Imperial College London

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DNV·GL

ENGINEERING RECOMMENDATION P2 REVIEW (PHASE 1)

Phase 2 Outline Programme and Plan

For the Energy Networks Association

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Applicable contract(s) governing the provision of this Report:

Objective:

This report builds on the foregoing work carried out during work streams 1 to 8, to develop a proposed[1] outline programme and plan for the possible works required in Phase 2 of the P2/6 review to deliver a new P2 Standard that will offer benefits to stakeholders and support the UK Government policy objectives of moving to a low carbon economy.

One area of great debate through work streams 1 to 8 has been the economics around the potential trade off between network redundancy and customer supply security and the potential use of non-network solutions as an alternative to building new networks to maintain present security levels. Any impact the direction of a new P2 standard may have on customer supply security risk would require agreement from policy makers and those who regulate the industry. The plan presented here assumes that any agreement required on security of supply levels has already been made.

Prepared by:	Verified by:	Approved by:
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DNV GL Distribution:

☒ Unrestricted distribution (internal and external)

☐ Unrestricted distribution within DNV GL

☐ Limited distribution within DNV GL after 3 years

☐ No distribution (confidential)

Keywords:

execution

[1] This plan is only for consideration of the DCRP P2 Working Group to assist them plan the next phase for the P2 review. The plan provides a number of component parts for one option to progress the review based on the works carried out in work streams 1 to 8 and the Consortium's engagement with the DCRP P2 Working Group. It should be recognised that many other options could be decided upon by the DCRP P2 Working Group.

☐ Secret

Rev. No.	Date	Reason for Issue	Prepared by	Verified by	Approved by
001	9/09/2016	Issue to DCRP P2 WORKING GROUP	R Druce	G Strbac	C MacKenzie
002	5/12/2016	Final issue to the DCRP P2 WORKING GROUP	R Druce	G Strbac	C MacKenzie

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1 INTRODUCTION

This document forms part of the Phase 1 works of the fundamental review of ENA Engineering Recommendation P2/6 commissioned by the Distribution Code Review Panel[2] (DCRP) through the Energy Networks Association[3] (ENA). A background overview to the P2/6 review is presented in Appendix A and includes a description of the various work streams that form the Phase 1 review process.

This report follows on from the Consortium conclusion that the option of retaining Engineering Recommendation P2/6 unchanged could not be recommended and that the review process should proceed into Phase 2 to further develop two of the high-level options identified during the Phase 1 work. Phase 2 will include developing each of these two options into a working format that can be used to carry out a full impact assessment on each option before deciding which option to take forward and codify into the new ER P2 standard and any supporting documents. A possible outline programme and plan for Phase 2 of the review to deliver the new ER P2 documents for consideration by the DCRP P2 Working Group is provided in this report.

Following this introduction, section 2 provides the outline details of the proposed Phase 2 delivery plan and programme. Concluding remarks are provided in Section 3 with any supporting information provided in the report appendices.

2 The Distribution Code Review Panel (DCRP) is the body responsible for overseeing the maintenance and development of the Distribution Code and its subordinate documents. Those subordinate documents include Engineering Recommendation P2/6. The ENA is the service provider to the DCRP for the physical maintenance of the Distribution Code and its subordinate documents.

3 Energy Networks Association is the industry body for UK energy transmission and distribution licence holders and is the voice and agent of the energy networks sector.

2 PHASE 2 OUTLINE PLAN AND PROGRAMME

Phase 1 of the P2 review has concluded that two high level options for reform of the present Engineering Recommendation P2/6 should go forward to Phase 2 for the more detailed review process to deliver the new ER P2 documents. The final work stream 8 report[4] also provides conclusions regarding the use of distributed energy resources (DER), operational measures, losses, construction outages and high impact low probability events associated with these options. The two high level options are:

Option 2

A new deterministic standard[5], with updated requirements in respect of the supply security DNOs are obliged to provide:

- The new standard should cover the key drivers of the economic level of network reliability, potentially including:
  - Network load ("group demand");
  - Network type (different mixes of OH and UG);
  - Network failure rates;
  - Restoration times;
  - Repair times;
  - Network upgrade costs;
  - Load profile;
  - Cost of interruptions; and
  - Use of smart grid technologies.
- It will also need to enable reliability to be provided in the most efficient way, making an efficient trade-off between network and non-network technologies, accounting for:
  - Network reliability performance; and
  - Economic levels of network redundancy.

Option 4

A new standard making some limited use of deterministic elements to set minimum reliability requirements, but with an obligation (that would apply in circumstances defined in the standard) to conduct Cost Benefit Analyses (CBAs) to identify the appropriate level of supply security to provide beyond these minimum values. The key drivers listed for Option 2 are also applicable to the CBA approach here.

- In developing this option, Phase 2 of the review will need to identify areas where it is possible to codify efficient investment rules in simple tables, and areas where placing more emphasis on conducting CBAs to select optimal investments could improve efficiency.

Option 4 will also need to include work to develop guidance on conducting CBAs[6] as part of the Phase 2 process.

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4 Consortium report "Engineering Recommendation P2 Review (Phase 1), Summary Report for the Energy Networks Association", report number 16011094/900, 25 August 2016.

5 In this context, we define a deterministic standard to be one in which network reliability requirements are specified based on parameters and criteria defined within the standard.

6 The Consortium recognise that the DCRP P2 Working Group has some considerable experience with conducting CBA. However, some stakeholders have asked that this guidance be provided which may make the CBA process more efficient. For instance, the guidance could specify parameters for which it is hard to form representative assumptions (like VOLL). Guidance on how CBAs should be conducted would also be useful for checking regulatory compliance.

Further, through the review of P2/6 a range of other conclusions were reached, listed below, which should be carried forward into Phase 2.

- Any new standard **should not** make any requirements in respect of the redundancy that should be built into the direct connection of embedded generation to a shared DNO network.
- To ensure efficiency at the transmission and distribution levels, any **new standard** should consider the possible need to align with the provisions in the National Electricity Transmission System (NETS) Security and Quality of Supply Standards (SQSS). However, given the DCRP is conducting a fundamental review of P2/6, Phase 2 should not be constrained by provisions in the current NETS SQSS.
- Any new deterministic standard **should** include guidance on the contribution to system security from non-network technologies.
- Any new deterministic standard **should** provide separate guidance as to the measures that DNOs should put in place during construction outages, separately from those measures that DNOs should put in place during maintenance outages and unplanned outages.
- The new standard **could** consider extreme events such as Common Mode Failures (CMFs) and High Impact Low Probability (HILP) events. In this context, as demonstrated in case studies carried out in Phase 1, the concept of Conditional Value at Risk could be applied to limit the probability of severe outages. The case for including this concept in the new standard should be considered during the Phase 2 review works.

The aim of Phase 2 is to assist the DCRP P2 Working Group[7] in selecting the most appropriate option for the new P2 Security of Supply Engineering Recommendation and to codify this into the final working documents. This may require translating each of the two recommended options for revision of P2/6 into a working format of tables, rules and guidance and then carry out a full economic impact assessment. The impact assessment will require application of the working format for both P2 review options against a range of real network scenarios. Further DCRP P2 Working Group and wider industry engagement and consultation will support the decision to adopt one of the two revision options to go forward to codification[8].

Therefore, to deliver the Phase 2 review output a number of fundamental tasks require to be carried out as illustrated in the high level programme for Phase 2 in Appendix B which consists of a number of work streams. The outline detail for each work stream forming the overall high level plan for Phase 2 is provided in the following sub sections. The plan assumes participation of a DCRP P2 Working Group and a delivery Consortium employed to deliver the majority of the Phase 2 programme. To provide a full high level programme, tasks are included in the plan that would require delivery by parties other than the appointed Consortium.

In order to transfer the learning from Phase 1 of the P2 review, the work stream descriptions in the following sections assume that the Phase 1 delivery Consortium is engaged to deliver Phase 2 of the

7 Reference is made throughout this document to a DCRP P2 Working Group, this would be a suitable group of industry stakeholder and customer representatives appointed by the DCRP to oversee Phase 2 of the review and ensure stakeholder support where required e.g. provision of data, review of model inputs and outputs, review of output documents etc.

8 Although this plan follows the conclusion from the WS 8 final report to develop two options for assessment, the DCRP P2 Working Group could consider alternatives that combine parts of these options for assessment and development of the new standard based on further review work they may decide to carry out.

review[9]. However, it should be noted that appointment of a delivery consortium is a decision for the DCRP[10].

2.1 Workstream 1: Project inception and management

Workstream 1 covers the project inception and basic management requirements in the Phase 2 programme and would include:

- The development and issue to industry of a Project Initiation Paper (PIP) which would highlight the key objectives of Phase 2 of the Engineering Recommendation P2/6 Review project to industry stakeholders. This is to include stakeholders with a technical understanding of the review subject matter and those that do not. The PIP would be the initial Phase 2 communication with all stakeholders; outlining the process as well as the expectations on stakeholder engagement. The PIP could be based on the Phase 2 plan presented here but would also allow the plan to be updated due to changing circumstances. Like the PIP development process in Phase 1, development would be in conjunction with the DCRP P2 Working Group and reviewed by their respective organisations. If the DCRP P2 Working Group feel that an independent review[11] of the PIP should be carried out prior to engagement with the wider industry, then this should be built into the proposed plan presented here. Workstream 6 includes for an industry event at the commencement of Phase 2 to present the PIP to industry to assist engage industry in the Phase 2 development process.
- Allowance is made for the DCRP P2 Working Group to review and input to the PIP development prior to issue to the wider industry.
- The monthly meetings of the Consortium and DCRP P2 Working Group were key to delivering the Phase 1 works and provided a vehicle for updating the Working Group on progress, findings, outputs, and support requirements which allowed the Working Group to provide direction and input to the Consortium work. We see these monthly meetings as critical for Phase 2 and hence have included these as a key task in the high-level plan. Based on Working Group member feedback, we would also advocate the following:
    - To assist the DCRP P2 Working Group understand the modelling and analysis to be carried out any contractor appointed provides details to the group that clearly explains the modelling techniques to be employed and the key assumptions that may have to be made.
    - Prior to commencement of Phase 2 there is agreement from Working Group members to provide the data that will be required by the appointed contractor to ensure that their modelling work can be completed accurately and on time.

9 Where an alternative party takes on the proposed phase 2 plan here, additional time may be required at the early stages to allow for progression up the learning curve and to adapt modelling techniques etc. However, the Consortium is unable to assess what these programme impacts may be.

10 The consortium has been advised that should the DCRP require further support on any future phases of this review that any such support would go through a formal open tender process.

11 The consortium suggest that the DCRP establish a suitable peer review panel prior to commencement of Phase 2 and set out and agree the panels terms of reference and ensure that the panel is free from conflicts of interest.

- Prior to commencement of Phase 2 the DCRP establishes a suitable peer review panel to examine the methodology, and sets out and agrees the panels terms of reference and ensures that the panel is free from conflicts of interest.

- Workstream 1 also includes the management activities required for successful delivery of the Phase 2 programme including but not limited to:

  - Programme management;
  - Process management;
  - Budget management;
  - Risk and issue management;
  - Progress reporting;
  - Deliverables issue;
  - Quality assurance of deliverables;
  - Stakeholder engagement;
  - ENA interface;
  - DCRP P2 Working Group interface, and
  - Consortium member interfaces.

  It is recommended that these management activities are carried out by the appointed contractor under their scope of work unless the ENA has the resources for this task. It should be noted that any appointed contractor will require to carry out their own management tasks.

2.2 Workstream 2: Data gathering to support modelling and model validation

Workstream objectives and scope

As we discuss below, the modelling tools that were used for Phase 1 of this assignment remain broadly appropriate for the work that will be required during Phase 2. Specifically, they were used in Phase 1 to identify economically efficient investments and reliability levels, which will be a key element of Phase 2, as we develop new guidance and rules to translate these economically efficient investments into a new planning standard.

As we move closer to implementing a new standard, we recognise the importance that the models used to develop the standard are widely understood by the industry and that the approach and input assumptions are accepted subject to suitable peer review and challenge facilitated by the DCRP. We therefore propose that Phase 2 should include a process of presenting the modelling approach to industry to provide DNOs and other interested parties with a briefing on the modelling approach and assumptions. (The modelling approach was specified in detail in the Imperial College report, but were we to be engaged for Phase 2 it will be important to explain the model and the assumptions it uses again to ensure clarity and transparency and buy-in from stakeholders. This would apply to the models developed or selected by any appointed contractor.)

Some elements of the modelling approach will also require additional data. Specifically, the Phase 1 modelling uses generic network designs representing mixes of distribution network designs currently in place in Great Britain. However, this approach does not consider some characteristics of real networks that will need to be factored into the Impact Assessment of any proposed reforms (see Workstream 5 following):

- The existing modelling approach identifies economically efficient investments as a function of network characteristics, and has identified that the investment requirements specified in the present P2/6 are in many cases economically inefficient. However, this approach cannot reliably estimate the likely welfare savings[12] from reform, because it does not estimate accurately enough the quantity of the real distribution networks that will influence future investment requirements. In the Phase 2 work, the developed network reliability modelling will be applied to *the real distribution networks*, rather than to the generic networks used in Phase 1. In the context of welfare analysis and modelling we will also consider the degree of headroom available within current networks to accommodate load growth before reinforcement is required. Headroom for EHV and 132kV networks might be estimated from DNO Long Term Development Statements (LTDS) loading information.
- As such, as part of Phase 2 (to prepare for the required Impact Assessment in Workstream 5), we will need to conduct a data gathering exercise, mainly for network loading and operational practices for supply restoration, to ensure that the derivation of the look-up tables (based on the rules and guidance developed for the new standard) is fully representative of real networks.

Modelling tasks to be conducted

Analysis of reliability performance of real distribution networks will be conducted to establish, in more detail than in Phase 1, a set of representative network topologies and characteristics aimed at forming the basis for the development of look-up tables for different network types to be incorporated into a new deterministic planning standard.

The methodology for network classification (based on the intact system states) would be developed taking into account Imperial College's experience gained in related projects[13]. These would need to be agreed with the DCRP P2 Working Group. The network reliability parameters used in Phase 1 will be scrutinised, modified as appropriate and also agreed with the DCRP P2 Working Group. Different levels of accuracies would be considered in order to balance this against transparency and simplicity of the application.

Task 2.1: Analysis of real HV networks and creation of a set of representative HV networks

HV networks supplying different network types with different mixes of overhead (OH) and underground (UG) circuits will be analysed to establish a set of representative HV network topologies and characteristics based on real networks[14]. Reference network and DS2030 projects could be used to inform this.

Task 2.2: Analysis of real EHV networks and creation of a set of representative EHV networks

EHV networks specified in the DNO Long Term Development Statements will be analysed to establish a set of representative EHV network topologies and characteristics. Validation will be carried out by comparing representative and real networks and the set will be agreed with the DCRP P2 Working Group.

12 In this context, welfare savings represent the societal benefits (which can be monetised) that come from DNOs taking more economically efficient planning decisions.

13 Distribution network reliability analysis involving seven DNO licensing areas, PB Power and Imperial team.

14 Distribution network data from previous Imperial College work can be used, including network data of ENW, NPG, WPD (Midlands), UK Power Networks.

Task 2.3: Analysis of real 132kV networks and creation of a set of representative 132kV networks

132kV networks specified in the DNO Long Term Development Statements will be analysed to establish a set of representative 132 kV network topologies and characteristics. Validation will be carried out by comparing representative and real networks and the set will be agreed with the DCRP P2 Working Group.

Task 2.4: Analysis of real substations and creation of a set of representative substations

The analysis to be carried out in tasks 2.1 to 2.3 will need to include evaluation of real primary and bulk supply substations and the creation of a set of representative configurations.

Task 2.5: Validation of modelling approach

This task will set the network reliability analysis approach and the criteria for investment that will be agreed with the DCRP P2 Working Group, including survey of relevant LCNF/ NIA/NIC projects

2.3 Workstream 3: Network modelling to inform development of a new deterministic standard (Option 2)

Workstream objectives and scope

It was demonstrated in Phase 1 of the review that there is likely an economic case for the reform of Engineering Recommendation P2. As such, Workstream 3 will seek to develop a new deterministic standard.

Like P2/6, a new deterministic standard would seek to specify minimum redundancy levels through new look-up tables. In order to achieve economically efficient investments, it may be necessary that a new deterministic standard is linked to the following drivers (i.e. the dimensions of the look-up tables):

- Network load and distributed generation;
- Network type (OH, UG);
- Network failure rates;
- Restoration times and cost associated with different measures (load transfer, mobile and backup generation, temporary cable laying, etc.);
- Use of smart grid technologies including demand side response;
- Network automation and implementation costs;
- Repair times;
- Network upgrade costs;
- Load profile;
- Load transfer capability;
- Construction outages;
- High-impact low-probability events;
- Cost of interruptions;

- Cost of electricity[15].

A new deterministic standard will also make use of non-network technologies, accounting for:

- Availability of different types of non-network technologies;
- Combined effect of a group of different non-network technologies;
- Impact of common mode failures of non-network technologies;
- Effect of relative size of non-network solutions in the context of group demand;
- Network reliability performance (including consideration of network failure rates, restoration times, cost associated with different measures etc.), and
- Economic levels of network redundancy.

While it identified clearly that the factors listed above are potentially important drivers of efficient investment, the Phase 1 work has not examined how practical it would be to set new deterministic requirements that capture these drivers of economically efficient investment. As such, Workstream 3 of the Phase 2 study will involve conducting network modelling in order to design and calibrate new look-up tables to be incorporated into a new deterministic planning standard. Specifically, this network modelling will need to consider both the appropriate "dimensions" of any look-up tables that define reliability requirements and the cost-effectiveness, which will be used for calibration.

As part of this process, we will also consider how to account for the key drivers of efficient investment and network design, while recognising that in some cases it may be challenging to identify all parameters in the deterministic standard that should be used to identify appropriate investments. This will also include analysis of uncertainties in input data (e.g. failure rates, electricity prices) and a potential lack of full information that may drive decisions.

In this context, it would be important to develop a relatively small number of options in relation to the design of the new deterministic standard. This will be necessary to capture the trade-off between simplicity and economic efficiency. Essentially, with a very large number of new look-up tables, it will probably be possible to define economically efficient investment solutions in the vast majority of situations. By contrast, a standard with fewer look-up tables may be simpler, but could compromise on the efficiency of the investments it prescribes.

Modelling required to develop new lookup-tables

The modelling tools required for this task are essentially the same as those used in Phase 1, such as the Imperial College model that selects the agreed level of reliability that should be provided in the range of conditions listed above (network load, network type, common mode failures etc.), and accounting for the trade-offs between network and non-network solutions. These modelling tools will also now be applied to the real networks and support the development of look-up tables for the new standards.

Within this work-stream the analysis will be focused on developing generic look-up tables for different network types that will define the trigger points for network reinforcements driven by load growth. The reliability of performance analysis will consider single, overlapping and common-mode faults, and faults overlapping maintenance. The analysis will consider failures of network circuits (overhead and underground), transformers, circuit breakers and busbars, while taking into account automation and alternative supply restoration approaches and related costs.

[15] Electricity prices effects the evaluation of network losses.

The analysis will be carried out on the representative networks for different network types, characterised with different network costs, different demand levels, failure rates, restoration times and associated costs etc. The analysis will include the impact of network losses, which might drive lower circuit utilisation and hence create opportunities for an economically efficient increase in the security of supply.

Corresponding parameters and granularity to be used in the look-up tables, that may be voltage level and demand group specific, will be informed through the modelling and agreed with the DCRP P2 Working Group.

Modelling will focus on determining the minimum degree of redundancy and corresponding generic look-up tables created taking into account customer outage cost, operational cost of mitigating the impact of outages and the reinforcement cost of different types of representative networks for the agreed range of drivers listed above, considering generic look-up tables for:

- **Task 3.1**: Development of LV network look-up tables
- **Task 3.2**: Development of HV network look-up tables
- **Task 3.3**: Development of EHV network look-up tables
- **Task 3.4**: Development of 132kV network look-up tables

The effect of existing topology and structure will be considered as well as network development[16] e.g. the impact of adding new substations, which may improve overall reliability performance on a larger network area.

This will include application of emerging network technologies, such as advanced voltage regulators, dynamic line rating equipment etc. (to be agreed with the DCRP P2 Working Group).

Similar analysis will be carried out for determining the design of substations:

Task 3.5: Development of primary and bulk supply substation look-up tables, considering substation topologies for an agreed range of drivers, resulting in the optimal degree of redundancy and the creation of the corresponding generic look-up tables. This will also include consideration and optimisation of transfer capacity that may be available through the network connecting to neighbouring substations.

Task 3.6: Development of generic look-up tables with inclusion of distributed energy resources

This task will derive the contribution that distributed energy resources - DER (distributed generation, demand side response and energy storage) could make to the security of supply considering their reliability characteristics including energy and time shifting related limits. The analysis will also consider common mode failures of DER technologies and take into account the effect of the magnitude of DER relative to the size of demand. Furthermore, the modelling will quantify the security contribution that different mixes of DER technologies provide. Alternative approaches to defining Group Demand in cases of the presence of various DER technologies will be considered.

Task 3.7: Construction outages

Likely scenarios for construction outages at different voltage levels will be defined in cooperation with the DCRP P2 Working Group. This task will include carrying out an assessment of the risk exposure to demand disconnections during construction outages and associated customer outage costs as well as

[16] DCRP P2 Working Group DNO member input into the type of reinforcement that would be considered in typical scenarios will be required here.

other consequences that impact on the DNO and other stakeholders. The cost-benefit analysis will consider trade-offs between alternative supply arrangements for management of construction outages.

In determining optimal degrees of network redundancy a conservative approach would be adopted such that reinforcement could be carried out with a higher level of redundancy than specified by the look-up tables, if economically justified when considering construction outages.

Task 3.8: High-impact low-probability events

The significance of high impact low probability (HILP) events and alternatives for dealing with prolonged outages will be analysed in this task. Historical HILP events will be analysed which would include outages driven by very extreme weather conditions and consequences of significant reductions in demand diversity following prolonged outages. The cost-benefit analysis will consider trade-offs between alternative mitigation measures. Furthermore, the concept of Conditional Value at Risk will be applied to limit the probability of severe outages, while respecting the cost of investment and mitigation measures.

2.4 Workstream 4: Developing a new, less deterministic standard involving greater use of CBA (Option 4)

As well as developing a new deterministic standard, Phase 1 of the review concluded that there is merit in considering a new standard that makes less use of deterministic obligations than the option to be investigated through Workstream 3. Instead, this option would make some limited use of deterministic elements to set minimum ("de minimis") reliability requirements, but with an obligation to conduct Cost Benefit Analyses (CBAs) to identify the appropriate level of reliability to provide beyond these minimum values, and possibly by what technological means.

In developing this option, Phase 2 of the review will need to identify areas where it is possible to codify efficient investment rules in simple tables, and areas where placing more emphasis on conducting CBAs to select optimal investments could improve efficiency. Hence, like Workstream 3, some network modelling work will be required to identify the dimensions of de minimis look-up tables:

- **Task 4.1**: Modelling approach for a new less deterministic standard involving more use of a CBA.

  Approach for identification of the efficient investment which could be achieved by the use of look-up tables will be developed. This will involve estimation of the accuracy for different input parameters.

- **Task 4.2**: Calibration of look-up tables for a new less deterministic standard involving greater use of a CBA.

  The approach for statistical identification of CBA approach steps which could be satisfactorily accurately represented by look-up tables will be used to develop and calibrate such look-up tables against the economically efficient results. This will also include simplified tables regarding capacity contribution of DSR technologies.

However, unlike Workstream 3, developing this less deterministic standard will also require that we develop guidance on conducting CBAs (shown as Task 4.3 in the programme in Appendix B). As

discussed in the NERA WS2.7 report produced during Phase 1[17], there are a range of different ways in which obligations could be specified within a new planning standard and these vary according to their degree of "specificity". For instance, at one extreme, an obligation to conduct CBAs could be little more than a sentence inserted at the bottom of the standard that obliges DNOs to conduct CBAs to assess the economic case for providing more reliability than the de minimis deterministic requirements. At the other extreme, this could also require the development of detailed guidance on conducting CBAs, or even a CBA model itself.

2.5 Workstream 5: Conducting an impact assessment of potential reforms

An important element of Phase 2 of this review will be a full Impact Assessment of the proposed reforms to inform the DCRP's assessment of the case for reform and its ultimate recommendations to Ofgem. This Impact Assessment will specifically aim to address some of the challenges identified during Phase 1 of the work associated with estimating the overall welfare benefits of the reform.

As discussed above, a key input into this work will be the data gathered on real network characteristics during Workstream 2. This will allow us to perform network modelling to identify more accurately than before the potential capex savings from reform, and any effects on losses and the costs of interruptions, etc.

Task 5.1: Quantification of cost effectiveness of the proposed standards

For a set of real network configurations and future load growth specified by agreed scenarios, the required network investment and corresponding reliability performance, including CI and CML, will be quantified considering real networks (by balancing cost of network investment and cost associated with supply restoration against cost of demand interruptions and network losses). This will be compared with the proposed look-up tables of both new standard options for all network types including consideration of proposed strategies for management of construction outages:

- Task 5.1a: CBA for HV network Tables;
- Task 5.1b: CBA for EHV network Tables;
- Task 5.1c: CBA for 132kV network Tables, and
- Task 5.1d: CBA for primary and bulk substation Tables
- Task 5.1e: CBA for construction outages for primary and bulk substation.

This will then be extrapolated at a GB level in order to enable the economic efficiency of the new standard to be established. The analysis will consider trade-offs between welfare[18] loss due to the simplified approach in a new standard against network design simplicity, transparency and applicability. The approach employed to obtain the set of real network topologies will be agreed with the DCRP P2 Working Group in order to cover the spectrum of different network topologies and characteristics.

[17] Consortium Work Stream 2.7 report "Engineering Recommendation P2 Review Workstream 2.7: Alignment of Security of Supply Standard in Distribution Networks with Other Codes and Schemes", prepared for the Distribution Code Review Panel, P2 Work Group, 20 November 2015

[18] In this context, changes in welfare represent the societal benefits (which can be monetised) that come from DNOs taking more economically efficient planning decisions.

Task 5.2: Sensitivity analysis of a proposed new standard

This task would estimate the robustness of a proposed new standard to different values of input parameters. It will rank the considered cases by difference between the approach in a standard and CBA. This will involve carrying out tasks specified under Workstreams 3 and 4.

Network Modelling to Assess the Costs and Benefits of New Deterministic Requirements

As a first stage in performing the Impact Assessment, we will use Imperial's network models (calibrated with the details of real networks following Workstream 2) to estimate the investment requirements associated with developing distribution networks over time following the requirements specified in P2/6. We will then compare this to the costs of developing those same distribution networks following alternative investment rules, as specified in the new standard developed through Workstream 3 (as well as the de minimis deterministic requirements developed through Workstream 4). In making this comparison, it will be possible to quantify differences in capex costs, the costs of distribution losses, and differences in the costs of interruption.

In conducting this analysis, a range of sensitivity analysis will also be important. For instance:

- In estimating changes in the costs of losses, we envisage it will be important to consider different assumptions related to the future energy costs, including Levelised Cost of Electricity (LCOE) associated with different low carbon generation technologies, adopted by the Committee on Climate Change. Similarly, when estimating the change in interruptions costs it will be important to consider a range of assumptions on how to quantify the economic consequences of interruptions (i.e. through VOLL or similar measures). Both these assumptions are somewhat subjective/uncertain, and the robustness of the new deterministic standard will be tested through comprehensive sensitivity analysis.
- We will also consider a range of different assumptions on the market context. For instance, as we have shown through our Phase 1 work, a key driver of the welfare savings from reform will be the rate of future demand growth, which in turn depends on factors such as macroeconomic conditions and the rate at which heat and transport are decarbonised. We therefore propose to develop a small number of market scenarios to examine the sensitivity of estimated welfare effects to changes in planning standards.

This impact assessment will also need to consider a range of other more "qualitative" factors that will affect the case for reform. For instance, the modelling may tend to overstate the efficiency savings associated with the potential reform of planning standards, because DNOs can mitigate the efficiency loss associated with P2/6 prescribing inefficiently high levels of capex through the use of derogations. Other regulatory incentives and obligations may also influence DNOs' planning decisions, and we will also need to consider these.

Assessing the Costs and Benefits of De Minimis Deterministic Standards Combined with CBA Obligations

The impact assessment of potential reforms that involve the use of less deterministic standards will be more challenging than the assessment of fully deterministic planning standards (described above). The challenge of modelling this approach is particularly acute because, if CBAs are performed correctly, then any obligation to perform CBAs ought in theory to result in efficient investment.

However, any conclusion that CBA obligations guarantee efficient investments (such as the conclusion one would obtain from relying solely on network modelling) exaggerates the potential benefits of reform options that would increase the role of CBA analyses. A range of the qualitative factors that influence the advantages and disadvantages of less deterministic planning standards are discussed in the NERA WS2.7 report, which we propose to investigate in Phase 2 using a range of research and analysis:

- One potential cost of reducing the scope of deterministic planning standards and obliging DNOs to undertake more CBAs is the additional cost of planning. We propose to estimate the extra costs that DNOs (and other parties) would face if Ofgem were to implement less deterministic planning requirements using a questionnaire that we would ask affected parties to complete. This is an approach widely adopted in energy sector impact assessments, and one NERA has used successfully in the past.
- Further, it would be overly optimistic to assume that a CBA standard will always result in economically efficient investments being undertaken by DNOs. To address this factor, we will also draw on practical experiences of where CBAs have been used in regulatory processes in the UK energy and other utility sectors to assess their effectiveness at identifying efficient investments. We also intend to examine the challenges that have been faced in other jurisdictions (e.g. Australia, South America) where CBA obligations have been used for network planning. For instance, we understand that the effectiveness of CBA obligations in parts of South America has been undermined by disputes about the appropriate level of VOLL to use for expansion planning; this insight might be one advantage of CBA methodologies that are more prescriptive.

Output: Robust Impact Assessment Report to Support the DCRP's Decision and Recommendation to the Authority

The output from this Workstream will be a full impact assessment of the options identified through Workstreams 3 and 4, accounting for both the qualitative and quantitative costs and benefits of reform. This report will be prepared (and the analysis conducted) with the overriding objective of presenting the evidence that the DCRP and the Authority can rely on to take a decision on reform of the P2 standard.

2.6 Workstream 6: Engagement with industry

Engagement with stakeholders was a key element of the Phase 1 works and will continue to be so through Phase 2. At a high level the key stakeholder engagement activities for Phase 2 have been gathered together under Workstream 6. However, stakeholder engagement forms a part of all the workstreams whether it relates to members of the DCRP P2 Working Group, the energy industry or a

wider group of stakeholders. The key high level engagement activities[19] identified in the Phase 2 plan are listed below with the timings identified in the programme in Appendix B.

- Associated with Workstream 1 is the initial industry presentation of the Project Initiation Paper (PIP) setting out the objectives and project plan for Phase 2. Like Phase 1 it is envisaged that this would be an industry event at a suitable venue organised by the ENA with presenters from the Consortium and DCRP P2 Working Group and question and answer panel sessions including other industry representatives as well as Consortium members.
- Workstream 3 and 4 includes the modelling and analysis to develop the rules and tables that would form the basis of a new standard based on either Option 2 (improved determinist standard) or Option 4 (limited deterministic rules and focused on cost benefit analysis). It is envisaged that there would be an industry presentation providing a briefing on the project history and ongoing objectives, and showing the detailed reform options identified through the early parts of workstreams 3 and 4, including the likely dimensions of the "lookup tables" in any new standards and on the options on conducting CBA guidance. This would be an industry event at a suitable venue organised by the ENA with presenters from the Consortium and DCRP P2 Working Group and question and answer panel sessions including other industry representatives as well as Consortium members.
- A presentation to industry of the final reform options from Workstreams 3 and 4, and presenting the outcomes from the modelling and the proposed "market scenarios" the Consortium will examine through the impact assessment in Workstream 5. This would be an industry event at a suitable venue organised by the ENA with presenters from the Consortium and DCRP P2 Working Group and question and answer panel sessions including other industry representatives as well as Consortium members.
- Workstream 5 would include an industry consultation on the results of the overall project and the findings following the impact assessment. This would be followed by synthesising the consultation responses and documenting the results in a report for publication.
- Workstream 5 would also include preparing a recommendations report in light of the impact assessment findings and consultation responses.

Other engagement activities carried out throughout Phase 2 would include the DCRP P2 Working Group monthly meetings with the consortium and the various presentations, debates and workshops conducted at these meetings. Also, engagement with the DCRP P2 Working Group during the Workstream 8 codification works to develop the final new ER P2 documents. At this point the Consortium is unclear if there would be a requirement for consultation outside of the DCRP P2 Working Group during the Workstream 8 codification works and it is assumed that this is not the case.

Workstream 9 which includes implementation considerations for the new ER P2 which would not form part of the Consortium scope of work. It is assumed that the implementation considerations identified in Workstream 9 would be limited to engagement of member organisations of the DCRP and DCRP P2 Working Group. If wider engagement and consultation is required as part of the governance requirements for implementation then this can be introduced as additional programmed tasks under Workstream 9.

[19] The decisions on what material is presented to industry and who presents it will remain a decision for the DCRP P2 Working Group, as was the case in Phase 1.

2.7 Workstream 7 Post impact consultation Ofgem/DCRP governance to agree how to proceed with standard codification

Workstream 7 considers the programme period between the Workstream 5 impact assessment recommendation of which of the two new standard options to proceed with and completion of the Ofgem/DCRP governance process to initiate codification of the new standard.

Workstream 7 is taken to be a DCRP led task and the programme period has been estimated to allow for any governance tasks by the DCRP and Ofgem necessary.

2.8 Workstream 8: Codification of the new standard

The plan for development of the new ER P2 documents assumes that the main ER document would cover the fundamental rules while guidance on the application of the rules and any supporting tables and data would be included in additional supporting documents i.e. guide documents to the main ER document. This will assist mitigate risks where rapid developments in the energy industry require more frequent or rapid amendments to areas of the new ER documents. In particular amendments to application guidance, supporting tables and data can be more rapidly and efficiently amended through the present governance processes if they are contained in guide documents to the main ER document.

The Workstream 8 programme splits the codification into two areas, one covering development of the main ER document and the other covering the guides to the main ER document. Information for the guide documents e.g. tables and data would be drawn from the modelling and analysis carried out in Workstreams 3 and 4, however, the programme assumes that some additional modelling and analysis may be required during the codification process.

The codification process allows for a number of iterations of draft documents developed and reviewed by the DCRP P2 Working Group to arrive at the final documents. Three main iterations of this process are reflected in the Programme in Appendix B.

Recognising that there are potential interfaces with the NETS SQSS and possibly other codes the programme allows time at the codification process to review how this may impact on the drafting of the new ER and guidance documents. There may also be a link between the early codification considerations and the Workstream 9 implementation considerations for "amendments to other codes impacted by a revision to P2". There is a programme timing dependency between the drafting process of the new ER and guide documents and the Workstream 9 task on the DCRP P2 Working Group to obtain user feedback for the review phases of the draft documents indicated in the Workstream 8 programme.

2.9 Workstream 9: Implementation considerations

Workstream 9 considers implementation tasks that are outside of the Consortium's work scope but are required in terms of the complete Phase 2 plan and in some cases impact on the Workstream 8 codification process and programme. These tasks include:

- Amendments to license conditions that Ofgem would require making, these may be a simple name change from P2/6 to the new standard[20].
- Amendments to other codes or industry governance documents[21] impacted by a revision to P2.
- End user feedback from those that will use the new standard in addressing security in future network planning. The DCRP may wish to consider the statements, clauses, supporting guidance and data in the new ER documents as they are developed through Workstream 8 to ensure they will be useable by end users.

20 See condition 24.1 part (a) of the Gas and Electricity Markets Authority, ELECTRICITY ACT 1989, "Standard conditions of the Electricity Distribution Licence", 30 October 2015, available on the Ofgem web site. https://epr.ofgem.gov.uk//Content/Documents/Electricity%20Distribution%20Consolidated%20Standard%20Licence%20Conditions%20-%20Current%20Version.pdf

21 The, EHV Distribution Charging Methodology (EDCM), published by the Energy Networks Association, April 2011, refers to the use of "F Factors" which are detailed in the P2/6 guide document ETR 130.

3 IN CONCLUSION

This document provides a possible outline programme and plan for the P2 review Phase 2 covering:

- The data gathering and additional research, modelling and analysis to prepare the look up tables that would form the basis for the two selected options from Phase 1 of the review; Option 2 for a new determinist standard and Option 4 for a less deterministic standard involving more use of Cost Benefit Analysis.
- The work to carry out full economic impact assessments against defined market scenarios for each of the two defined options for a new ER P2, and to recommend which option should be adopted.
- The work to codify the adopted option for a new ER P2 and implementation considerations.
- The stakeholder engagement and consultations to support the Phase 2 works.
- The management requirements to support the Phase 2 works.

APPENDIX A P2 REVIEW BACKGROUND

Engineering Recommendation P2[22] has been in place since the 1950s and has played a major role in the development of secure and reliable distribution networks. Whilst a number of changes have been made over the years, notably the introduction of P2/5 in 1978, the document has served the industry and consumers well for over 30 years.

Engineering Recommendation P2/6 is a subordinate document to the Distribution Code and also forms part of a Distribution Network Operator's (DNO) License conditions. Distribution Code[23], clause DPC4.2.1 Security states that "In accordance with the Condition 5 of the Distribution Licence, DNOs shall plan and develop their DNO's Distribution Systems to a standard not less than that set out in DGD Annex 1 Item 4, Engineering Recommendation P2/6 – "Security of Supply" or such other standard of planning as DNOs may, with the approval of the Authority, adopt from time to time."[24] The standard conditions of the Electricity Distribution Licence[25], condition 24.1 indicates a similar requirement.

The most fundamental issue regarding the future evolution of the P2/6 Engineering Recommendation is whether it continues to prescribe economically efficient investments, given the many changes affecting the energy markets and networks at present, including the (anticipated) prolific deployment of new and emerging technologies and the changing role of the customer including demand, generation and prosumer customers. This potentially gives rise to the need for a fundamental review of the baseline philosophy of distribution network planning to ensure that the UK Government's energy policy objectives can continue to be met in a cost effective and pragmatic way[26].

The review of Engineering Recommendation P2/6 is formed of two distinct phases. The objective of Phase 1 is to identify and agree a range of options for a future UK security standard and agree the most appropriate approach that should be taken forward into Phase 2 which is the development and codification of the new standard.

The fundamental review of Engineering Recommendation P2/6[27] is being directed by the Distribution Code Review Panel P2 Working Group (DCRP P2 Working Group)[28] through the Energy Networks Association (ENA).

In January 2014, the DCRP P2 Working Group, through the ENA, engaged a consortium consisting of DNV GL[29], Imperial College London (ICL)[30] and NERA[31] to carry out Phase 1 of the P2 review.

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22 Engineering Recommendation P2 is intended as a guide to system planning covering security of supply that defines the required capability of electrical networks to maintain supply to a defined level of demand under defined outage conditions. P2 is neither a design standard nor an operational standard.

23 "THE DISTRIBUTION CODE OF LICENSED DISTRIBUTION NETWORK OPERATORS OF GREAT BRITAIN", Issue 27 – 01 January 2016, available on the DCODE web site, http://www.dcode.org.uk/assets/files/dcode-pdfs/DCode%20v27%20121015v2%20DPC6.2%20and%20G12-4-1%20and%20guide%20stripped%20out%20161215.pdf

24 While DNOs can opt to invest in security above the minimum requirement prescribed by P2/6 where they can justify this, to propose design solutions below the minimum level the DNO is required to seek a derogation for this from the Regulator where they cannot self-derogate (a DNO can presently self-derogate for Class of Supply A, B and C listed in Table 1 of P2/6).

25 Gas and Electricity Markets Authority, ELECTRICITY ACT 1989, "Standard conditions of the Electricity Distribution Licence", 30 October 2015, available on the Ofgem web site, https://epr.ofgem.gov.uk//Content/Documents/Electricity%20Distribution%20Consolidated%20Standard%20Licence%20Conditions%20-%20Current%20Version.pdf

26 It is assumed by the DCRP P2 Working Group that within these policy objectives there is a need to maintain a security of supply that meets customers' expectations.

27 The present version of the Engineering Recommendation P2/6 document is available on the DCODE website for this review and can be accessed using the following link: http://www.dcode.org.uk/assets/files/Working%20Groups/P2/ENA_ER_P2_Issue_6_(2006).pdf

28 On behalf of the Distribution Code Review Panel (DCRP).

29 DNV GL is a Global certification and advisory business working in the maritime, oil and gas, business assurance and energy sectors.

30 Imperial College London is a university of world-class education and research in science, engineering and medicine, with particular regard to their application in industry, commerce and healthcare.

Phase 1 of the P2 review is essentially a comprehensive research, analysis and modelling engagement supported by a consultation process being carried out by the Consortium with direction and support provided by the DCRP P2 Working Group and the ENA.

Phase 1 of the project commenced in February 2015 with the development of a Project Initiation Paper (PIP)[32] under work stream 1. The PIP highlighted the key objectives of Phase 1 of the Engineering Recommendation P2/6 review project to industry stakeholders and the process adopted to achieve these objectives.

The process to deliver the Phase 1 objectives outlined in the PIP consists of a number of work streams which can be broadly summarised as follows[33]:

- **Work Stream 1**; set out the Phase 1 objectives and process, and included an initial engagement with all key industry stakeholders.
- **Work Stream 2**; identified, researched and evaluated options for a future UK security standard.
- **Work Stream 3**; engaged with the DCRP P2 Working Group to examine the deliverables from WS 2 and derive and describe the range of options that informed the processes in WS 5.
- **Work Stream 5**; included an industry wide workshop that focused on introducing and discussing the deliverables from WS 3 (both quantitative and qualitative exercises).
- **Work Stream 6**; further supported WS 5, through a formal industry wide consultation to seek and gather written feedback from all industry parties on some of the more pertinent issues and concerns associated with the proposed options for reform of the security standard.
- **Work Stream 7**; developed a summarised and tabulated view of the WS 6 consultation question responses and identified and structured actions to be taken with regards to the final Phase 1 recommendations report.
- **Work Stream 8**; is the final Phase 1 recommendations report that lays out the arguments and all the supporting evidence for the development route for any new standard while critically highlighting the benefits of such a route.
- **Work Stream 9**; will scope the work needed to implement the final recommendations from Phase 1 that will be undertaken in Phase 2 including a work programme for Phase 2 with an associated project plan.

The options report[34] based on the evidence developed in work stream 2 and developed with the DCRP P2 Working Group in work stream 3 sets out the assessment of the high-level options for reform of P2/6 drawing on evidence from the various quantitative and qualitative tasks carried out together with inputs from a range of stakeholders including DCRP P2 Working Group members. It provided a set of potential recommendations for reform that have been further considered here based on the analyses of the responses to the formal industry consultation (carried out through work streams 5, 6 and 7). The DCRP

31 NERA Economic Consulting is a global firm of experts dedicated to applying economic, finance, and quantitative principles to complex business and legal challenges.

32 DNV GL, NERA and Imperial College document "Engineering Recommendation P2 Review (Phase 1), Project Initiation Paper", report number 16011094/110, rev 001, 13/04/2015. Available on the DCODE website for this review and can be accessed using the following link: http://www.dcode.org.uk/assets/files/Working%20Groups/P2/project%20initiation%20paper%2020150413%20V%20004.pdf

33 Work Stream 4 is an optional work stream for further, more in depth modelling and analysis presently not commissioned by the ENA for the Phase 1 works and hence is excluded in the list shown. If necessary a second iteration of the techno-economic modelling could be carried out under Work Stream 4 during Phase 2 to confirm one option to proceed within Phase 2 if a single option is not fully identified at Phase 1.

34 Consortium/ENA report "Options for future development of distribution network planning security standard", dated 17 March 2017.

P2 Working Group agreed set of recommendations set out here under Work Stream 8 will be presented to the DCRP to be managed under their standard governance process[35]. The latter part of this Phase 1 project will set out the high level plan for the Phase 2 standard development and codification works through work stream 9. The content of the WS9 phase 2 plan will be dependent on the outcome of the recommendations review by the DCRP and possibly subsequent interactions with Ofgem.

[35] Reform to P2/6 recommended by the DCRP would require agreement with Ofgem and an Ofgem consultation as P2/6 is referenced in the DNO license conditions.

APPENDIX B PHASE 2 OUTLINE PROGRAMME

Notes:

1. The programme shown is an outline based on the plan described in the text of this document.
2. The "lead advisor" indicated in the following programme is for illustration only and these roles could be carried out by any suitable organisation appointed by the DCRP.

Workstreams	Lead Advisor	Months from Inception:																											
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
Workstream 1: Project inception and management																													
1.1: Project inception report setting out objectives and project plan	*DNV GL*																												
1.2. Review and agreement of the inception report with the DCRP WG	*DNV GL*																												
1.3: Monthly meetings with DCRP P2 Review Group	*DNV GL*																												
1.4: Programme management	*DNV GL*																												
Workstream 2: Data gathering to support modelling and model validation																													
2.1: Analysis of real HV networks and creation of a set of representative HV networks	*Imperial*																												
2.2: Analysis of real EHV networks and creation of a set of representative EHV networks	*Imperial*																												
2.3: Analysis of real 132kV networks and creation of a set of representative 132kV networks	*Imperial*																												
2.4: Analysis of real substations and creation of a set of representative substations	*Imperial*																												
2.5: Validation of modelling approach	*Imperial*																												
Workstream 3: Network modelling to inform development of a new deterministic standard																													
3.1: Development of LV network look-up tables	*Imperial*																												
3.2: Development of HV networks look-up tables	*Imperial*																												
3.3: Development of EHV networks look-up tables	*Imperial*																												
3.4: Development of 132kV networks look-up tables	*Imperial*																												
3.5: Development of primary and bulk supply substations look-up tables	*Imperial*																												
3.6: Development of look-up tables with inclusion of DG, DSR and Energy Storage	*Imperial*																												
3.7: Construction Outages	*Imperial*																												
3.8: High-impact Low-probability events	*Imperial*																												
Workstream 4: Developing a new, less deterministic standard involving more use of CBA																													
4.1: Modelling approach for a new less deterministic standard involving more use of CBA	*Imperial*																												
4.2: Calibration of look-up tables for a less deterministic standard involving more use of a CBA	*Imperial*																												
4.3: Designing alternative forms of obligation to identify efficient investments through CBA modelling,	*NERA*																												
Workstream 5: Conducting impact assessment																													
5.1: Quantification of cost effectiveness of the proposed standards	*Imperial*																												
5.2: Sensitivity analysis of the proposed new standards	*Imperial*																												
5.3: Defining "market scenarios" against which we can model economically efficient distribution investment requirements using the models established for workstreams 3 and 4, and compare these against the investment outcomes under the various reform options.	*NERA*																												
5.4: Designing a questionnaire to seek respondents views as to the costs of implementing the various reform options	*NERA*																												
5.5: Conducting an impact assessment of the various reform options, drawing on quantitative analysis in 5.1 - 5.4 and preparing a written report on recommended reform options	*NERA*																												
Workstream 6: Engagement with industry																													
6.1. Initial industry presentation of the inception report setting out the objectives and project plan for Phase 2	*DNV GL*																												
6.2: Industry presentation providing a briefing on the project history and ongoing objectives, and showing the detailed reform options identified through the early parts of workstreams 3 and 4, including the likely dimensions of the "lookup tables" in any new standards and on the options on conducting CBA guidance	*DNV GL*																												
6.3: Industry presentation of final reform options, and presenting the outcomes from the modelling and the proposed "market scenarios" we will examine through the impact assessment.	*DNV GL*																												
6.4: Industry consultation on results of the overall project and the findings following the impact assessment	*NERA*																												
6.5: Synthesising consultation responses	*DNV GL*																												
6.6: Preparing recommendations report in light of findings and consultation responses	*NERA*																												
WS 7 Post Impact Consultation Ofgem/DCRP governance to agree how to proceed with standard codification.																													
7.1: Ofgem and the DCRP agree to proceed with codification of the new standard.	*DCRP*																												
Workstream 8: Codification of the new standard																													
8.1: Development of the draft primary standard, this will include several drafts for DCRP WG governance reviews.	*DNV GL*																												
8.2: Agreement with DCRP WG on standard format, content and alignment with NETS SQSS and other codes etc.	*DNV GL*																												
8.3: Governance reviews.	*DCRP WG*																												
8.4: Development of the supporting guide documents, his will include several drafts for DCRP WG governance reviews.	*DNV GL*																												
8.5: Agreement with DCRP WG on guide format, content and alignment with NETS SQSS and other codes etc.	*DNV GL*																												
8.6: Governance reviews.	*DCRP WG*																												
Workstream 9: Implementation considerations																													
9.1. Amendments to license conditions	*Ofgem*																												
9.2. Amendments to other codes impacted by a revision to P2.	*ENA*																												
9.3. User feedback, this will align with the various codification reviews carried out by the DCRP P2 WG	*DCRP WG*																												

About DNV GL

Driven by our purpose of safeguarding life, property and the environment, DNV GL enables organizations to advance the safety and sustainability of their business. We provide classification and technical assurance along with software and independent expert advisory services to the maritime, oil and gas, and energy industries. We also provide certification services to customers across a wide range of industries. Operating in more than 100 countries, our 16,000 professionals are dedicated to helping our customers make the world safer, smarter and greener.