Consultation

ED3 Sector Specific Methodology Consultation – Climate Resilience Metrics and Indicators (CRMI) Annex

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This document is for Electricity Distribution Network Companies to enable them to provide Ofgem with views on the proposed framework and potential metrics and indicators to be reviewed. It explains best practice of how CRMI may be developed jointly with Ofgem.

Once the consultation is closed, we will consider all responses. We want to be transparent in our consultations. We will publish the non-confidential responses we receive alongside a decision on next steps on our website at ofgem.gov.uk/consultations. If you want your response – in whole or in part – to be considered confidential, please tell us in your response and explain why. Please clearly mark the parts of your response that you consider to be confidential, and if possible, put the confidential material in separate appendices to your response.

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Executive summary

We know that impacts from extreme weather events are already being felt by energy consumers. Even though the GB electricity system is very reliable, it is imperative that we understand further actions to be resilient to extreme weather.

One current barrier to addressing climate resilience is lack of agreed metrics on climate resilience. We committed in RIIO-ED2 to work with network companies and the Energy Networks Association (ENA) to introduce Climate Resilience Metrics and Indicators (CRMI) within the ED3 price controls. For ED3, as set out in our Sector Specific Methodology Consultation (SSMC), we are aiming to introduce new CRMI by the start of the price control alongside a period of learning to build confidence in these metrics before they could be used to influence decisions in the future (either future price controls or within the period via a resilience re-opener).

However, measuring climate resilience is complex and difficult to address without an agreed initial framework. This document sets out the latest thinking on CRMI, including a framework developed through a joint project between our Climate Resilience Team and an academic secondee, Dr Natalia Zografou-Barredo, funded by HI ACT's Flex Fund Secondment Call and supported by EPSRC Supergen Energy Networks and Newcastle University.[1] The aim of the work was to establish a way for us to identify relevant aspects for measuring climate resilience of regulated network companies to help inform the setting of new CRMI for the start of the ED3 period. There are several objectives that would need to be measured to capture resilience theory and climate hazards, cut across regulated network companies and be deliverable for price controls. Our thinking suggests that a suite of metrics and indicators would be the most appropriate option as outlined by the framework set out in this report.

Our plan is to use this framework and continue to work collaboratively with network companies to shortlist CRMI, start data collection and set out routes for reporting ahead of and during ED3.

We are sharing this document now to allow wider stakeholders to provide views on this as part of our SSMC process to help inform further development between now and the time of our Sector Specific Methodology Decision (SSMD). It is intended to be read alongside the wider SSMC document. The specific questions related to CRMI in the climate resilience section (Chapter 4) of the SSMC core document are:

[1] Flex fund secondment call - HI ACT, Energy networks community - Supergen

Q96. Do you agree with our approach to introduce Climate Resilience Metrics and Indicators (CRMI) at the start of ED3 and use the learnings to shape future decisions (either for future price controls or via a re-opener)?

Q97. Do you have any views on the proposed CRMI Framework (Climate Resilience Metrics and Indicators (CRMI) Annex)? Do the CRMI Framework objectives and attributes reflect what's needed to measure climate resilience? Are there specific metrics or indicators we should consider?

This work has identified several key findings.

- **CRMI framework** - Chapter 3 presents the proposed CRMI Framework. The framework proposes three objectives which show from a regulatory perspective what would need to be captured by climate resilience metrics and indicators to measure network company climate resilience. This is also composed of 'attributes' which represent a list of features that characterise these metrics and indicators and thus their relative pros and cons of candidate metrics and indicators.
- **CRMI Excel tool** - along with the framework, this work produced the Climate Resilience Metrics and Indicators Excel Tool, which serves as a practical tool for Ofgem to have visibility over pros and/or cons of candidate indicators and flag the ones that serve (or do not serve) the framework objectives. We will use this tool to review CRMIs for inclusion in a suite which attempts to measure climate resilience of network companies; and
- **Future work** - Chapter 4 presents some suggested future directions of this work.

Structure of document

The first part of this document outlines why and how we developed a framework.

The second part presents the framework and explains our plans to develop, and assess the suitability of, a list of candidate CRMIs to understand how these relate to the framework objectives and their respective pros and cons. We are seeking views on the proposed framework and potential candidates for CRMIs.

The document is structured as follows:

- **Chapter 1** presents the scope of the work and its limitations, including how climate resilience is or is not currently part of price controls, and the place of this work within Ofgem's climate resilience programme;

- **Chapter 2** presents the background behind the framework;
- **Chapter 3** presents the framework, its objectives and attributes, and how the proposed framework can be used; and
- **Chapter 4** concludes this work, presents suggestions for future work, presents a list of candidate CRMI which is draft and non-exhaustive, and suggests questions for our SSMC.

1. Introduction

Context

1.1 One major gap for monitoring and addressing climate resilience is a lack of agreed climate resilience metrics. Whilst lagging metrics on historic impact from weather events exist (such as Customer Minutes Lost (CML) and Customer Interruptions (CI)), metrics included in annual reports exclude disruptions from the most severe events. This can distort the true picture of disruption and provide false reassurance (see section on severe weather threshold for more reasoning). Furthermore, there is a need for forward looking metrics that consider the levels of resilience to future high impact, low probability events (which is linked to the work we are carrying out on stress testing).

1.2 Recognising the need to address this gap, in December 2020, we published the RIIO-ED2 SSMD,[2] stating:

> "8.119 We will work with DNOs on the appropriate data that could be gathered with a view to developing a climate resilience metric. We believe that the annual reporting process, including the development and population of the RIIO-ED2 Regulatory Instructions and Guidance, will form an integral part of this process. We expect this metric to be developed ready for implementation in ED3."

1.3 In July 2024, we published the RIIO-3 -SSMD,[3] stating:

> "6.115 We will consider all the factors stated above collaboratively with the network companies through the Climate Change Resilience Working Group (CCRWG). We have also decided to refer to 'climate resilience metrics and indicators' because feedback indicates that development of a single metric may not be possible given the complex nature of climate resilience. […]"
>
> "6.122 We have decided that the following activities [including metrics and indicators] will start development in RIIO-2 and ramp up throughout RIIO-3. Network companies are not required to submit material on these activities in their business plans in

[2] RIIO-ED2 Sector Specific Methodology Decision | Ofgem
[3] RIIO-3 Sector Specific Methodology Decision for the Gas Distribution, Gas Transmission and Electricity Transmission Sectors | Ofgem

December. Instead they should provide updated on their progress in their RIIO annual reporting. We expect network companies to fully comply with the approach [including on metrics and indicators] by the second annual reporting submission. […]"

- "Network companies should continue work on developing climate resilience metrics and indicators, as well as other industry best practice, through the CCRWG. They should begin monitoring and reporting on the climate resilience metric and indicators in their annual report once they have been established."

"6.123 We have decided to continue developing the climate resilience metrics and indicators, as noted above, but not to continue developing an overarching resilience metric. This is based on feedback from the SSMC, and due to the complexity of developing an overarching metric which captures the wide range of resilience activities that network companies undertake."

1.4 In our ED3 SSMC, published alongside this document, we have reiterated our aim to introduce CRMIs by the start of ED3. This will include a period of learning during ED3 to build confidence in these metrics before using them to influence decisions in the future.

1.5 We have been working with the network companies over the past few years to develop a joint understanding of what CRMIs could cover, the types of questions we need to be aware of and how the metrics could be introduced.

1.6 Through this work it has become clear that in order to make progress on the complex and multifaceted issue of measuring climate resilience, we need an agreed framework before being able to confidently set new metrics. With this in mind, this document sets out a CRMI Draft framework. This is a principles-based document that we have worked on with the network companies, and it presents questions and answers regarding CRMIs. We have engaged with academics to understand the limitations of our proposed methodology, including an academic secondment through which the CRMI framework was developed.

Scope and work limitations

Hazards against which resilience is addressed

1.7 The focus of this work is climate resilience. Other hazards that network companies need to be resilient against, such as cyber hazards, are outside of the scope of this document.

Regulatory context

1.8 Multiple risk and resilience frameworks have been developed across infrastructure sectors, including energy, from a range of perspectives, including governments, institutions, working groups, utilities, research and innovation projects and others. Some of these frameworks are discussed later in the report.

1.9 Metrics and indicators that measure network company climate resilience for price controls will be referred to as 'Climate Resilience Metrics and Indicators' or 'CRMI'. This term may refer to one or more indicators depending on context. 'Metrics' can be defined as a standard of measurement ie MWh and 'Indicators' can be defined as a particular element being assessed ie energy not served.

Sectors considered

1.10 The CRMI Framework is being developed with consideration for all four sectors currently subject to price controls: Electricity Transmission (ET) and Distribution (ED), and Gas Transmission (GT) and Distribution (GD). The application of the framework is intended to inform ED3, with the potential to support future price controls across the other sectors as well. We will work with network companies within these sectors to sense check the CRMI Framework and its application and determine whether any amendments are required.

Electricity distribution - RIIO-ED2

1.11 Distribution Network Operators (DNOs) in RIIO-ED2 currently have five outputs to ensure long-term safety and resilience as set out in Annex 1 of the RIIO-ED2 Methodology Decision (ED2 Annex 1).[4] These are related to the Network Asset Risk Metric (NARM), Workforce Resilience, Cyber Resilience Information Technology (IT), Cyber Resilience Operational Technology (OT) and Environmental Resilience.

1.12 There are three main strands to ensuring DNOs deliver safe and resilient networks: asset resilience, environmental resilience and information/other resilience. Climate resilience falls under the strand of environmental resilience.

[4] RIIO-ED2 Methodology Decision: Annex 1 - Delivering value for money services for consumers

In the first category, NARM, as explained in RIIO-ED2 Annex 1, 'considers the probability and impact of an asset failing' and provides information on reliability.

1.13 RIIO-ED2 required network companies to provide a Climate Resilience Strategy, detailing flood mitigation and vegetation management plans. There are also two incentives on reliability enforced: the Interruptions Incentive Scheme (IIS) and the Guaranteed Standards of Performance (GSOP).

Electricity distribution - ED3

1.14 The ED3 Framework Decision acknowledges that climate resilience is a key component of network resilience.[5] NARM itself is a key component of the price control framework, and it is reported it should incorporate climate change impacts. However, NARM is a metric that focuses on answering questions on asset reliability rather than resilience. It is also more focused on chronic risk (ie asset deterioration) whereas climate resilience covers both chronic and acute risk (ie resilience to high impact, low probability extreme weather events).

1.15 The ED3 Framework Decision also acknowledges that climate resilience should be embedded into distribution networks, with a focus of benefits in future-proofing investments as the transition to net zero takes place. The benefits of incorporating climate resilience are also included in the RIIO-3 SSMD document.[6] It is explained that 'To ensure that both the stress testing exercise and the climate resilience goal are informative and provide clear pathways, we will develop climate resilience metrics and indicators', which acknowledges that CRMI metrics and indicators are currently not included in ED price controls.

Gas distribution, gas transmission and electricity transmission - RIIO-3

1.16 RIIO-3 SSMD also considers NARM as a risk metric. It is explained in the SSMD that climate resilience metrics and indicators will need to be developed, and factors such as scope, their value and how they will be used, will be considered.

Standards

1.17 Resilience standards are complex and wide ranging. There are two industry standards that have relevance to CRMI in the context of ED and have been developed by industry:

- ETR 132 which relates to overhead line resilience and tree cutting; and
- ETR 138 which relates substation resilience to flooding events.

[5] ED3 Framework Decision
[6] RIIO-3 Sector Specific Methodology Decision – Overview Document

Section conclusions

1.18 Price controls across electricity and gas sectors incorporate reliability and network resilience (eg asset resilience, environmental resilience) and use NARM to quantify asset reliability. However, there are not currently metrics and indicators in place to measure the network companies' climate resilience. Even though the GB energy system is very reliable, there is a need to understand current and future levels of climate resilience and set out how climate resilience may be enhanced in future regulations to future-proof investments related to net zero targets and be prepared for future impact of plausible but extreme weather events.

Ofgem's climate resilience programme

1.19 This section presents an overview of our climate resilience programme objectives and approach to address climate resilience and where this document sits within this programme. The climate resilience programme is composed of three levels which are published in detail in our climate resilience fourth round climate adaptation reporting.[7]

Climate resilience programme three-level approach

1.20 The first level is a twin-track approach representing the two parallel objectives of the climate resilience programme. These objectives are to:

- accelerate setting goals for climate resilience; and
- strengthen climate consideration through upcoming regulatory decisions.

1.21 The second level presents the four strategic priorities:

- Roles and Responsibilities - Provide strategic direction to government, NESO and Ofgem to drive the step change required.
- Valuing and measuring resilience - Develop economic framing, tools, and metrics to value and inform / drive investment decision on climate resilience.
- Consistent & Impactful stress testing - Ensure decisions at all levels of the energy system are informed by consistent consideration of high impact, low probability events.
- Standards - Review standards and their role in driving investment decisions on climate resilience for new build.

[7] Climate resilience report – fourth round climate adaptation reporting

1.22 The third level presents some of the actions that are being taken to achieve these objectives and strategic priorities. These actions include:

- working closely with DESNZ, NESO and other key stakeholder to establish goals for climate resilience;
- consider and refine options for climate resilience in upcoming price controls;
- set requirements for stress testing for network companies;
- develop approaches to improve the valuation of resilience;
- build understanding of public acceptability for climate resilience; and
- work with DESNZ, NESO, industry and others to review standards which support resilience to future climates.

1.23 The CRMI Framework aims to support the second objective which is to strengthen climate considerations through upcoming regulatory decisions, support the strategic priority on valuing and measuring resilience, and the actions of considering and refining options for climate resilience in upcoming price controls and the development of approaches for the valuation of climate resilience. It also is planned to support wider Ofgem activities including stress testing, which we are currently developing.

1.24 During the development of the programme, our climate resilience team has sought the views of a range of experts and stakeholders both within the UK and overseas. This includes our panel composed of UK and international experts, engagement with the CCRWG, international engagement with other energy regulators, the Met Office,[8] and the National Energy System Operator (NESO).[9] We will continue to engage with others, including international partners, to further our understanding of climate resilience on our future energy system.

1.25 The proposed CRMI framework applies to both climate resilience goals, valuing and measuring resilience alongside consistent and impactful stress testing and actions within price controls.

Related publications

1.26 ED3 Sector Specific Methodology Consultation core document.

[8] Weather and climate change - Met Office
[9] National Energy System Operator (NESO) | National Energy System Operator

2. CRMI framework overview and background

A non-exhaustive review of resilience and adaption frameworks

2.1 This section outlines existing literature for measuring climate resilience, climate resilience frameworks, and more general risk/resilience frameworks. Our review included asking questions such as, 'What are other regulators doing to measure network company climate resilience?', 'Are there any utilities, consultancies and/or working groups locally or overseas working to develop ways to value and measure climate resilience?'.

2.2 The review in this section is non-exhaustive in that it does not seek to include all relevant frameworks that exist. However, it aims to capture a diversity of reports across organisations, industry and research to show a range of work related to resilience assessment and climate change impact assessment and quantification. Their relevance to this work is highlighted and some of these may be useful in future work which would focus on choosing the most appropriate metrics/indicators based on the CRMI framework.

Reports by organisations

2.3 **OECD** – The Organisation for Economic Co-operation and Development supports countries with international best practice on climate resilience,[10] and approaches to embed and measure aspects of climate resilience.[11] In the United Kingdom, there is a range of central and devolved governments including independent bodies that deliver or contribute to the development and implementation of climate resilience and adaptation strategies including England, Scotland, Northern Ireland and Wales, the Climate Change Committee (CCC) and its Adaptation Committee, and Defra (Department for Environment, Food and Rural Affairs).[12] Even though there may be overlaps, these bodies approach the topic from different perspectives (eg Ofgem takes a regulatory approach).

2.4 **UNECE** - The United Nations Economic Commission for Europe report presents a framework for resilient energy systems which is divided into the demand, storage and transmission, and supply sides, and includes a category on innovations.[13] This framework seems to have a different viewpoint to that which we intend to have for the CRMI framework as it represents a 'high-level' approach of energy systems resilience.

[10] Climate adaptation and resilience | OECD
[11] Measuring Progress in Adapting to a Changing Climate | OECD
[12] Department for Environment, Food & Rural Affairs - GOV.UK
[13] Resilient Energy Systems_EN.pdf

2.5 **IEA** – The International Energy Agency has published a section on climate resilience for power systems with a conceptual framework that divides climate resilience performance across time into i) equilibrium, ii) long-term impacts of climate change, iii) immediate impacts of extreme weather events and iv) recovery back to equilibrium.[14] The way climate resilience is thought of in the first objective of the CRMI framework can be mapped to this representation of climate resilience, which is presented in Chapter 3.

Industry and research reports

2.6 **Sandia National Laboratories** - The Sandia National Laboratories have produced a conceptual framework for developing resilience metrics for the electricity, oil and gas sectors.[15] The resilience metric framework is defined by the relationship between the probability of a particular consequence given a particular threat and is accompanied by a list of principles or features that resilience metrics should have. The proposed CRMI framework shares similarities in the sense that it is composed of attributes which specify pros and cons of candidate metrics and indicators for price controls; however, the attribute categories listed in the CRMI framework seem to specify metrics/indicators from a different viewpoint than in the Sandia Report.

2.7 **Arup** - Arup, a global consultancy, has produced the energy resilience framework which focuses on non-technical parts factors of energy system resilience and is composed of four factors: technical, financial, organisational and social. Arup describes the framework as made to support governments, regulators, generators, customers, utilities and investors.[16] Conceptually, it seems to capture a few parts that the proposed CRMI framework also captures, but as it is intended for a broad range of organisations and types of resilience, it cannot capture aspects specific to Ofgem's price controls and/or climate resilience programmes.

2.8 **CS-N0W** – The Climate Services for a Net Zero Resilient World research programme 'analyses the climate hazards facing natural and human systems to inform UK and international adaptation policies and plans'.[17] This analysis is delivered for UK infrastructure including water-intensive energy infrastructure, energy networks, and others.

[14] Climate resilience – Power Systems in Transition – Analysis - IEA
[15] EnergyResilienceRpt-Sandia-Sep2014.pdf
[16] energy-resilience-framework.pdf
[17] Climate services for a Net Zero resilient world - GOV.UK

2.9 **Climate READi** – The Climate READi power framework provides 'a comprehensive, integrated approach to assess physical climate risk and response options for an evolving energy system'.[18] The outputs of this work can be useful to list candidate CRMI metrics and indicators.

2.10 **Research projects CReDo, ACCELERATED, WELLNESS** – Other research on climate change impact and/or adaptation impacts have been investigated by:

- CReDo (Climate Resilience Demonstrator), on the 'impact of flooding on energy, water and telecoms networks';[19]
- the ACCELERATED (Assessment of Climate Change Event Likelihood Embedded in Risk Assessment Targeting Electricity Distribution) project, which aimed 'to determine the impact of Climate Change on the future reliability of the network';[20] and
- the Whole Energy System Resilience Vulnerability Assessment (WELLNESS) project, which aimed to provide 'core evidence and a coherent approach to resilience standards, assessment, and quantitative metrics that can inform the decision-making process of electricity network stakeholders'.[21]

2.11 **Resilience trapezoid** - An academic paper presents the 'ΦΛΕΠ resilience assessment framework' which includes resilience metrics to quantify power systems resilience based on the resilience trapezoid.[22] The way climate resilience is thought of in the first objective of the CRMI framework can be mapped to the conceptual interpretation of the resilience trapezoid.

2.12 **Hydrogen framework** - A framework to assess resilience of hydrogen energy infrastructure is proposed in an academic paper with technical, social, economic and organisational resilience key indicators and recoverability, redundancy and robustness listed as contributing factors under the technical resilience indicator.[23] In the CRMI framework, hydrogen integration can be incorporated as part of net zero target changes, and resilience theory is close to the representation of resilience in this paper.

[18] Metrics to Evaluate Effectiveness of Resilience Strategy Deployment
[19] Climate Resilience Demonstrator - Digital Twin Hub
[20] National Grid - Assessment of Climate Change Event Likelihood Embedded in Risk Assessment Targeting Electricity Distribution (ACCELERATED), Accelerated closedown report
[21] Whole Energy System Resilience Vulnerability Assessment (WELLNESS) | ENA Innovation Portal
[22] Power Systems Resilience Assessment: Hardening and Smart Operational Enhancement Strategies | IEEE Journals & Magazine | IEEE Xplore
[23] (Yazdi & al, 2024)A comprehensive resilience assessment framework for hydrogen energy infrastructure development

2.13 **Hydrogen framework** - A resilience framework of Offshore Wind-to-Hydrogen Systems is presented in an academic paper for strategic and investment decisions related to these systems.[24] This work presents an analysis on how different offshore wind-to-hydrogen configurations were incorporated into the framework and suggests resilience metrics for such systems.

Building the CRMI framework

Resilience

2.14 How we describe resilience is dependent on multiple parameters and the way resilience is measured may change depending on which of these parameters hold true. For example, some parameters are:

- the system in question (eg offshore wind farm resilience would be measured differently to resilience of an electricity network substation or network company climate resilience);
- hazards considered (eg cyber hazards vs climate hazards);
- the information available (eg volume and existence of relevant data);
- budget (eg some data may need new measuring points which implies financial expense);
- resources (this includes the available software but also skills and staff required); and
- general context (is it for a private company, at a national level, for a regulatory mechanism etc).

2.15 To create a scope for measuring network company climate resilience, two key questions were initially identified that needed to govern the CRMI framework:

- 'What should the CRMI conceptually cover?' - This is important to set the conceptual limitations of i) what is climate resilience and ii) which aspects of regulated organisations are measured by CRMI in price controls and if something is not measured by CRMI, to understand what this is and why.
- 'Can this be included within our price controls?' - This is important for the scoping of the metric and indicator types (kWh, ££, Probability, etc), and to bring into perspective the CRMI roll out pace, feasibility and deliverability.

2.16 The work concluded that a framework was required in order to establish climate resilience metrics and indicators into the price controls. The first question

[24] Resilience Assessment of Offshore Wind-to-Hydrogen Systems

formed the basis to then build two out of three objectives of the CRMI framework. The second formed the basis to build the third objective of the CRMI framework.

2.17 The first question is important to set the conceptual limitations of what climate resilience is and which aspects of regulated organisations may be measured by the CRMI through price controls, and if something is not measured by CRMI, to understand what this is and why. The second question is important to set out whether the concepts that CRMI cover can easily be included into the delivery and roll out of specific metrics and indicators within the price control.

CRMI framework objectives

2.18 These two governing questions formed the basis for what we refer to as the objectives of the climate resilience metrics and indicators framework. These three objectives are:

- 'capture resilience theory and hazards addressed';
- 'cut across network companies now and in the future'; and
- 'be suitable and deliverable for price controls'.

2.19 We refer to these as 'Objectives' to reflect the fact that this is the direction of what should be measured by climate resilience metrics and indicators but may not necessarily be what is included into price controls due to practical, financial or other challenges. Objectives are presented in the next sections in more detail.

CRMI framework attributes

2.20 The framework objectives cover the direction of what needs to be measured by climate resilience metrics and indicators. These however do not necessarily form pros and/or cons of candidate climate resilience metrics and indicators for price controls. This is why the framework is also composed of the metrics and indicators 'attributes' which form a list of features that describe the benefits and drawbacks or candidate metrics and indicators. These are divided into the following:

- attributes in terms of applicability (for example, if the candidate CRMI is suitable for cascading events or not):
  - interdependence / cascading events;
  - accounting for unprecedented changes in climate;
  - fairness across network companies; and

- roll out (for example, if the candidate CRMI is aligned with stress testing actions of the climate resilience programme):
  - new data /knowledge needed;
  - how easy is it to 'game' it;
  - too expensive?; and
  - how it links to stress testing / other climate resilience activities.

3. CRMI framework objectives and attributes

First objective - capture resilience theory and hazards to be addressed

Aims of objectives

3.1 This objective sets out which elements of resilience the CRMI are measuring and against which climate hazard(s).

Resilience theory

3.2 There is a broad range of terminology that can be found to describe the elements that describe the core meaning of resilience. Some of these are 'anticipation', 'redundancy', 'resistance' and 'recovery'; but the list is much longer than these terms. This is why an important part of this work is to establish a way to describe resilience within the climate resilience metrics and indicators framework that is simple to understand from a range of stakeholders, Ofgem and energy customers. A range of definitions for resilience can be found in the CIGRE report.[25]

3.3 It has been noted that elements that compose resilience can broadly be categorised into three phases: before, during and after a hazard (in this case a climate hazard) occurs. This aims to align with terms used by industry and academic literature. Table 1 below presents the wide range of terms proposed in works that define resilience and how these would map across these three phases that are suggested to be followed by the climate resilience metrics and indicators framework.

[25] Power System Resilience: definition, features and properties | CSE

Table 1: The three phases of resilience used in the CRMI framework mapped on elements of resilience of reports and literature (non-exhaustive)

Before Phase of resilience	**During phase of resilience**	**After phase of resilience**	**Notes**
Prepare Pre-event Absorptiveness Adaptiveness	Withstand disruption During event Robustness	Respond / Restore Recover Post-event Resourcefulness Recoverability	Reference also uses three phases.[26] It is noted that the three phases of this report were chosen independently but this work re-affirm this choice.
Anticipate Resist	Reat Absorb	Recover Adapt / Transform	NIC[27]
Anticipate Equilibrium	Absorb Robustness Resourcefulness Long-term impacts of climate change Immediate impacts of extreme weather	Recover Resourcefulness Recovery / Restore system functions Recovery back to equilibrium	IEA[28]
Plan / Prepare	Absorb	Recover Adapt	Reference[29]
Pre Disturbance Resilience state	Disturbance progress	Post-disturbance degraded state Restorative state Post-restoration state	Resilience trapezoid[30]
Resistance	Redundancy	Response Recovery	Set under 'Flood Resilience Standard and Critical National Infrastructure (CNI)'

[26] Resilient Electric Grid
[27] (National Infrastructure Commission, 2020)
[28] Climate resilience – Power Systems in Transition – Analysis - IEA
[29] Metrics for energy resilience - ScienceDirect and (PDF) Measurable Resilience for Actionable Policy
[30] Power Systems Resilience Assessment: Hardening and Smart Operational Enhancement Strategies | IEEE Journals & Magazine | IEEE Xplore

Before Phase of resilience	During phase of resilience	After phase of resilience	Notes
			Reliability is also introduced as a component of resilience.[31]
Pre-event	During-Fault Downtime part	Recovery Post-restoration	Resilience metrics are split into multiple timelines in Table I of (Dehghani & al., 2021): 'Pre-event', 'During Fault', 'Downtime part', 'Recovery part', 'Post restoration'.[32]
Prevention	Absorption	Recovery	Proposal of a resilience framework for critical infrastructure. In this thesis these are called 'resilience lifecycle stages'.[33]

Interpretation of before, during and after resilience phases

3.4 **Before** - During this phase, CRMI would measure actions and/or performance before a climate hazard occurs. Phase 1 captures a range of terminology in the literature that describe resilience as the ability of a system to 'prepare for', 'anticipate', 'adapt', 'transform' and others.

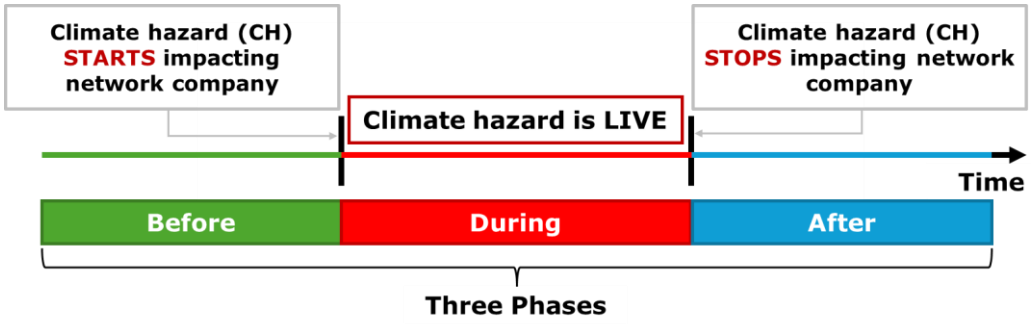
3.5 **During** - CRMI measure actions and/or performance during the occurrence of the climate hazard. Phase 2 captures a range of terminology in the literature that describe resilience as the ability of a system to 'absorb', 'withstand', have 'redundancy', be 'robust' and others.

3.6 **After** - CRMI measure actions and/or performance after the occurrence climate hazard. Phase 3 captures a range of terminology in the literature that describe resilience as the ability of a system to 'restore', 'recover', 'lessons learned' and others.

[31] Keeping the country running: natural hazards and infrastructure - GOV.UK
[32] (Dehghani & al., 2021)
[33] Leire Labaka.pdf (SECURED)

3.7 These phases can be seen represented by current literature including the resilience trapezoid and are presented in Figure 1 below, having in mind network company climate resilience.

Figure 1: A simplified representation of the three phases of resilience proposed within the climate resilience metrics and indicators framework



Hazards

3.8 An analysis of climate variables and climate hazards that need to be followed in principle for price controls has been performed by the CCRWG composed of Ofgem, the ENA and network company experts. The outputs of this analysis is presented below in Table 2.

Table 2: Climate variables and climate hazards relevant for the CRMI framework

Climate Variables	Climate-related hazards
Precipitation and Flooding	Rainfall - Intensity / Durations / Seasonal Snow/ Ice / Hail - Intensity / Duration / Seasonal Flooding - Fluvial / Pluvial High / Low Soil Moisture High / Low Air Moisture
Coastal impacts	Sea Level - Rise / Pressure Saline Pollution Coastal Erosion Coastal Flooding e.g. Storm Surge
Temperature	High / Low Air Temperatures - Extremity / Duration / Seasonal Wildfires Ground / Soil Temperatures Large Diurnal Temperature Range Heatwaves / Cold Spells
Wind and Storm events	High / Low Wind Speeds - Extremity / Durations / Seasonal Wind Direction Lightning Activity - Intensity / Frequency Storm Events - Combination of any intense Wind / Rain / Lightning / Snow - Intensity / Severity / Duration / Frequency

Suggested future work for the first objective

3.9 The interpretation of the three phases can be updated as this work progresses in order to be aligned with other workstreams of the climate resilience programme and as candidate CRMI metrics and indicators are populated into the CRMI table (that is also proposed later in report as a tool to use this framework). This includes the fact that this interpretation may need to be paired and thought of with respect to climate hazards.

3.10 The timeline of climate hazard duration also needs to be considered is the sense that climate change may affect the way some climate hazards pose risks to network companies today, compared to some decades from now.

Second objective - cut across network companies now and in the future

Aims and objectives

3.11 This objective will identify which parts of network companies should be measured for climate resilience.

Parts of network companies being regulated

3.12 Network company resilience can reflect resilience of different parts of regulated organisations and has been identified that it can be divided into physical network assets and network operation to climate hazards. Therefore, CRMIs need to cover one or both aspects in this regard to ensure that different elements of network company resilience are captured.

Net zero

3.13 Regulated organisations are composed of assets, infrastructure and operations that need to adjust to changes that affect the energy sector, with a major part of this being the transition to achieve net zero targets.[34] This may include hydrogen integration, or 'other' net zero decisions. These changes are dynamic and have a range of actions and decisions to be delivered.

Suggested future work for the second objective

3.14 'Business' or 'organisational' resilience has been mentioned by us and in the CCRWG report as a potential aspect of network companies that CRMI could measure. This might include a range of activities (ie resilience governance process, etc) and it requires further thought to potentially be incorporated into the second objective of the CRMI framework. However, future work may define and incorporate this into the proposed framework.

Third objective - be suitable and deliverable for price controls

Aims and objectives

3.15 This objective set outs whether CRMI are already available or used within wider price control processes, and how fast these CRMI can be delivered.

Climate Resilience Metric and Indicator place (or not) in price controls

3.16 This part of objective three aims to bring awareness if the candidate CRMI is already used in price controls and, if so, which ones and for what purpose (is it

[34] (Burnett & et al, 2024) The UK's plans and progress to reach net zero by 2050 - House of Commons Library

for resilience, reliability, or something else?). We are seeking to use existing metrics and indicators first before deciding if new metrics need to be developed.

Deliverability

3.17 To increase understanding on whether or not candidate CRMI can be delivered at a fast, medium or slow pace, this part introduces these three timeframes. Some suggested periods, if this is broken down into these three timeframes, are:

- slow - 18 months or more;
- medium - 12-18 months; and
- fast - 0-12 months.

3.18 This aims to capture feasibility of existing metrics and the difficulty (or not) of implementing required processes, acquiring data needed, and having the skills in place, etc, to implement the necessary actions or activities for the CRMI to have a reasonably acceptable value and be included into the intended price control.

Suggested future work for the third objective

3.19 There are two further questions that could be included in this part but require work to be fully incorporated:

- what is the metric typology; and
- does the CRMI consider consumer vulnerability and/or CNI?

3.20 The former has been based on the classification made by Climate READi. The latter reflects the increasing focus on CNI and single point failures within the networks.

Attributes: listing

Pros and cons

3.21 This section aims to build awareness on the pros and cons of individual CRMI through a list of categories which fall under CRMI 'applicability' or under CRMI 'roll-out'. These have been developed to accompany the objectives described in the previous sections and aimed to form a list of pros and cons of candidate climate resilience metrics and indicators. Table 3 and Table 4 below show these but they are not exhaustive lists and will be updated as this work is consulted upon and other climate resilience workstream plans mature.

Table 3: Attributes for measuring CRMI's 'applicability'

Category	Question to be answered
Interdependencies	How well does it capture interdependencies between different infrastructure or energy vectors (water, telecoms, transport, hydrogen production/supply etc)
Cascading events	How well does CRMI capture cascading events where an initial failure causes subsequent events?[35]
Fairness	How consistent is the CRMI across network companies?

Table 4: Attributes for measuring CRMI's 'roll-out'

Category	Question to be answered
New Inputs	Is there a high level of new knowledge/resources needed?
'Gaming'	How much can the intended goal be abused?
CRMI Cost	Is the CRMI too expensive to measure? (applicable if CRMI 'new' or unknown process of producing the measurement)
Stress testing	How well does it link to stress testing work?

How can the CRMI framework be used?

Steps to choose the suite and/or index of CRMI for price controls

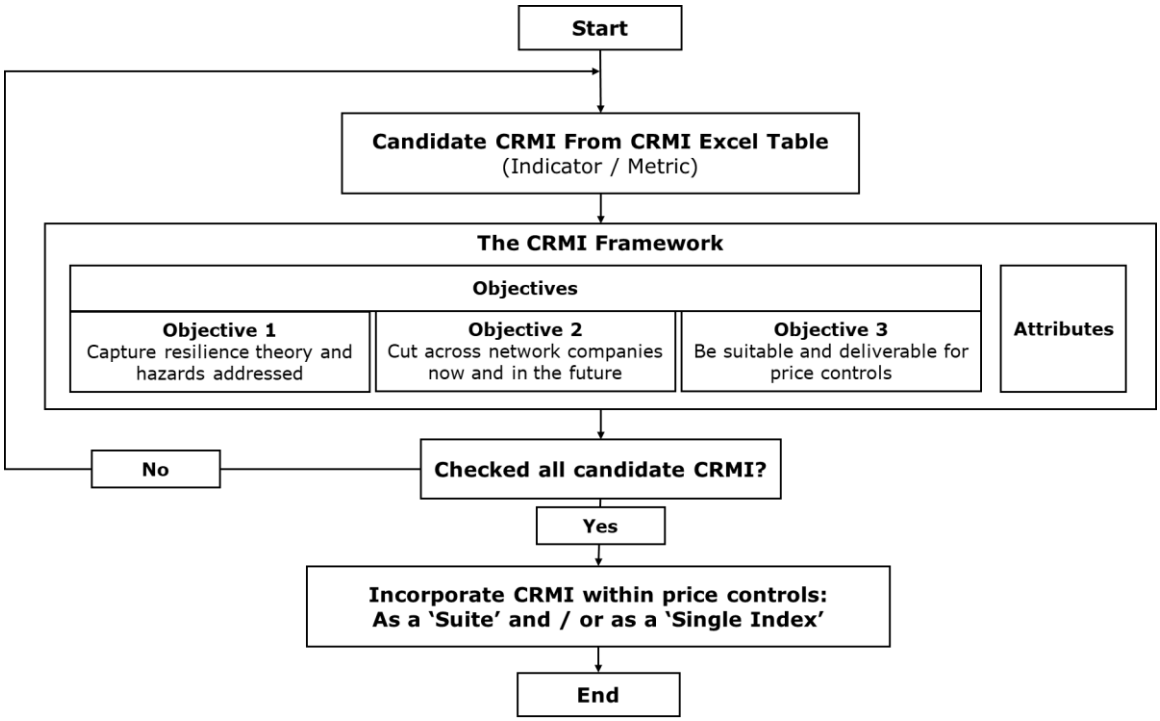
3.22 The CRMI framework can be used as shown in Figure 2 below. Candidate CRMI are first listed (an early sample of what the CRMI list may look like is presented later in this document) and then mapped against the framework objectives and attributes in order to understand which of the objectives and attributes are, or are not, met by that metric/indicator. We will work with network companies and experts to identify as many candidate CRMI as possible.

3.23 A list of the most appropriate CRMI will emerge once candidate CRMI have been checked against the framework objectives and attributed. It will need to decide if all, some, or only a small selection of CRMI will be used to measure climate

[35] Categorisation that might be useful here can be found in Table I of (Dehghani & al., 2021)

resilience for the price control. The process can then be repeated when further candidate CRMI are identified and whether the new candidates should replace existing CRMI or be added to the suite which has been decided upon.

Figure 2: The CRMI selection process as suggested in this report



4. Conclusions and next steps

Conclusions

4.1 It is not an easy ask to measure resilience. Resilience describes the three phases outlined in this document in respect to a particular hazard.[36] This makes it a multifaceted concept, made up of several contributing dynamic elements not only of the energy system but also by the nature of the climate risk or hazard presented. This brings challenges for measuring resilience.

4.2 Initially, the core question with the work on CRMI was 'Should climate resilience be measured using a single indicator or a suite of indicators, and what are the pros and cons of each approach?' This is a complex task and difficult to answer without an agreed initial framework. Therefore, this guidance work focused on developing a framework to underpin how to inform and answer that question.

4.3 Given the proposed framework and the components and characteristics that the CRMI would be required to measure in order to (as much as possible) address the objectives that have (to date) been identified, it may be the case **that having a suite initially might be the most appropriate solution in order to fully capture resilience theory, climate hazards, network company governance and price control requirements**. Once a suite is populated, this could facilitate discussions of having one single index that encapsulates the suite.

Knowledge limitations

4.4 The proposed draft CRMI Framework is based on knowledge to date. It aims to serve as a guide to understand if and how network company climate resilience is being regulated by Ofgem and is designed in a way that it can be amended/updated in the future depending on new information or requirements.

Stress testing/Ofgem workstreams related to climate resilience

4.5 We are developing a stress testing process for network companies for ED3 and we have published guidance alongside the SSMC for the first phase of stress testing which will produce outputs by December. Future phases of stress testing will be developed and iterated. As this work moves forward, this framework can help add and/or remove indicators or even be updated to reflect interactions with these workstreams.

[36] Based on (Wilkinson, 2023)

CRMI framework objectives

4.6 Future work has been flagged under some of the elements of the objectives of this framework, under the respective sections.

Early work on listing CRMI

4.7 An early list of CRMI has been developed and is not meant to represent an exhaustive set of CRMI options. Provided the proposed framework is taken forward, this list would be iterated and developed with network companies, the CCRWG, and the expert panel that supports our climate resilience activity.

4.8 A comprehensive place to support the list of candidate metrics and indicators for climate resilience measurement in price controls can be found in the Climate READi work.[37]

Table 5: Example list of CRMIs

No.	Indicator / Metric
1	Customer Interruptions (CI)
2	Customer Minutes Lost (CML)
3	ETR138 Compliance
4	ETR132 Compliance
5	Back up / emergency plans

[37] (Climate READi, 2025) Metrics to Evaluate Effectiveness of Resilience Strategy Deployment