NETWORK OUTPUT MEASURES METHODOLOGY

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1.0 PURPOSE AND SCOPE

1.1 Methodology Purpose

1. RIIO-T1 (Revenue = Incentives + Innovation + Outputs) is a new regulatory framework. It places emphasis on incentives to drive the innovation that is needed to deliver a sustainable energy network to consumers. Outputs are a fundamental element of the RIIO framework. The Network Output Measures are binding secondary deliverables that provide The Authority with a means to monitor and assess the Transmission Licensees' network renewal performance over the longer-term.

2. For the price control period RIIO-T1 (Revenue = Incentives + Innovation + Outputs) which covers the eight year period 1 April 2013 to 31 March 2021, special licence condition 2L sets out the requirements for the Network Output Measures for each of the Transmission Licensees.

3. Special Licence Condition 2L requires that the GB Transmission Licensees have in place a methodology for a set of Network Output Measures which are designed to enable the evaluation of:
   a. Network Asset Condition
   b. Network Risk
   c. Network Performance
   d. Network Capability
   e. Network Replacement Outputs

4. This Network Output Measures Methodology describes:
   a. The requirements in the Licence Conditions
   b. The common framework (concepts and principles) behind the Network Output Measures
   c. Comparisons of the Network Output Measures with measures produced by other Asset Management organisations
   d. Communication of information about the Transmission Licensees' systems to The Authority, including confidentiality issues surrounding publishing the content of this Network Output Measures Methodology to external (outside The Authority) parties
   e. How the Network Output Measures will be regulatory reviewed and continuously improved by the Transmission Licensees

2.0 APPLICATION OF NETWORK OUTPUT MEASURES

2.1 Licence Requirements

5. 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 Network Output Measures
   c. is implemented by the Licensee to provide information (whether historic, current, or forward-looking) about the Network Output Measures; supported by such relevant other data and examples of network modelling, as may be specified for the purposes of this condition in any Regulatory Instructions and Guidance ("RIGs") that have been issued by the Authority in accordance with the provisions of Standard Condition B15 (Regulatory Instructions and Guidance) of the Transmission Licence.

6. 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; and
   e. the assessment of customer satisfaction derived from the services provided by the licensee as part of its Transmission Business

7. The NOMs Methodology is designed to enable the evaluation of:
   a. the Network Assets 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; and
   e. the Network Replacement Outputs, which are used to measure the licensee's asset management performance as required in Special Condition 2M (Specification of Network Replacement Outputs).

8. This methodology is designed to enable the evaluation of all five Network Output Measures. Each measure is reported to the Authority annually to facilitate the ongoing assessment of each licensee's performance.

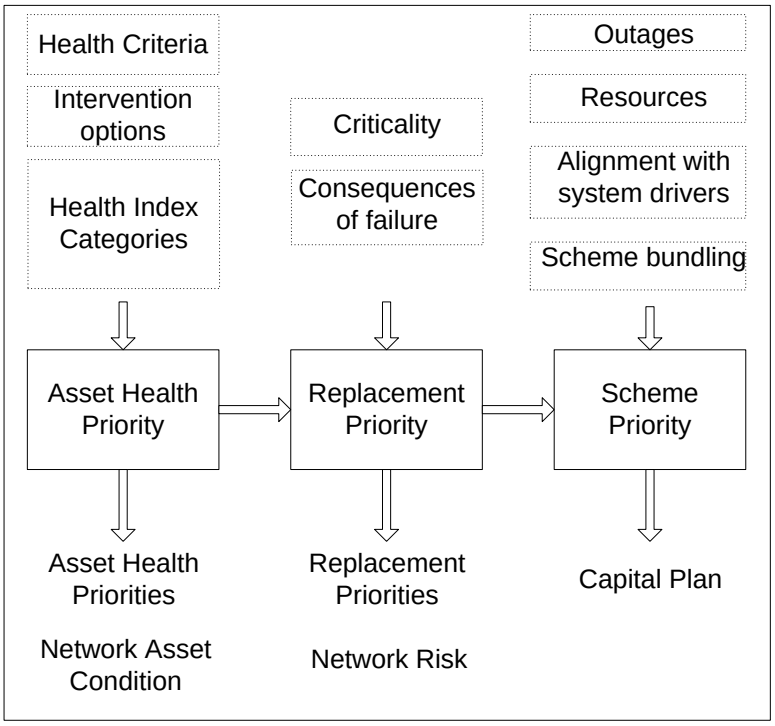
2.2 Using the Network Output Measures

9. The Transmission Licensees' Network Output Measures 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.

10. In addition to the Joint Methodology Statement, the Transmission Licensees have included Specific Appendices which describe how they use the Network Output Measures within their respective businesses.

11. Figure 1 shows how elements of the Network Output Measures feed into a Capital Plan. Health criteria (e.g. condition, performance) categorised into Health Indices are used with knowledge of intervention options (e.g. refurbishment) to determine the Asset Health Priorities which represent Network Asset Condition. These Asset Health Priorities 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 Capital Plan.

Figure 1: Understanding Network Expenditure Requirements



It should be noted that the inclusion of Criticality may or may not have the impact of bringing forward/pushing back the Replacement Priority when compared with the corresponding Asset Health Priority. In addition outages, resources, alignment with system drivers and scheme bundling may or may not bring forward/push back the actual asset replacement when compared with the corresponding Replacement Priority.

12. The Replacement Priorities help determine the Network Replacement Outputs, secondary deliverables that will provide the Authority with the ability to monitor and assess Transmission Owners' asset management performance (which is used in licence condition 2L.4(e)) . The non-load related targets for the Network Replacement Outputs are coded into the respective licences for each Licensee in Special Condition 2M.

13. The Replacement Priorities also 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 include both asset condition and criticality and take account of changes to asset populations, including load and non-load related replacement volumes.

14. 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' (those assets which have temporarily been removed from service as a result of an unreliability related event) and is used to understand the impact of unreliability on the licensees' networks. This measure was not considered by the Authority to be fully mature, so work is ongoing to further develop this metric by the end of 2014.

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. Work has also been undertaken to forecast ACU. Figure 2 shows the network performance triangle - the conceptual relationship between energy not supplied events and other network performance metrics. The licensees are continuing to develop their understanding of the relationship between asset health and network performance.

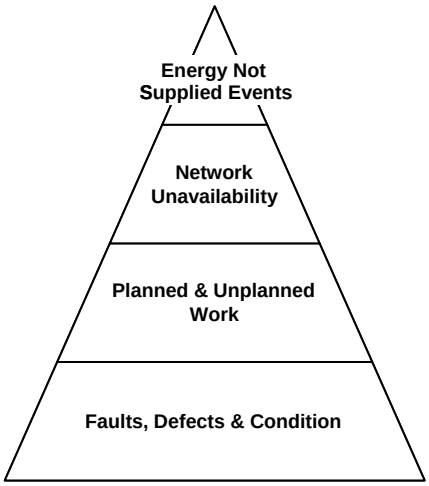


Figure 2: Network Performance Triangle

15. Network Utilisation and Capability are 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 element records the impact of specific schemes on the capability for each boundary, using thermal, voltage and stability incremental capability across each boundary.

2.3 Ongoing Review and Development of the Network Output Measures

16. 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 NOMs Methodology Objectives.

17. The Network Output Measures methodology is jointly reviewed by all licensees. The licensees regularly discuss the methodology as well as the development of the Network Output Measures. When it is agreed that changes should be made, the licensees follow the process for consulting stakeholders, as defined in the Licence.

18. The licensees are committed to developing a method to enable the Authority to assess risk trade-offs for the Network Replacement Outputs in order to

determine whether each Licensee has met or exceeded its targets at the end of the RIIO-T1 period, the aim being to develop a consistency of approach when assessing risk across different asset categories. Work undertaken in this area by Electricity and Gas Distribution companies is a critical input. The licensees will develop this measure by the end of 2015.

3.0 REPORTING TO THE AUTHORITY

3.1 Licence Requirements

19. The Network Output Measures will be reported to The Authority as part of the annual Transmission Regulatory Reporting Packs as required in Standard Condition B15: Regulatory Instructions and Guidance (RIGs).

3.2 Reporting Timescales

20. The reporting year for the provision of information is from 1 April to 31 March the following calendar year. For the RIIO-T1 period, the first reporting period will be 1 April 2013 to 31 March 2014.

21. The information required under the RIGs will be provided not later than 31 July following the end of the relevant reporting year.

4.0 METHODOLOGY

4.1 Network Asset Condition

4.1.1 Licence Requirements

22. Paragraph 2L 4(a) of the Licence Condition requires the Transmission Licensees to enable the evaluation of:
    a. the Network Assets 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;

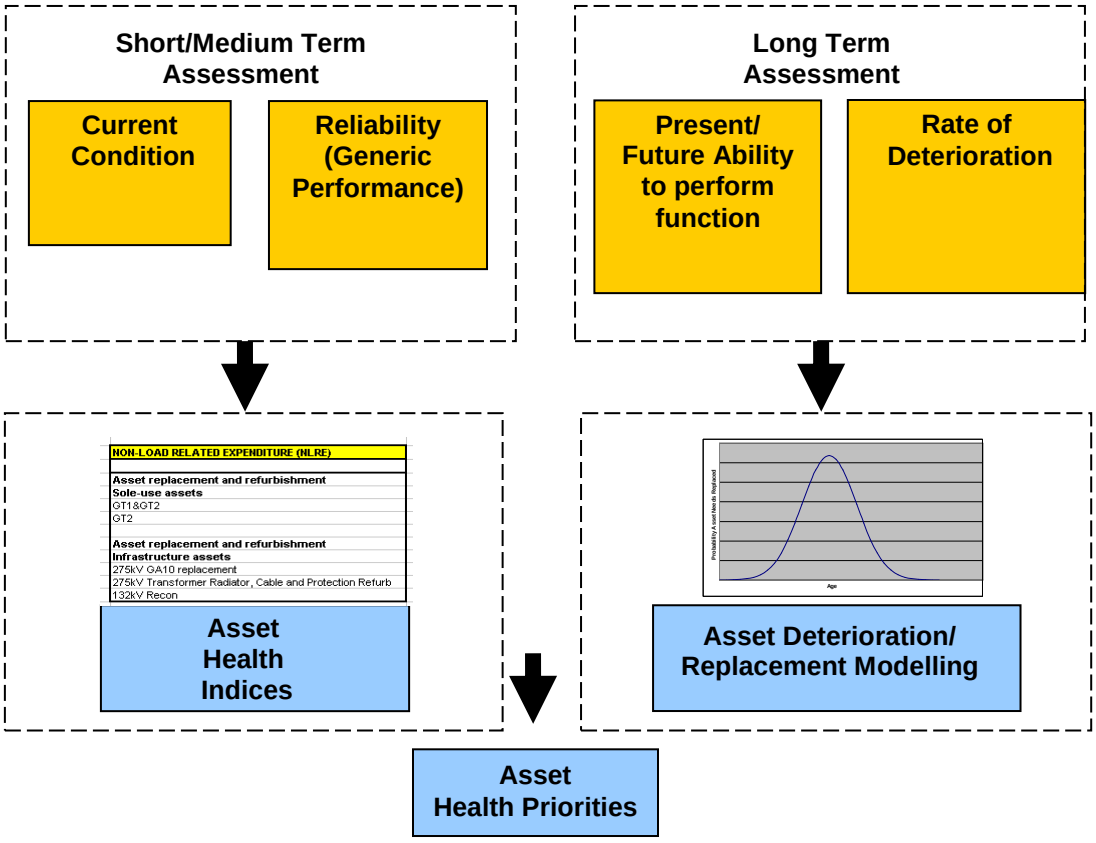
23. The key elements from this Licence Condition are:
    a. Current condition of the assets
    b. Reliability of network assets
    c. Predicted rate of deterioration in condition
    d. Present/future ability of network assets to perform their function

4.1.2 Methodology

24. The Licence Condition requirement can be summarised as the need to enable the evaluation of the Asset Health of the Transmission Licensee's assets. Figure 1 describes how Asset Health Prioritisation feeds into the assessment of the Capital Plan.

25. Figure Figure 3 presents how the key elements of asset condition combine to determine the number and category of assets to be replaced within specific timescales (i.e. Asset Health Priorities). Each section of the diagram is described in the proceeding paragraphs.

Figure 3: The development of the Asset Health Priorities from short, medium and long term assessment



26. This assessment approach to determine the Asset Health Priorities can be described in two separate timescales:
    a. Short and medium term assessment
    b. Long term assessment

4.1.3 Short and Medium Term Assessment

27. Asset condition is the main factor in determining asset health. Asset Health Indices (AH) are categorised in Table 1 as follows:

Table 1: Health Indices

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

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

29. The Asset Health Indices do not represent a requirement for routine intervention options such as maintenance, repair or inspection.

30. The above categorisation gives a common and consistent definition that the Transmission Licensees are using to represent Network Asset Condition and ensure that remaining useful life is calibrated across Transmission Licensees.

31. Asset Health Indices are based on a number of objective factors, examples of which are noted in Table 2.

Table 2: Example Factors used to determine Health Indices

No	Factor	Measure
1.	External Condition	Photographic comparison by graded comparators
2.	Fault Rate	Using national fault database – collated view of faults
3.	Internal Condition	Dissolved Gas Analysis (BS EN 60567)
4.	Issues Arising	Specific to asset types – ENA NEDeRs, Operational Restrictions

32. Asset performance information (e.g. fault rate, failure information), which provides a measure of the reliability of network assets is factored into the Health Indices.

33. Due to the differing asset portfolios and asset management strategies across the Transmission Licensees, there will be some differences in the assessment of Health Priorities. An example of these differences include:
    - Assessment of tape corrosion and sheath failure on cables. National Grid has experienced significant unreliability from cables which are subject to a design fault on certain types of oil-filled cables. SPTL and SHETL do not have these cable types and so are not experiencing these deterioration mechanisms

34. Asset Health Priorities will be produced for the following:
    a. Circuit Breakers
    b. Transformers

c. Reactors
d. Overhead Lines – Split into the three following categories
    i. Line conductors
    ii. Line fittings
    iii. Towers
e. Underground Cables

35. The classification of Health Indices is determined based on condition, performance and other relevant information (e.g. family design factors, duty) as included within Appendix A.

4.1.4 Long term Assessment

5.1.4.1 Asset Deterioration / Replacement Profiles

36. The long term assessment is based on asset deterioration/replacement profiles. This allows the review of historical/forecast capital expenditure.

37. Determining asset deterioration profiles requires an understanding of the rate of deterioration of asset health. The volume of assets identified from replacement modelling provides a measure of the volume of assets in the future that are no longer able to perform their function.

38. Asset deterioration/replacement profiles are determined based on agreed condition, performance and other relevant criteria, which are consistent across the Transmission Licensees, as included within Appendices A and B.

5.1.4.2 Projection of Asset Health Indices

39. The Transmission Licensees define the rate of deterioration by the age at which a typical asset will be at a particular Health Index. An example of the minimum information required to define this rate of deterioration is shown in Table 3.

Table 3: Example of Minimum Information Provided for Health Index Progression

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

40. This rate of deterioration can then be used to predict future Asset Health Indices at a particular asset age using the current Health Index.

41. The rate of deterioration assumptions and modelling undertaken to predict the Asset Health Indices is documented in the individual Transmission Licensees' Specific Appendices.

42. In developing the rates of deterioration, the Transmission Licensees have shared information in how they determine how their profile of Health Indices will change with time.

4.1.5 Ensuring Consistency and Calibration between Transmission Licensees

43. Transmission Licensees have shared relevant internal documentation including the Transmission Licensees' Specific Appendices regarding processes for assessing Health Indices.

44. The experts in the Transmission Licensees have shared information on the derivation of Asset Health Priorities and asset deterioration/replacement profiles and have agreed a consistent set of factors which is contained within Appendix A. This information will be reviewed as part of the annual review of the Network Output Measures Methodology as required in Licence Condition 2L.

45. Appendix B lists the deterioration mechanisms for each equipment group which have been agreed by the experts in the Transmission Licensees – these are the mechanisms which result in changes in condition and thus the Health Indices. This information will be reviewed as part of the annual review of the Network Output Measures Methodology as required in Licence Condition 2L.

4.1.6 Reporting

46. The short, medium and long term assessments result in the delivery of Asset Health Priorities which measure the overall condition of assets. The table for Network Asset Condition is Table 6.15 of the Transmission Regulatory Reporting Pack. 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 5.2.2).

47. Additionally, using the asset deterioration modelling, the Transmission Licensees produce a best view forecast of asset condition across the population of assets for future periods as agreed with The Authority.

4.1.7 Continuous Improvement

48. The Transmission Licensees will continue to develop their understanding of the health, performance and condition of their transmission assets and consequently the methods for determining Asset Health Priorities and rates of deterioration. These enhancements will be reflected in reissues of the Transmission Licensees' Specific Appendices as required as part of the annual review of the Network Output Measures Methodology as required in Licence Condition 2L.

49. As part of the annual review of the Network Output Measures Methodology as required in Licence Condition 2L,.the Transmission Licensees will continue to

share information about the processes and factors which feed into the assessment of Network Asset Condition to ensure that the Network Output Measures are consistent and comparable across the Transmission Licensees.

4.1.8 Additional Material Included within Transmission Licensees' Specific Appendices

50. Each Transmission Licensee covers how the framework set out in this section on Network Asset Condition is implemented within their Specific Appendix.

51. Each Transmission Licensee provides information within their Specific Appendix which will support the Network Output Measures Methodology on how the rate of deterioration is included in the asset deterioration/replacement profiles and Health Indices, including worked examples.

4.1.9 External Publication of Network Output Measures

52. There are no confidentiality issues concerning the external publication of the proposed Methodology for Network Asset Condition. However, the summary tables that form part of the Transmission Regulatory Reporting Packs should not be published externally.

4.2 Network Risk

4.2.1 Licence Requirement

53. Paragraph 2L 4 (b) of the Licence Condition requires the Transmission Licensees to enable the evaluation of:
    a. The overall level of risk to the reliability of the Licensee's transmission system as a result of Network Asset Condition and the interdependence between network assets ('network risk')

54. The key elements from this Licence Condition are:
    a. Overall level of risk
    b. Inclusion of Network Asset Condition
    c. Interdependence between network assets

55. The Transmission Licensees carefully considered this Licence Condition and in the development of the proposed measures used the following definition for Network Risk:

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

4.2.2 Methodology

56. When evaluating Network Risk, the Transmission Licensees include information used in the development of their optimised Capital Plans.

57. When developing of an optimised Capital Plan, prioritised candidates for asset replacement are produced for the following:
    a. Circuit Breakers
    b. Transformers
    c. Reactors
    d. Overhead Lines – Split into the three following categories
        i. Line conductors
        ii. Line fittings
        iii. Towers
    e. Underground Cables

58. Replacement Priorities provide the prioritised candidates for asset replacement. Figure 1 shows how Replacement Priorities feed into the development of the Capital Plan.

59. Replacement Priorities allow the Transmission Licensees 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)

60. This allows the Transmission Licensees to target assets economically and efficiently which pose the greatest Network Risk and thus manage the impact of Network Risk upon the customer.

61. Replacement Priorities are determined through three activities:
    a. Assessment of Asset Health Priorities – already defined as part of Network Asset Condition
    b. Assessment of Criticality
    c. Derivation of Replacement Priorities

62. Replacement Priorities are a measure of the priority ordering of the replacement of assets. The Replacement Priorities' function in the network expenditure process is shown in Figure 1. There are four categories:
    a. RP 1 (highest risk)
    b. RP 2
    c. RP 3
    d. RP4 (lowest risk)

63. Table 4 shows the expected timescales for intervention for each Replacement Priority.

Table 4: Replacement Prioritisation

RP1	0-2 years
RP2	2-5 years

RP3	5-10 years
RP4	10+ years

64. Criticality is a representation of the risk to the stakeholders and has three elements:
    a. Safety Criticality
    b. Environmental Criticality
    c. System Criticality

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

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

67. High level criteria for determining Safety Criticality are described in the Table 5.

68.

Table 5: High Level criteria for determining Safety Criticality

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.

69. 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.

70. High level criteria for determining Environmental Criteria are described in 6. Criteria are not included for the Very High category for Environmental Criticality to ensure comparability with Safety Criticality.

Table 6: High level criteria for determining Environmental Criticality

Environmental Criteria	Very High	High	Medium	Low
Location		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		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.

71. Safety and Environmental Criticality need to be assessed on an individual 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 (i.e. Very High, High, Medium, and Low), the assessment of Safety and Environmental Criticality are documented separately for each Transmission Licensee in the Specific Appendices.

72. Safety and Environmental criticality scoring depends upon the asset type and the unreliability or 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 from asset type to asset type and a safety or environmental consequence may not apply for some assets.

73. Figure 4 shows where safety and environmental criticality affects equipment groups. This Figure has been discussed and agreed across the Transmission Licensees.

Figure 4: Safety and Environmental Criticality Impact by Equipment Type

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

✓ 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)

74. System Criticality covers the impact of the transmission system not delivering services to the customers of the Transmission Licensees and any indirect impact to the safety to the public (through energy not supplied (ENS)) or the smooth operation of UK infrastructure and economy. System Criticality specifically includes: nuclear power station connection sites, with reference to the Nuclear Site Licence Provisions Agreement and Scottish Nuclear Site Licence Provisions Agreements in place; infrastructure that supports key transport links; Control of Major accidents and hazards (COMAH) sites; infrastructure that supports key sites of economic activity within the UK; infrastructure that supports Black Start sites.

75. The Transmission Licensees 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 Transmission Licensees.

76. System criticality can be defined at both a circuit and substation level. It is built up of a number of elements with specific examples (not exhaustive) highlighted in Figure 5.

Figure 5: Elements of System Criticality

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
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

77. System Criticality is scored using a consistent methodology (i.e. Very High, High, Medium, and Low).

78. The parameters which are used by the individual Transmission Licensees reflect the differing sizes of their Transmission Network. The methodology used for System Criticality which is used by the three Transmission Licensees is shown in Figure 6.

Figure 6: Definition of System Criticality

Criticality	Criteria: 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]-[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

79. Criteria are not included for the Very High category for System Criticality to ensure comparability with Safety Criticality.

80. Vital infrastructure represents the infrastructure which is crucial to our stakeholders.

81. Substation demand is taken from the submissions from customers rather than the assessments by the individual Transmission Licensees. Substation demand is defined as the required demand at the yearly peak as submitted by customers as part of P2/6 (historically P2/5) process. This demand data is reported in the GB Seven Year Statement. Using the customer submitted demand ensures customer requirements are being taken into account in defining System Criticality.

82. The general principles used to determine System Security are:
    - Local Group Demand Criteria: Determined by the unsupplied demand at peak for an N-2 loss taking into account the demand transfer capability within switching time (assume 30 minutes) and a contribution from fully embedded generation: The greater the unsupplied demand, the greater the assigned Criticality.

- For the Main Interconnected Transmission System:
  a. Generation Concentration: Areas where there is a high concentration of net generation and little supporting infrastructure to transport the energy away to demand centres. The higher the concentration relative to the supporting infrastructure, the higher the assigned Criticality.
  b. 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.
  c. 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/costs, the higher the assigned Criticality.

83. The actual scoring mechanisms are detailed within the Transmission Licensees' Specific Appendices.

84. The Transmission Licensees investigated using financial consequences to provide the comparison of the safety, system and environmental Criticality elements. However, using financial values to balance investments which address safety and environmental statutory duties against reliability investments would not be a justifiable or challengeable defence if the resultant failure to act resulted in a breach of the law.

85. 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 the 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.

86. Figure 7 shows how the System, Safety and Environmental Criticality elements map against each other to determine the overall Criticality Score.

Figure 7: Criticality Mapping across Safety, System and Environment

	Criteria				
Criticality	**System**		**Safety**		**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]-[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 sensitive environment
	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

87. The table indicates 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.

88. A method of weighting and combining Criticalities was considered but 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 factor being overlooked.

89. Figure 8 shows how Asset Health Priorities and Criticality are mapped to obtain a Replacement Priority category.

Figure 8: Mapping of Replacement Priorities

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

90. In the development of the Replacement Priorities across the Transmission Licensees, a comparable and consistent approach has been reached by categorising the Replacement Priorities from Priority 1 to 4, Priority 1 being the highest priority for replacement or other intervention options.

91. By sharing the principles for deriving and applying Criticality and assigning Replacement Priorities, the Transmission Licensees have reached this common approach.

92. The Transmission Licensees provide further information on how Figure 7 is used to assign Replacement Priorities within the Specific Appendices.

93. To ensure the Network Risk outputs are consistent and comparable across the Transmission Licensees, as part of the annual review of the Network Output Measures Methodology as required in Licence Condition 2L,, the Transmission Licensees 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

4.2.3 Reporting

94. The Replacement Priorities are summarised and included within the Transmission Regulatory Reporting Pack (Table 6.15 in a table agreed with The Authority. This allows the Transmission Licensees to show the overall level of Network Risk and the potential impact to their customers in terms of reliability of services, safety performance and environmental performance.

95. The Transmission Licensees have agreed a table with The Authority which reports the constituent elements of Criticality on a circuit and substation basis (Table 6.16).

4.2.4 Longer Term Network Wide Risk

96. To understand longer term Network Wide Risk , the Transmission Licensees consider the following principles are important:
    a. Consistency with the current Network Risk information i.e. Asset Condition and Criticality
    b. Ability to determine longer term Network Wide Risk under different investment scenarios (e.g. planned network expenditure, no replacement investment)
    c. Information which is used internally within the Transmission Licensees' businesses

97. For this longer term Network Wide Risk measure, the Transmission Licensees have developed a forward projection predicting the Replacement Priorities at the end of each price control cycle under different investment scenarios (e.g. planned network expenditure, no network expenditure).

98. This forward projection of Network Risk (i.e. a forward projection of the Replacement Priorities) is produced by combining the forward projection of Health Indices using the rates of asset deterioration with Criticality.

99. The detailed approaches used by the Transmission Licensees to forecast Replacement Priorities into the future is contained within the Transmission Licensees' Specific Appendices.

100. The detailed approaches used by the Transmission Licensees to forecast Replacement Priorities have been shared to ensure consistency and comparability across the reported longer term Network Risk Measure.

101. The output for Network Risk at the end of the RIIO-T1 is given in Table 1 in Special Condition 2M 'Specification of Network Replacement Outputs' and assumes that the planned Network Expenditure addressing asset replacement (non-load) volumes is actioned and completed. Transmission Licensees produce the best view forecast of asset condition across the population of assets. This forecast is used as the Network Replacement Output (see Section 5.5) which will be assessed by the Authority at the end of the RIIO-T1 period to determine delivery against these secondary output measures and the level of reward or penalty associated with over- or under-delivery against these measures.

4.2.5 Continuous Improvement

102. As part of continuous improvement, the Transmission Licensees will develop their understanding of the Criticality of their transmission assets and consequently further enhancements will be made to the Replacement Priorities.

4.2.6 Additional Material Included within Transmission Licensees' Specific Appendices

103. The parameter values for System Criticality for each Transmission Licensee are documented within their Specific Appendices.

104. A more detailed approach for determining System Security (part of System Criticality Methodology) are documented for each Transmission Licensee within their Specific Appendices.

105. Each Transmission Licensee covers how Network Risk is implemented within their Specific Appendices.

106. The detailed approaches used by each Transmission Licensee to forecast Replacement Priorities (the longer term Network Wide Risk Measures) are contained within their Specific Appendices.

4.2.7 Ensuring Consistency and Calibration between Transmission Licensees

107. The Transmission Licensees undertook other activities to ensure consistency and calibration of the Network Output Measures between the Transmission Licensees.

a. The Specific Appendices to the Network Output Measure Methodology have been shared at each stage of the process

b. The Transmission Licensees shared relevant internal documentation regarding processes for determining Replacement Priorities

c. Technical experts from the three Transmission Licensees attended a three-day session to share the information used in the assessment of Network Expenditure.

4.2.8 External Publication of Network Output Measures

108. The information on System Criticality at an asset level is highly sensitive in terms of physical security and so information on the methodology used to derive the categories or any of the outputs from applying this methodology should not be published. In addition, the methodology used to derive 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. The summary tables that form part of the Transmission Regulatory Reporting Packs should not be published externally.

4.3 Network Performance

4.3.1 Licence Requirement

109. Paragraph 2L 4 (c) of the Licence Condition requires the Transmission Licensees to enable the evaluation of:
    a. Those aspects of the technical performance of the Licensee's transmission system which have a direct impact on the reliability and cost of services provided by the Transmission Licensee as part of its transmission business ('network performance')

110. The key elements from this Licence Condition are:
    a. Performance of the Licensee's transmission system
    b. Direct Impact on the reliability and cost of the services

4.3.2 Methodology

111. Network Performance is a key output for the customers of the Transmission Licensees.

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

113. The Transmission Licensees report a comprehensive set of Network Performance Measures in the form of unavailability, faults and failure information with associated commentary through the Transmission Regulatory Reporting Packs.

114. Reduced reliability of the transmission network increases the risk of loss of supply for directly connected customers and increases costs to market participants which impacts 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.

115. Average Circuit Unreliability 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 as:

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

116. Duration in the context of Average Circuit Unreliability is a continuous number and is not rounded or truncated at any stage of the calculation, thus no errors are introduced into the calculation. The monthly duration will be 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.

117. The outages which are classified as being included within the definition of Average Circuit Unreliability 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.

118. All unreliability related outages are included within the definition of Average Circuit Unreliability. 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.

119. The Transmission Licensees have investigated whether the fault and failure data provides a statistically significant dataset to derive correlations between asset condition. The actual number of faults and failures is very small across all the Transmission Licensees. This is as a result of:

    a. Actual population sizes of the assets – The population of assets is not large enough to experience a great number of reliability related faults and failures
    b. Asset management approach within our businesses – the Transmission Licensees maintain assets to manage the number of faults experienced and aim to replace before failure using asset condition and criticality to prioritise asset replacement candidates (see Figure 1). This means many faults and failures that might occur are avoided.

120. The number of faults and failures have proven insufficient to enable accurate correlations with asset condition. Details of the investigations undertaken by each Transmission Licensee are included in the Transmission Licensees' Specific Appendices.

121. By looking at 'Functional Failures' i.e. those assets which have been removed from service (on a temporary basis) as a result of an unreliability related event, there is a greater set of data which can be used for correlation and forecasting with asset condition.

122. 'Functional Failures' include those unreliability related outages which are used to determine Average Circuit Unreliability.

123. Each Transmission Licensee has varying historical datasets with which to produce correlation of asset unreliability with asset condition. In addition, given the introduction of Health Indices on a consistent basis across the Transmission Licensees, 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.

124. The investigations undertaken by each Transmission Licensee include the analysis undertaken to identify correlations between asset unreliability and asset condition are detailed in the Transmission Licensees' Specific Appendices.

4.3.3 Reporting

125. Average Circuit Unreliability is a network related measure. Outages taken for unreliability reasons whether planned or enforced have an impact on the reliability of service.

126. The Average Circuit Unreliability table is included in the Transmission Regulatory Reporting Pack as part of the Network Output Measures for Network Performance (Table 5.10).

127. The total number of circuits used in this calculation varies by Transmission Licensee and will vary from year to year as the networks are modified. For this reason the number of circuits used as part of the Average Circuit Unreliability calculation are reported as at 31 March each year

128. Network Performance reporting also includes a number of tables already reported in the Transmission Regulatory Reporting Packs e.g. faults and failures (Table 5.2).

4.3.4 Additional Material Included within Transmission Licensees' Specific Appendices

129. Each Transmission Licensee will cover how Network Performance is implemented within their Specific Appendix including specific detail regarding the classification of circuits which are included within the calculation of Average Circuit Unreliability.

4.3.5 Further Development of Network Performance measure

130. The licensees are committed to developing the network performance measure further by the end of 2014.

4.3.6 External Publication of Network Output Measures

131. There are no issues with the external publication of the Network Output Measure Methodology for Network Performance. The summary tables as reported in the Transmission Regulatory Reporting Packs should not be published externally.

4.4 Network Capability

132. Paragraph 2L 4 (d) requires the Transmission Licensees to enable the evaluation of:
    a. 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.

133. The key elements from this Licence Condition are:
    a. Information about Transmission System Capability

b. Information about Transmission System Utilisation

4.4.1 Methodology

134. The Transmission Licensees report on transmission system capability as part of the Transmission Regulatory Reporting Pack. This reports the existing and future transmission capacity being provided by the Transmission Operators on the main interconnected transmission system.

135. Likewise, the Transmission Regulatory Reporting Pack requires the individual Transmission Licensees 'to collect information relating to more localised demand driven need for developing transmission infrastructure'. This is presented in Table 5.5 'Demand and Supply Capacity for Access Groups' 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.

136. Where data is available the Transmission Licensees will provide forecasts into the future as agreed with The Authority.

137. Adopting these measures ensures consistency in reporting and interpretation of requirements across all Transmission Licensees

4.4.2 Provision of Information on Voltage & Stability

138. Information is reported in the Electricity Ten Year Statement at a boundary level. This boundary capability is calculated based on the most onerous limitation whether this is thermal or voltage.

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

140. Where data is available the Transmission Licensees will provide forecasts into the future as agreed with The Authority. This is incorporated into the Transmission Regulatory Reporting Table (Table 5.4).

4.4.3 Reporting

141. Tables 5.3 and 5.4 of the Transmission Regulatory Reporting Pack table reflect the 'Capability' requirement. Table 5.5 of the Transmission Regulatory Reporting Pack table reflects the 'Utilisation' requirement.

142. Table 5.3 Boundary Transfer Capability provides information about the planned transfer and required capability for each boundary.

143. Actual capability information is provided in Table 5.4 Boundary Capability Development Schemes. This table 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 rules for creating Table 5.4 are taken from the 'Price Control Review Reporting Rules: Instruction and Guidance'. Further rules are as follows:

a. Boundaries: A system boundary splits the network into two parts across which transfer capabilities can be assessed
b. Boundary Capability: Assessed according to the National Electricity Transmission System (NETS) SQSS

144. The rules for creating Table 5.5 are taken from the 'Price Control Review Reporting Rules: Instruction and Guidance'. 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. Seasonal Peak Demand: Equal to peak demand or if more onerous conditions arise with lower demand and the accompanying relevant rating
    c. n-1 Capacity: The first circuit outage condition as defined in the NETS SQSS
    d. n-2 Capacity (300MW demand groups only): The second circuit outage condition as set out in the NETS SQSS – only applicable for substations where the peak group demand is greater than 300MW

4.4.4 Continuous Improvement

145. The Transmission Licensees will continue to review the submitted information for Network Capability and System Utilisation.

4.4.5 Additional Material Included within Transmission Licensees' Specific Appendices

146. Any additional relevant measures which the individual Transmission Licensee considers useful for internal business use and addressing the Licence requirement will be reported within the individual Transmission Licensee's Specific Appendix.

4.4.6 External Publication of Network Output Measures

147. There are no issues with the external publication of the proposed Network Output Measures Methodology. The summary tables which form part of the Transmission Regulatory Reporting Packs should not be published externally.

4.5 Network Replacement Outputs

4.5.1 Licence Requirements

148. Special Licence Condition 2M specifies the Network Replacement Outputs the licensee must achieve by the end of the Price Control Period and the principles associated with material over or under deliveries against those outputs.

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

150. Transmission Licensees 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

151. The Transmission Licensees have submitted forecast Network Risk Replacement Priorities at 31 March 2021 as part of their RIIO-T1 submissions. These forecasts represent the Network Replacement Outputs, that is, the level of Network Risk at the end of the RIIO-T1 price control period. Table 1 in Special Condition 2M of each Transmission Licensee's licence details the expected Network Replacement Output for each asset category and this table is specific to each Licensee.

152. Management of the asset base is a continuous process and the Transmission Licensees will continually review their asset management strategies to ensure that the most appropriate decisions are being made, based on the latest information about asset condition and performance, in the best interests of the consumer.

153. If these decisions result in changes to the NOMs methodology, any such changes will be reported in accordance with licence condition 2L Part E (see Section 7.2)

4.5.3 Reporting

154. The Transmission Licensees will report Table 6.15 annually as part of the Regulatory Reporting Pack. The information will comprise actual Replacement Priorities as at 31 March of the reporting year as well as the current forecast for 31 March 2021. The Network Replacement Outputs target figures are detailed within the table as well, for the purposes of comparing the current forecast with the target.

4.5.4 Further Development of Network Replacement Outputs

155. Work is continuing to be undertaken to develop an approach for justifying trade-offs between asset categories by the end of 2015. In developing this, the work undertaken by the Electricity and Gas Distribution companies will be a critical input as well as the development of Transmission specific requirements such as low probability, high impact events.

5.0 COMPARATIVE ANALYSIS

5.1 Licence Requirements

156. Within this section the Transmission Licensees have considered the following parts of the Licence Condition 2L3c:
    a. The Network Output Measures shall be designed to facilitate the comparative analysis over time between:
        i. Geographic areas of, and network assets within the Licensee's transmission system
        ii. Transmission systems within Great Britain
        iii. Transmission systems within Great Britain and within other countries
        iv. Transmission systems and Distribution Systems within Great Britain

5.2 Geographic areas of, and Network Assets within the Licensee's Transmission System

157. The Network Output Measures Methodology has been designed to enable comparability of network assets e.g. common Health Index definitions, common Replacement Priority definitions. The constituent elements of Criticality recognise geographic differences.

5.3 Transmission Systems within Great Britain

158. By developing the Network Output Measures Methodology across the Transmission Licensees, the Network Output Measures are produced in the same format to allow comparative analysis across Transmission Licensees.

159. By continually sharing information across the Transmission Licensees with the aim of calibrating the Network Output Measures this will enable comparison across the Transmission Licensees.

5.4 Transmission Systems within Great Britain and Other Countries

160. The names of specific companies have not been included within this Network Output Measures Methodology to enable external publication of these comparisons.

161. In addition to the development of the Network Output Measures, the three Transmission Licensees have researched methods used to report similar measures within Great Britain and other countries. 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 these methodologies are highly configurable so the companies using them can align the measures to their asset base and statutory, regulatory and business requirements.

Transmission Systems and Distribution Systems within Great Britain

162. Throughout the development of the Network Output Measures, the Transmission Licensees reviewed the DPCR5 Distribution Network Output Measures to establish consistency in reporting across transmission and distribution.

163. The transmission Network Output Measures Methodology have similar features to the DPCR5 Distribution Network Output Measures by including Health Indices and forecast projections of Health Indices but differed in that the transmission Network Output Measures additionally included Criticality by agreement with The Authority.

164. The Transmission Licensees have attended workshops run in conjunction with The Authority and the Distribution Network Operators to understand the development of the Distribution Network Output Measures and asset management strategies going forward.

6.0 ONGOING REVIEW AND DEVELOPMENT OF NETWORK OUTPUT MEASURES

6.1 Licence Requirements

165. Part E of Licence condition 2L has the following requirements:

166. 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 NOMs Methodology Objectives.

167. The Transmission Licensee shall make such modifications to the approved Network Output Measures Methodology as may be required to better facilitate the objectives.

168. 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 licensee's modification proposal; and

(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 licensee 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 provided, where reasonably practicable, for a

period of at least ten years prior to the date 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 Condition 2M (Specification of Network Replacement Outputs), that are necessary as a result of the proposed modification to the NOMs Methodology; and
(vii) a timetable for the implementation of the proposed modification, including an implementation date.

6.2 Process to Modify Network Output Measures Methodology

169. The Network Output Measures Methodology will be jointly agreed by all Transmission Licensees and jointly reviewed annually in accordance with Part E of Licence condition 2L to reflect any proposed changes or further developments to ensure that it facilitates the objectives of the Licence Condition.

170. The terms of reference of these review meetings are – "The Transmission Licensees will meet to discuss the appropriateness of the current Network Output Measures in meeting the requirements of Licence Condition 2L; Share information to ensure consistency and calibration across the Transmission Licensees and to discuss and resolve common issues with the implementation of Network Output Measures"

171. Outside of the annual review if a Transmission Licensee determines that a modification is needed to the Network Output Measures Methodology that Licensee will call for a joint review with the other Transmission Licensees.

172. Changes to the Network Output Methodology and specific appendices will follow the process outlined above. Changes to specific company documentation affecting Network Output Measures will be reported annually as part of the Regulatory Reporting Pack.

Appendix A: Factors used in determining Health Indices

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

Appendix B: Deterioration Mechanisms & Factor which bring about 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