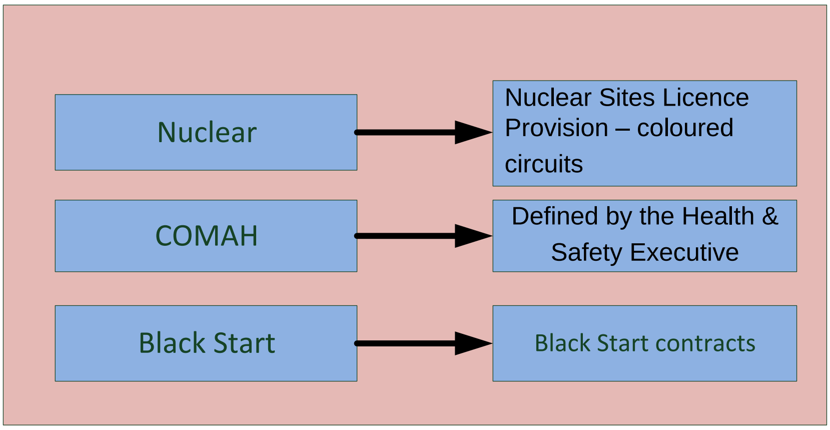

Figure 25: HILP designation and data source

242. Whereas the Criticality score for deriving a Replacement Priority for an asset is based upon the greatest impact in a single category, the Monetised Criticality is derived by adding the values for each Criticality element.

243. Table 13 below shows which Criticality elements have been monetised. Only the Safety Criticality element can be scored in the Very High category.

Criticality	Safety	System (Reliability)	Environment
Very high	£	X	X
High	£	£	£
Medium	£	£	£
Low	£	£	£

Table 13: Monetisation of Criticality Elements

The Monetised Criticality values have been selected based on the assumptions in Table 14 below. Detailed explanations, including calculations, showing how these values have been derived can be found in Appendix B.

Criticality Area	**Justification**	**Very High C1**	**High C2**	**Medium C3**	**Low C4**
Safety Criticality	Average Value of Statistical Life derived from Hedonic Wage Risk studies (excluding outlier) scaled by fatality; serious injury, reportable injury, and non-reportable minor injury	£10,000,000	£1,000,000	£50,000	£10,000
System Criticality – Economic Key Point	Average cost per minute for commercial service outages, multiplied by median loss of supply duration with additional factor for systems recovery time	X	£845,000	X	X
System Criticality – Transport	Average cost per minute for transport events, multiplied by median loss of supply duration with additional factor for recovery time	X	£1,079,000	X	X
System Criticality – Substation Demand	Value of Lost Load scaled by substation demand.	X	Transmission Licensee specific	Transmission Licensee specific	Transmission Licensee specific
System Criticality – System Security	Generator compensation payments and constraint costs scaled by 90, 50, 10 percentiles.	X	Transmission Licensee specific	Transmission Licensee specific	Transmission Licensee specific
Environmental Criticality	Maximum Environment Agency fine with additional clean up costs.	X	£500,000	£25,000	£5,000

Table 14: Proposed Monetised Criticality Values

244. The proposed monetary values for Criticality are common for the Safety Criticalities, Environmental Criticalities and the non-HILP vital infrastructure elements of System Criticality. However, due to the different scales of the TOs' networks, the substation demand and system security elements will be different. These are detailed in the TOs' Specific Appendices.

245. In Stage 2 further work will be undertaken by the TOs to determine exactly what is common and what is specific in terms of monetising Criticality. In addition more work

will be undertaken on the monetary Criticality value for Environmental Criticality following feedback from a number of stakeholders provided during the stakeholder consultation conducted during October 2015.

246. The vital infrastructure elements of System Criticality that include NSLPA, COMAH and Black Start sites have not been assigned a monetary value. The proposed approach is that the TOs do not intend to trade assets exposed to HILP events .Monetary values will be assigned for these assets exposed to HILP events for all other Criticality categories.

247. If the condition of those assets exposed to HILP events deteriorates such that they require an intervention, it is intended that the asset will be brought into the investment plan. For those assets designated as HILP, their asset performance will be assessed along with all other assets in the inventory in terms of meeting the Network Replacement Outputs targets

Financial Consequence

248. The Financial Consequence is derived from two elements:

a. Historic failure events that have occurred on the TOs' Transmission systems. These failure events are reported to Ofgem as part of the RRP and represent events that will lead to replacement of the asset, or significant repair
b. Cost for replacement of the asset

249. On the basis that catastrophic failure of the asset leads to replacement, the Financial Consequence values are derived according to Equation 3

Financial Consequence in £ for lead assets = Max (cost of recovery following catastrophic failure, cost to replace asset)

Equation 3: Financial Consequence

250. The Financial Consequence values are specific to each TO and are detailed in the Specific Appendices. The cost for replacement of an asset remains confidential to each TO.

251. In Stage 2 further work will be undertaken by the TOs to determine exactly what is common and what is specific in terms of assessing financial consequence.

How the trade-off mechanism works

252. Each asset has a Monetised Criticality and Financial Consequence in £, and an average Conditional Probability of Failure which is dependent on its current AHI.

Monetised Risk in £ for lead assets = Σ {Conditional Probability of Failure x (Monetised Criticality + Financial Consequence)}

Equation 4: Monetised Network Risk

253. The RIIO-T1 Monetised Network Risk target is derived using Equation 4. This can then be compared with the current Monetised Risk in £. Forecasts for Network Risk can be derived against different investment scenarios.

254. An example showing how the mechanism works is presented in Table 15 using dummy data.

Asset type	**Asset**	**Monetisation of criticality**	**Financial Consequence**	**Asset health end of T1**	**Probability of failure end of T1**	**£ Risk end of T1**
Transformer	SGTA	£5,000,000	£1,000,000	5	10.95%	£657,000
Circuit Breaker	SWGRB	£10,000,000	£2,000,000	1	0%	£0
Overhead Line	OHLC	£15,000,000	£3,000,000	5	13.55%	£2,439,000
Cable	CableD	£20,000,000	£4,000,000	1	0.05%	£12,000

Table 15:Demonstration of trade-off mechanism using dummy data

255. The sum of the Monetised Risk, £, can be compared with sum of the target Monetised Risk, £. This enables trading between asset types and enables the comparison of different investment scenarios.

256. For example, Table 16 shows the total Network Risk target set at the end of the RIIO-T1 period (31 March 2021) using dummy data.

Asset Categories	**Target (31 March 2021) Monetised Risk**
Switchgear	£73,000,000
Transformer	£126,000,000
Underground Cables	£92,000,000
Overhead Line	£1,040,000,000
Total	**£1,331,000,000**

Table 16: Example Monetised Risk target using dummy data

How the Network Replacement Outputs are translated to Monetised Network Risk Target

257. Each asset's condition score at the time of the RIIO submission is converted into a Conditional Probability of Failure and multiplied by (Monetised Criticality and Financial Consequence). This provides a Monetised Risk value for each asset type in £ at the time of submission.

258. Each asset's condition score is deteriorated according to its movement through the AHIs and the forecast condition is derived for each asset at the end of RIIO-T1. If an

asset is replaced (accordingly to the RIIO-T1 submission business plan excluding the impact of LR replacement) its AHI is reset to AHI 1.

259. At the end of the RIIO-T1 period, the asset's final forecast condition is converted into a Conditional Probability of Failure and then multiplied by the Monetised Criticality and Financial Consequence to produce a Monetised Risk value for each asset type.

260. The price base for the Monetised Criticality will be agreed with Ofgem and fixed.

261. The total Monetised Risk for each asset type is summated and this total represents the Monetised Network Risk target. As the Monetised Risk has been derived from the original investment plan at the time of RIIO-T1 submission, the original Network Replacement Outputs targets are retained, but converted to Monetised Risk.

262. A process map showing the conversion from Replacement Priorities to Monetised Network Risk target is show in Figure 26

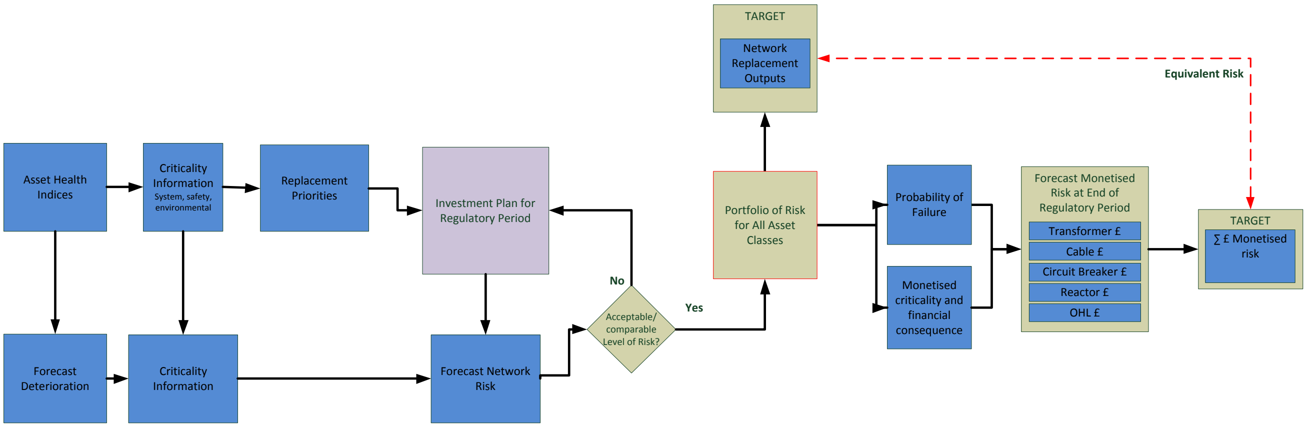

Figure 26: Conversion of RIIO Target to Monetised Risk

Under- and over-delivery against the target

263. Scenario 1 is presented in Table 17 and shows an example of under-delivery compared with the target. The left hand columns show Monetised Risk at 31 March 2021 and the right hand columns show the comparison between the declared Monetised Risk and the target.

264. The total Monetised Risk is higher than the target as presented in Table 16, hence the TO has under-delivered.

Asset Categories	Target (31 March 2021) Monetised Risk

Switchgear	£73,000,000
Transformer	£126,000,000
Underground Cables	£92,000,000
Overhead Line	£1,040,000,000
Total	**£1,331,000,000**

Asset Categories	Scenario 1 (31 March 2021) Monetised Risk
Switchgear	£72,000,000
Transformer	£127,000,000
Underground Cables	£91,000,000
Overhead Line	£1,050,000,000
Total	**£1,340,000,000**

Asset Categories	Calculation: Target minus Scenario 1
Switchgear	£1,000,000
Transformer	-£1,000,000
Underground Cables	£1,000,000
Overhead Line	-£10,000,000
Total	**-£9,000,000**

Table 17: Scenario 1 demonstrating under-delivery at 31 March 2021

265. Scenario 2 is presented in Table 18 and shows an example of over-delivery compared with the target. The left hand columns show Monetised Risk at 31 March 2021 and the right columns show the comparison between the declared Monetised Risk and the target.

266. The total Monetised Risk is lower than the target as presented in Table 16 hence the TO has over-delivered.

Asset Categories	Target (31 March 2021) Monetised Risk
Switchgear	£73,000,000
Transformer	£126,000,000
Underground Cables	£92,000,000
Overhead Line	£1,040,000,000
Total	**£1,331,000,000**

Asset Categories	Scenario 2 (31 March 2021) Monetised Risk
Switchgear	£72,000,000
Transformer	£123,000,000
Underground Cables	£94,000,000
Overhead Line	£1,032,000,000
Total	**£1,321,000,000**

Asset Categories	Calculation: Target minus Scenario 2
Switchgear	£1,000,000
Transformer	£3,000,000
Underground Cables	-£2,000,000
Overhead Line	£8,000,000
Total	**£10,000,000**

Table 18: Scenario 2 demonstrating over-delivery at 31 March 2021

267. There will be a number of different combinations of interventions that can achieve the same level of Network Risk.

268. The process for evaluation Monetised Network Risk in the context of meeting the Network Replacement Outputs targets is shown in Figure 27.

269. Accompanying this methodology is the spreadsheet model which calculates Monetised Risk. It contains the equations for Conditional Probability of Failure, monetised Criticality and financial consequence. The numbers provided are illustrative. It presents two scenarios demonstrating how the trade-off would work.

270. In Stage 2 further work will be undertaken to define what reasons will be accepted as justified and unjustified under- and over- delivery.

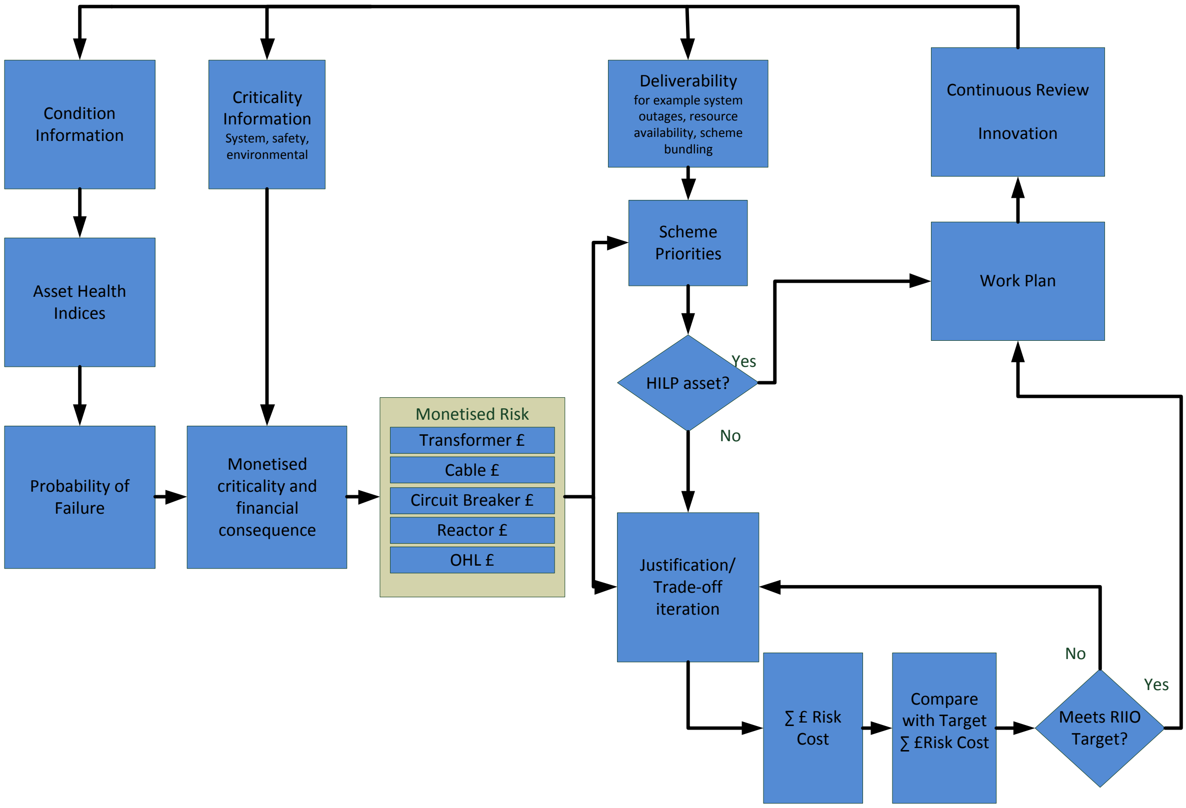

Figure 27: Process for evaluating Monetised Network Risk Against Network Replacement Outputs targets

4.5.3 Ensuring Consistency

271. The TOs will calibrate their Probabilities of Failure according to the methods described in Section 5.1 to ensure consistency for asset types that have operated under similar conditions (environmental, duty etc).

272. The TOs will use the same monetisation values for Criticality where they are able. However due to the differing scales of the networks, some Criticality elements, most notably System Criticality, may have different values. Financial consequence values will also be different for each TO. However the process for calculating Monetised Risk is identical for each TO.

4.5.4 Reporting

273. The TOs report Table 6.15 annually as part of the Transmission RRP. The information will comprise current Replacement Priorities as at 31 March of the reporting year, as well as the forecast for 31 March 2021. The TOs will describe how the Criticality changes contribute to the forecast Replacement Priorities at end the of the RIIO-T1 period in the narrative. The TOs propose the following revised Table 6.15 which additionally includes actual Replacement Priorities at 31 March 2021. See Appendix D for the proposed reporting table for the Network Replacement Outputs.

274. The Network Replacement Outputs targets figures are detailed within the table as well, for the purposed of comparing the current forecast against the target. The TOs will work with Ofgem to agree the reporting tables and update the RIGs. The TOs

propose the following revised Table 6.15 which additionally includes actual Replacement Priorities at 31 March 2021.

4.5.5 Continuous Improvement

275. The TOs will continue to develop their understanding of asset condition and performance and their deterioration and hence will review asset performance against the probabilities of failure, refining these values as more information becomes available. As part of this process the TOs will review the monetised criticality values.

4.5.6 External Publication

276. There are no confidentiality issues associated with the external publication of the proposed methodology for the Network Replacement Outputs and the trade-off mechanism. The Criticality Monetisation information is in the public domain. However, cost information used for the Financial Consequence remains confidential to each TO. The summary tables that form part of the Transmission RRP should not be published externally.

5.0 TESTING THE METHODOLOGY

277. The methodology will be tested to provide assurance that specifically the Monetised Risk accurately reflects the performance of the assets.

5.1 Calibration

278. All three TOs will work together to ensure that the application of the methodology is consistent.

Calibration of Condition

279. The TOs will compare their asset condition information. It is expected that for assets in the same condition with the same history, operating regime, operating environment and duty, each asset would expect to have the same AHI for all the TOs.

Calibration of Criticality

280. Criticality scoring will be compared across the TOs. Where it is possible to compare criticalities these would be expected to have the same scores for the same criteria. It is expected that Safety and Environmental Criticality scoring would demonstrate a greater degree of consistency between the TOs. However, due to the differing scales of the TOs respective networks, there may be some instances where specific Criticality scores may need to be used, most notably with System Criticality. The TOs can compare the ratio of Criticality scores that fall into the very high, high, medium and low categories to ensure a consistency of approach.

5.2 Validation

281. Validation of the methodology will involve confirmation that the numbers of assets that are expected to be replaced over the RIIO_T1 period are consistent with the TOs' plans for asset replacement/refurbishment. This involves monitoring the network risk with intervention (i.e. how the outturn network risk based on asset deterioration and the TO investment plans) and network risk without intervention (i.e. based solely on asset deterioration). The difference between these network risk outturns will confirm whether the TOs' investment plans reflect that the number of assets that are planned for replacement are consistent with the need for intervention.

282. The probabilities of failure will be validated by ensuring the summated values are consistent with actual asset performance.

283. The Criticality monetary values will be validated by adding new events as they occur and comparing them against the value being used.

5.3 Testing

284. In order to test the Monetised Risk, the spreadsheet models for each asset class will be populated with data:

a. Current asset condition converted to a Conditional Probability of Failure
b. Forecast future asset condition converted to a future Conditional Probability of Failure
c. Monetised Criticality and financial consequence

285. Monetised risk will be calculated for current condition and forecast condition for each asset type.

286. An independent expert will be appointed to check the spreadsheet and provide assurance that its internal calculations are correct, verifying that the models perform according to the methodology.

6.0 COMPARATIVE ANALYSIS

6.1 Licence Requirements

287. Special Licence Condition 2L.3(c) requires that: The NOMs shall be designed to facilitate the comparative analysis over time between:

6.2 Geographic areas of and network assets within the TO's Transmission system

288. The NOMs methodology has been designed to enable comparability of network assets (e.g. common AHI definitions, common Replacement Priority definitions). The constituent elements of Criticality recognise geographic differences.

6.3 Transmission Systems within Great Britain

289. By developing the NOMS methodology across the TOs, the NOMs are produced in the same format to allow comparative analysis across TOs.

290. By continually sharing information across the TOs with the aim of calibrating the NOMs, this enables comparison across the TOs.

6.4 Transmission Systems within Great Britain and other Countries

291. The names of specific companies have not been included within the NOMs methodology to enable external publication of these comparisons.

292. In addition to the development of the NOMs, the TOs have researched method used to report similar measures with Great Britain and other countries.

293. Examples of these systems are Condition Based Risk Management, Health Indices and Criticality Indices. Whilst adopting a methodology used by other Transmission companies would indicate the outputs will have the same definitions, the evidence collected shows theses methodologies are highly configurable so the companies using them can align the measures to their asset base and statutory, regulatory and business requirements.

6.5 Transmission Systems and Distribution Systems within Great Britain

294. Throughout the development of the NOMs, the TOs have reviewed the Distribution Network Output Measures methodology, 'The DNO Common Network Asset Indices Methodology', and the Gas Distribution Network methodology, the 'Network Output Measures Health And Risk Reporting Methodology and Framework' to determine the

level of consistency in reporting across Transmission and Distribution. See Appendix E.

295. In terms of Network Replacement Outputs, the Transmission NOMs methodology has similar features to the NOMs of the DNOs and GDNs by including Health Indices and forecast projections of Health Indices.

296. The Transmission NOMs methodology will not require a re-baseline of the Network Replacement Outputs targets and concentrates on the trade-off mechanism around the existing targets based on the TOs' respective RIIO-T1 business plans.

297. The DNOs' and GDNs' methodologies concentrate on providing consistency of Asset Health and Criticality using monetised risks. Both the DNOs and GDNs have regulatory output targets which is the difference between the risks with, and without, intervention. This is different to the regulatory output target (Network Replacement Outputs) for the TOs which is the risk remaining on the network. Figure 28shows the differences between the TO targets and the DNO and GDN targets.

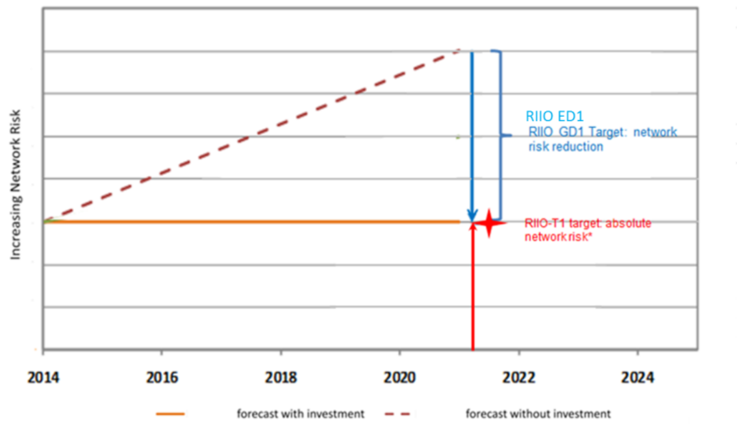

Figure 28: Differences between the TO and DNO/GDN targets

298. The TOs have, and continue to engage with the DNOs and GDNs to understand the development of the Distribution NOMs and asset management strategies going forward.

299. Specifically, the TOs have interacted with the DNO and GDN Network Output Measures working groups to understand the work they have been undertaking and to compare our respective methodologies. Table 19 below shows a comparison between the TO, DNO and GDN approaches.

NOMs Topic	ETO	DNO	GDN
Basic Conceptual Framework	Similar building blocks used within each methodology: health indices, criticality, monetised risk		
Derivation of Health index	Starts with condition/asset health process and derives probablility from these	Starts with condition/asset health process and derives probablility from these	Starts with probability of failure and then determines asset health. (Greater amount of observed data available hence use of probability - where less data available then similar approach to ETO/DNO adopted.
Level of repairable assets within network.	Limited repairable options available to ETO	More repairable interventions available	More repairable interventions available
Consequence value of assets	Greater amount of high value consequence assets	Fewer high value consequence assets than ETO	Fewer high value consequence assets than ETO
Forecasting deterioration	Deterioration models used - probabilistic from asset health position	Deterioration models used but single curve and more deterministic	Deterioration by a percentage at end of each year
Interventions covered by Network Output Measures	Asset Replacement /refurbishment	Asset Replacement/ refurbishment	All interventions covered
Network risk targets	The target is an absolute risk position with interventions excluding the impact of load-related replacements. The information used was based on HI at submission. The TOs will be preserving their target.	Target is delta risk. A number of assets are planned for replacement. During ED1 risk with and without intervention was submitted What actual risk is represented is not relevant at the target setting stage, the target is based on delta.	Target is based on monetised risk Matrices have been submitted showing this for the start, middle and end of regulatory period: HI vs criticality The target is the delta between start and end of period
Redundancy	Inherent within system security scoring in system criticality (SQSS)	n-1 condition, scaling factor applies	Event trees. PoF adjusted based on configuration of system
High Impact, Low Probability	Black start, COMAH, nuclear	Black start, Flooding risk	Not yet considered

Table 19: Comparison between DNO and GDN methodologies

APPENDIX A: References For Worldwide Events For Monetised Criticality External Reference Work

Criticality Element	Derivation/Source
Value of Statistical Life	Henrik Andersson and Nicolas Treich: The Value of a Statistical Life, Toulouse School of Economics, 2009 [references: Beattie et all 1998, Carthy et al. (1999), Ghosh et al. (1975),Jones-Lee et al (1985), Melinek (1974)] Brett Day: A Meta-Analysis of Wage-Risk Estimates of the Value of Statistical Life Viscusi & Aldy: The Value of a Statistical Life: A Critical Review, The Journal of Risk and Uncertainty, 27:1; 5–76, 2003 [references Marin and Psacharopoulos (1982), Siebert and Wei (1994), Sandy and Elliott (1996), Sandy et L. ((2001), Arabsheibani and Marin (1999)], Harvard Law School, 2003 Bickel et al, Developing Harmonised European Approaches for Transport Costing and Project Assessment, HEATCO, 2006 F. Bellavance et al:Journal of Health Economics 28, (2009) Henrik Lindhjem and Ståle Navrud: Meta-analysis of stated preference VSL studies: Further model sensitivity and benefit transfer issues, Organisation for Economic Co-operation and Development, 2012 National Center for Environmental Economics, Frequently Asked Questions on Mortality Risk Valuation, http://yosemite1.epa.gov/ee/epa/eed.nsf/pages/MortalityRiskValuation.html#whatisvsl OECD (2011), "Valuing Mortality Risk Reductions in Regulatory Analysis of Environmental, Health and Transport Policies: Policy Implications", OECD, Paris, www.oecd.org/env/policies/vsl Gas Distribution Networks: Network Output Measures Health & Risk Reporting Methodology & Framework, 2015 Wakelen et al: DNO Common Network Asset Indices Methodology, 2015 Health and Safety Executive: Costs to Britain of workplace fatalities and self-reported injuries and ill health, 2012/13 HM Treasury: THE GREEN BOOK Appraisal and Evaluation in Central Government, 2011 Review of Highways Agency Value of Life Estimates for the Purposes of Project Appraisal, Deloitte, 2009 (ref DfT 2008)
Blackouts	Jane L Corwin and William T Miles: Impact Assessment of the

	1977 New York Blackout, SCI Systems Control, 1978 Royal Academy of Engineering: Counting the cost: the economic and social costs of electricity shortfalls in the UK A report for the Council for Science and Technology, November 2014 Fiona Rotherham: Auckland's fifth major outage since 1998 — Key warns network upgrade would hit consumers http://www.nbr.co.nz/article/aucklands-fifth-major-outage-1998-%E2%80%94-key-warns-network-upgrade-would-hit-consumers-bd-163513, NBR, 2014 Power Technology.com: The 10 worst blackouts of the last 50 years, 2015 Günther Beck, Dusan Povh,Dietmar Retzmann, Erwin Teltsch: Global Blackouts – Lessons Learned, Siemens, 2011 Connell Wagner: Review of Report on Auckland Transmission Outage of 12 June 2006. Ministry of Economic Development, 2006 the Authority: report on Support Investigations into Recent Blackouts in London and West Midlands, 2004 London Assembly: The Power Cut in London on 28 August 2003, London Assembly's Public Services Committee, 2004 Daniel Kirschen Goran Strbac: Why investments do not prevent blackouts, UMIST, 2003 U.S.-Canada Power System Outage Task Force: Interim Report: Causes of the August 14th Blackout in the United States and Canada, 2003
Transport Outages and Loss of Service	Daily Telegraph report on bed weather affecting Heathrow: http://www.telegraph.co.uk/finance/newsbysector/transport/8254246/Heathrow-operator-BAA-says-December-snow-cost-24m.html ; http://www.telegraph.co.uk/finance/newsbysector/epic/bay/8217784/Snow-has-cost-British-Airways-40m-in-lost-profits.htmlhttp://www.theguardian.com/uk/2011/jan/10/virgin-atlantic-heathrow-airport-snow NATS: Control Air Traffic Control Disruption 7th December 2013, A Report to the Civil Aviation Authority, 2014 National Audit Office: Reducing Passenger Rail Delays by Better Management of Incidents, Comptroller and Auditor General, 2008 Daily Telegraph report on impact of Iceland volcano, 2010 http://www.telegraph.co.uk/finance/newsbysector/epic/bay/8217784/Snow-has-cost-British-Airways-40m-in-lost-profits.html Evening Standard Report on disruption from London Underground

	strike. http://www.standard.co.uk/news/transport/tfl-tube-strike-total-shutdown-of-tube-set-to-cost-london-300-million-10377756.html
Economic Key Points	Arthur D Little: Reliability and Distributed Generation, 2000 Vision Solutions: Assessing the Financial Impact of Downtime Understand the factors that contribute to the cost of downtime and accurately calculate its total cost in your organization, Lyons, S., Morgenroth, E. and Tol, R.S.J.:Estimating the value of lost telecoms connectivity. Electronic Commerce Research and Applications, Vol. 12: 40–51,20 Channel Insider: Unplanned IT Outages Cost More than $5,000 per Minute: Report, 2011 Jim O'Neill: Study: Data center outages cost telecom businesses more than $11,000 a minute, 2011 Matt Williams: Network outages cost mobile operators $15 billion per year, Faronics.com, 2014 Downtime, Outages and Failures - Understanding Their True Costs , Evolven,
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Nuclear	Wikipedia.org: List of nuclear Power Accidents by Country http://en.wikipedia.org/wiki/List_of_nuclear_power_accidents_by_country
Loss of supply (LOS) duration	National Electricity Transmission System Performance Reports
Substation Demand	GB Ten Year Statement.
Generator compensation payments	The Connection and Use of System Code (CUSC) Paragraph 5.10
Generator Registered Capacities	Appendix F - Generation data from the GB Ten Year Statement
Constraint Costs	Monthly Balancing Services Summary (MBSS) http://www2.nationalgrid.com/UK/Industry-information/Electricity-transmission-operational-data/Report-explorer/Services-Reports/
Environmental Criticality	Environment Agency: Enforcement and Sanctions - Guidance Operational Instruction 1428_10, Version 3 Environment Agency: Enforcement and sanctions statement Policy 1429_10 (previously EAS/8001/1/1), Version 3.

APPENDIX B: Calculations Used To Derive Monetised Criticality Values

Derivation and Sources of Monetised Criticality Values

Criticality Element	Derivation/Source	Value Proposed
Value of Statistical Life	Average Value of Statistical Life derived from Hedonic Wage Risk studies (see Appendix C) (outlier [Sandy&Elliot 1996] excluded from calculation)	£10,000,000
Cost per minute of service outages	Average cost per minute for commercial service outages derived from referenced papers (see Appendix C) for each system criticality vital infrastructure criterion. The papers presented durations of outages and the costs associated with them. These were converted (where necessary) to a cost per minute. An additional factor (25 mins) was added to account for recovery time for the service following the initial disruption	Transport outages: average cost per minute £31,000 Economic Key Point outages: average cost per minute £24,000
Loss of supply (LOS) duration	Based on historic loss of supply events recorded since 1990 and reported annually in the National Electricity Transmission System Performance Reports	Specific to each TO. National Grid Example values: Median: 10 mins 10^{th} percentile: 1 min 90^{th} percentile: 104 mins *Median used because of the skewed distribution of events.
Value of Lost Load	Defined in the Transmission Licence	£20,000 / MWhr (Value of Lost Load £16,000 at 2009/10 prices as defined in the Transmission Licence inflated to 2014/15 prices)
Substation Demand	Defined as the required demand at the yearly peak as submitted by customers as part of P2/6 process. This demand data is reported in the GB Ten Year Statement.	Individual to each TO's network
Generator compensation payments	Calculation of 'Interruption Payment' under The Connection and Use of System Code (CUSC) Paragraph 5.10	The sum equal to the System Buy Price as defined in the Balancing and Settlement Code for each Settlement Period (or part therof) from the start of such Relevant Interruption until the first Settlement Period for which Gate Closure had not (at the time the Relevant Interruption started) occurred multiplied by: The MW arrived at after deducting from the Transmission Entry

		Capacity for the Connection Site the sum of the Connection Entry Capacity of the unaffected BM Units at the Connection Site The average system buy price and market price for each of the 48 half hour settlement periods in a day was calculated for the year 2014.
Generator Registered Capacities	Derived from generator registered capacities listed in Appendix F - Generation data from the GB Ten Year Statement	Specific to each TO. National Grid Example values: Average: 690 MW 10^{th} percentile: 25 MW 90^{th} percentile: 1569 MW
Constraint Costs	Daily constraint cost derived from Monthly Balancing Services Summary (MBSS) http://www2.nationalgrid.com/UK/Industry-information/Electricity-transmission-operational-data/Report-explorer/Services-Reports/	Daily constraint costs derived from MBSS from 1/4/14 to 1/6/15: Specific to each TO. National Grid Example values: Average: £853,000 10^{th} percentile: £159,000 90^{th} percentile: £1,406,000
Environmental Criticality	Maximum Environment Agency fine detailed in Appendix C + Clean up costs associated with the loss of cable oil leaking into an environmentally sensitive area	£250,000 defined in EA document plus £250,000 clean up costs (maximum expected cost)

Table 20: Derivation and Sources of Monetised Criticality Values

Criticality Monetisation Calculations for Deriving Very High, High, Medium and Low Values

Criticality Element	Very High C1	High C2	Medium C3	Low C4
Safety Criticality	Average Value of Statistical Life derived from Hedonic Wage Risk studies (Appendix C)	Scaling according to Table 5, Review of Highways Agency Value of Life Estimates for the Purposes of Project Appraisal, Deloitte, 2009 (ref DfT 2008)		
System Criticality – Economic Key Point	X	Average cost per minute for service outage x (10 min median duration + 25 minute recovery factor)	X	X
System Criticality – Transport	X	Average cost per minute for x (10 min median duration + 25 minute recovery factor)	X	X
System Criticality – Substation Demand	X	VOLL x High substation demand x median LOS duration	VOLL x Med substation demand x median LOS duration	VOLL x Low substation demand x median LOS duration
System Criticality – System Security	X	(Average Generator Compensation payment for 24 hours x 90th percentile generator registered capacity (MW)) + Average daily constraint costs	(Average Generator Compensation payment for 24 hours x Average generator registered capacity (MW)) + Average daily constraint costs	(Average Generator Compensation payment for 24 hours x 10th percentile generator registered capacity (MW)) + Average daily constraint costs
Environmental Criticality	X	Maximum Environment Agency fine with additional clean up costs.	Scaling ratios as per Safety Criticality	

Table 21: Criticality Monetisation Calculations for Deriving Very High, High, Medium and Low Values

APPENDIX C: Processes that the System Operator has available in order to re-secure the transmission system in the event of asset failure

In the event of an asset failure at a particular site, the System Operator may follow a number of procedures. For example, Transmission Procedure TP105 (Operational Liaison and Practice) sets out the operational practices that apply to events (unscheduled or unplanned occurrences, including faults, incidents and breakdowns) that might occur on the Transmission system.

The purpose of TP105 is to specify the working arrangements and information exchanges that would be employed to assess possible risks and take appropriate action to comply with safety regulations and maintain the integrity of the system.

It contains a number of decision trees which contain such actions as assessing contingency measures available on the system, undertaking condition assessments for the affected asset, determining whether there is an option for another circuit to be restored (e.g. returning an asset that is out of service for maintenance), establishment of risk management hazard zones and liaising with asset specialists before returning the affected asset to service.

This is supported by procedures which detail the process for responding to system events and risk assessment of equipment in abnormal condition.

These procedures have to be compliant with relevant legislation. Regulation 5 of the Electricity at Work Regulations 1989 states that:

No electrical equipment shall be put into use where its strength and capability may be exceeded in such a way as may give rise to danger.

At times this regulation conflicts with other statutory duties (e.g. the need to retain equipment in service to meet statutory standards for security of supply as specified in the Electricity Act 1988 (Section 96 – Direction for Preservation and Security of Electricity Supply)).

Regulation 20 of the Electricity at Work Regulations 1989 provides a defence to leaving equipment in service, provided that a company takes all reasonable steps and exercises all due diligence to avoid danger arising. Compliance with this duty can be achieved by the implementation of risk management procedures.

The Management of Health and Safety at Work Regulations 1992 outlines the fundamental requirements for carrying out risk assessments and then managing the risks using appropriate control or protective measures. The Electricity Safety, Quality and Continuity Regulations 2002 outlines the duties to the general public.

APPENDIX D: Proposed Reporting Table For Network Replacement Outputs

National Grid Electricity Transmission 2014/15

6.15.2 Network Output Measures - Replacement Priority

NOMs Definitions

Replacement Priorities

RP1	0-2 years
RP2	2-5 years
RP3	5-10 years
RP4	10+ years

Replacement Priorities matrix (Scots)

RP	AH1	AH2	AH3	AH4	AH5
C4	RP4	RP4	RP4	RP3	RP2
C3	RP4	RP4	RP4	RP3	RP2
C2	RP4	RP4	RP4	RP2	RP1
C1	RP4	RP4	RP4	RP1	RP1

Replacement Priorities matrix (NGET)

RP	AH1	AH2	AH3	AH4a	AH4b	AH5
C4	RP4	RP4	RP4	RP4	RP3	RP2
C3	RP4	RP4	RP4	RP3	RP3	RP2
C2	RP4	RP4	RP4	RP3	RP2	RP1
C1	RP4	RP4	RP4	RP3	RP1	RP1

Actual Network Risk

Asset Categories		Units	Actuals (Reporting Year End) Replacement Priority				Total
			RP1	RP2	RP3	RP4	
400kV Network							
1	Circuit Breaker	No.					-
2	Transformer	No.					-
3	Reactor	No.					-
4	Underground Cable	circuit km					-
5	OHL Conductor	circuit km					-
6	OHL Fittings	circuit km					-
7	OHL Tower (SHET & SPTL)	No.					-
275kV Network							
1	Circuit Breaker	No.					-
2	Transformer	No.					-
3	Reactor	No.					-
4	Underground Cable	circuit km					-
5	OHL Conductor	circuit km					-
6	OHL Fittings	circuit km					-
7	OHL Tower (SHET & SPTL)	No.					-
132kV Network							
1	Circuit Breaker	No.					-
2	Transformer	No.					-
3	Reactor	No.					-
4	Underground Cable	circuit km					-
5	OHL Conductor	circuit km					-
6	OHL Fittings	circuit km					-
7	OHL Tower (SHET & SPTL)	No.					-

With NLR Investment Only

Asset Categories		Units	Actuals (Reporting Year End) Replacement Priority				Total
			RP1	RP2	RP3	RP4	
400kV Network							
1	Circuit Breaker	No.					-
2	Transformer	No.					-
3	Reactor	No.					-
4	Underground Cable	circuit km					-
5	OHL Conductor	circuit km					-
6	OHL Fittings	circuit km					-
7	OHL Tower (SHET & SPTL)	No.					-
275kV Network							
1	Circuit Breaker	No.					-
2	Transformer	No.					-
3	Reactor	No.					-
4	Underground Cable	circuit km					-
5	OHL Conductor	circuit km					-
6	OHL Fittings	circuit km					-
7	OHL Tower (SHET & SPTL)	No.					-
132kV Network							
1	Circuit Breaker	No.					-
2	Transformer	No.					-
3	Reactor	No.					-
4	Underground Cable	circuit km					-
5	OHL Conductor	circuit km					-
6	OHL Fittings	circuit km					-
7	OHL Tower (SHET & SPTL)	No.					-

With NLR Investment only

Asset Cat's	Forecast (31 March 2021) Replacement Priority				Total
	RP1	RP2	RP3	RP4	
400kV Network					
1					-
2					-
3					-
4					-
5					-
6					-
7					-
275kV Network					
1					-
2					-
3					-
4					-
5					-
6					-
7					-
132kV Network					
1					-
2					-
3					-
4					-
5					-
6					-
7					-

Licence Special Condition 2M Table 1 - TARGET

Asset Cat's	Target (31 March 2021) Replacement Priority				Total
	RP1	RP2	RP3	RP4	
400kV Network					
1					-
2					-
3					-
4					-
5					-
6					-
7					-
275kV Network					
1					-
2					-
3					-
4					-
5					-
6					-
7					-
132kV Network					
1					-
2					-
3					-
4					-
5					-
6					-
7					-

Difference : TARGET - FORECAST

Asset Cat's	Target (31 March 2021) Replacement Priority				Total	Check versus T5.15.1 Acuals	Check versus T5.15.1 Forecasts
	RP1	RP2	RP3	RP4			
400kV Network							
1					-	OK	OK
2					-	OK	OK
3					-	OK	OK
4					-	OK	OK
5					-	OK	OK
6					-	OK	OK
7					-	OK	OK
275kV Network							
1					-	OK	OK
2					-	OK	OK
3					-	OK	OK
4					-	OK	OK
5					-	OK	OK
6					-	OK	OK
7					-	OK	OK
132kV Network							
1					-	OK	OK
2					-	OK	OK
3					-	OK	OK
4					-	OK	OK
5					-	OK	OK
6					-	OK	OK
7					-	OK	OK

APPENDIX E: References

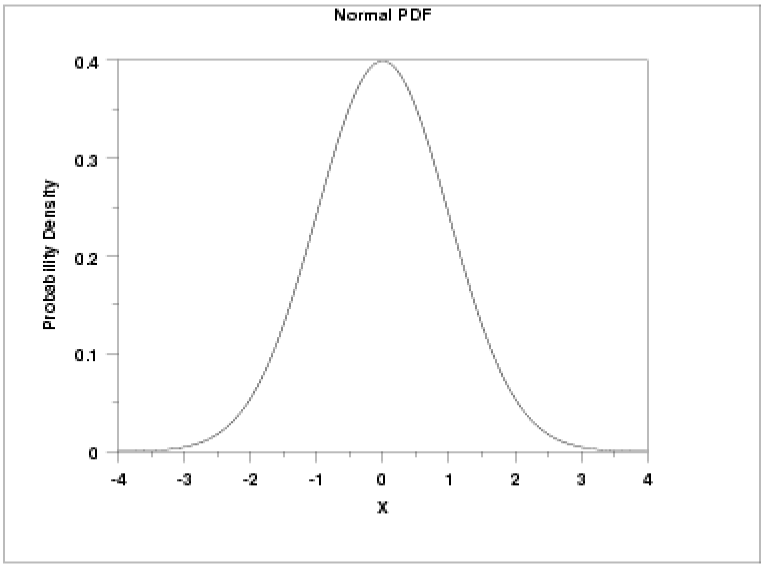
The DNO Common Network Asset Indices Methodology:
https://www.ofgem.gov.uk/publications-and-updates/dno-common-network-asset-indices-methodology
Notice of decision to direct modifications to the Common Network Asset Indices Methodology under Part C of SLC 51:
https://www.ofgem.gov.uk/sites/default/files/docs/2015/10/decision_and_direction_to_modify_the_common_network_asset_indices_methodology_under_slc51.pdf

Gas Distribution Network methodology, the 'Network Output Measures Health And Risk Reporting Methodology and Framework:
https://www.ofgem.gov.uk/sites/default/files/docs/2015/11/gdn_asset_health_risk_reporting_methodology_-_v2.0.pdf
Consultation November 2015:
https://www.ofgem.gov.uk/sites/default/files/docs/2015/11/gas_noms_consultation_nov_15.pdf
Decision document: https://www.ofgem.gov.uk/sites/default/files/docs/151215_-_noms_decision_document.pdf

Equivalent age calculation principles: http://www.bupa.com/au/health-and-wellness/tools-and-apps/tools-and-calculators/quick-health-age-check

Conditional Probability principles: A Course in Applied Statistics, Third Edition Chris Chatfield. 3.3.3

Probability Density Function (PDF) and Cumulative Distribution Function (CDF):
A probability density function (PDF) of a continuous random variable is a function that describes the relative likelihood for this random variable to take on a given value. The probability of the random variable falling within a particular range of values is given by the integral of this variable's density over that range. The integral of the probability density function over the entire space is equal to one. The following shows the plot of probability density function for a normal distribution:



The Cumulative Distribution Function (CDF) is the probability that the variable takes a value less than or equal to x.