Future World Impact Assessment

CLIENT: Energy Networks Association

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Version History

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Executive Summary

Context and Background

Energy network companies have a crucial role to play in the transition to a low carbon economy, facilitating the connection of low carbon generation and providing network capacity for new technologies to help decarbonise heat and transport. The Energy Networks Association's (ENA) Open Networks Project is bringing together a range of stakeholders to understand how network operators can perform this new role, in a way that minimises costs while providing high levels of customer service. This could require changes to the way networks are operated, the roles and responsibilities of different network operators and how network users interact with them. This is widely referred to as the transition to Distribution System Operators (DSOs). Similar transitions are occurring elsewhere in the world as energy systems become more decentralised and new technologies are transforming the way that energy is produced, transported and consumed.

One theme that is emerging strongly in this transition is the importance of flexibility from distributed energy resources (DER). Without this flexibility, the changing nature of load on the system would likely require very significant new investment in networks. Given the inherent uncertainty in the rate of uptake of low carbon technologies, some of that investment might turn out not to have been necessary. Flexible DER provides optionality, as well as the potential to defer or negate the need for network reinforcement. Maximising the use of flexibility is not just a question of market design but how to change network planning and operating practices to make effective use of flexible resources.

The Open Networks project has identified five 'Future Worlds' which represent different market, organisational and operational structures to access and utilise flexible DER to operate the transmission and distribution systems.[1] The Worlds are differentiated by the respective responsibilities of the DSO and the Electricity System Operator (ESO), the role of reformed network access rights and price signals and the possibility of greater independence in certain system operation functions. The ENA summarised these Future Worlds in the following way:

- **World A: DSO Coordinates** – a World where the DSO takes a central role for all distribution connected parties acting as the neutral market facilitator for all DER and provides services on a locational basis to the ESO.
- **World B: Coordinated DSO-ESO Procurement and Dispatch** – a World where the DSOs and ESO work together to efficiently manage networks through co-ordinated procurement and dispatch of flexibility resources.
- **World C: Price-Driven Flexibility** – a World where changes developed through Ofgem's reform of electricity network access and forward looking charges have improved access arrangements and forward looking price signals for Customers. [2]

[1] http://www.energynetworks.org/assets/files/14969_ENA_FutureWorlds_AW06_INT.pdf

[2] It should be noted that since the ENA defined these Worlds, Ofgem has set out detailed arrangements on reforms of forward looking charges and access arrangements. It should be noted that since the ENA defined these Worlds, Ofgem has set out detailed arrangements on reforms of forward looking charges and access arrangements in its Significant Code Review launch. We have not included these in the assessment. These options include non-firm access rights, which would allow for active control through curtailment, or time-profiled access options. If implemented, these options could provide some primary control benefits which do not feature in the set of simple access arrangements we have assessed

- **World D: ESO Coordinate(s)** – a World where the ESO takes a central role in the procurement and dispatch of flexibility services as the neutral market facilitator for DER, with DSOs informing the ESO of its requirements; and
- **World E: Flexibility Co-ordinator(s)** – a World where national (or potentially regional) third party(ies) acts as the neutral market facilitator for DER, providing efficient services to the ESO and DSO, as required.

These Future Worlds represent stylised models which have been deliberately chosen to draw out the range of options for the DSO transition. Following a competitive tender process, the ENA asked Baringa to undertake an independent Impact Assessment of these Future Worlds. This is an initial, high-level impact assessment, designed to understand the relative strengths and weaknesses of the Future Worlds and the subsequent impact on network operators and network users. It is not intended to provide a definitive answer on which Future World should be implemented but to understand how they might perform and provide a starting point for further analysis. The results of this assessment can help to start inform the choices for the DSO transition over the coming years, and identify areas where future work might be required.

Approach

The Impact Assessment is based around a broad qualitative assessment of the Future Worlds against over 30 different criteria identified by the ENA and stakeholders, under the headings set out by the Treasury's five case model for assessing business cases. In addition, we have considered the quantitative costs and benefits of the different Future Worlds, including how they can best help avoid network investment, reduce the cost of Balancing Services, or avoid the need to build new generation plant. We have assessed these benefits under two of National Grid's Future Energy Scenarios (FES) – Community Renewables and Two Degrees.[3] In this initial impact assessment, we have not had the data and information available to quantify the wider costs and benefits of the Future Worlds, for example the business case for flexibility providers. Where possible, we have looked to capture this through the qualitative assessment.

The focus of the Impact Assessment has been on the relative assessment of the Future Worlds and not the absolute net benefits they can deliver. Consequently, we have adopted a high-level approach, that is relatively simple and transparent and have sought to reference publically available data, wherever possible. This can allow the assessment to be challenged and developed over time, as more information and evidence becomes available. The spreadsheet models which underpin the analysis have been made available alongside this report, to allow others to build on this initial work.

While conscious that this is an independent assessment, we have engaged with the Open Networks groups throughout the four-month project to receive challenge on our approach and assumptions. We were provided access to stakeholder responses to the ENA's consultation on the Future Worlds. These suggested additional criteria to be used in the Impact Assessment, which we adopted. We have also run workshops with broader industry stakeholders to gain wider perspectives and inputs, including on the unintended consequences which can arise from the Future Worlds. This input has directly fed into our qualitative assessment and broader insights and conclusions.

To undertake the Impact Assessment, we had to make a number of assumptions around how the Future Worlds would operate in practice. We took the decision to include the features of World C,

[3] These were chosen as the two scenarios which deliver Government Policy but through a different mixture of centralised and decentralised generation.

namely improved network access and forward looking charging arrangements, as a component of all other Future Worlds, not just World B (as was originally set out by the ENA). This means that in isolation the scope of operation of World C is narrower than the remaining Worlds. However, it provides a useful reference point of the benefits improved access and charging arrangements can provide and the additional benefits achievable through improved system operation. This analysis of World C is not a substitute for the regulatory impact assessments that Ofgem will be doing as part of its Significant Code Review of network access and forward looking charging, which will likely be more detailed in this area.

We also decided to separate each Future World into two stages of development. Stage 1 is an initial stage of development (assumed to be implemented from 2019) where the coverage of some Future Worlds is limited. For example, in World D, the ESO only co-ordinates flexibility down to the High Voltage (HV) network. Stage 2 is a more mature state of development and captures the full scope of each Future World as envisaged in the ENA's consultation. A key assumption was that in Stage 2, the Future Worlds can be designed in theory to deliver all the available benefits of optimising the use of flexible resources for effective system operation.[4] The only differences between the Future Worlds, therefore, are the costs of implementing and operating them, and the timescales to evolve to the more mature state of development in Stage 2. This assumption was designed to ensure that the Impact Assessment focussed on the development of the Future Worlds, rather than attempt pre-judge how the Future Worlds might perform in a 2050 end state, when so many assumptions are inherently uncertain. We considered that this would produce a set of results which could more helpfully inform nearer term decisions.

Since many of the inputs required for the quantitative assessment around future costs and benefits are so highly uncertain, we applied a range of uncertainty to the inputs used in the assessment – a pessimistic range comprised on high costs and low benefits and an optimistic range based on lower costs and higher benefits.

Results of the Impact Assessment

The qualitative assessment provided a broad insight into the performance of the Future Worlds. The key conclusion is that there is no Future World which excels across all criteria but there are different relative strengths and weaknesses of each. It highlights that there are trade-offs associated with each Future World which will need to be weighed up against each other. This conclusion was supported through the stakeholder engagement sessions we ran. Different priorities among stakeholders drove them to favour different Future Worlds. Table 1 outlines which Future World is likely to be best placed to meet specific objectives and what the subsequent trade-offs are.

[4] The exception to this assumption was World C where we felt it unlikely that price signals and access arrangements alone could deliver all the potential benefits.

Table 1 Summary of trade-offs between the Future Worlds

Most important objective	Likely World(s)	Subsequent trade-offs
Decarbonisation of heat and transport (particularly if this accelerates in 2020s)	**World A or B**	• Potentially more complex to operate (World B) • May require mitigations to be put in place for any perceived conflicts of interests
Ease of market engagement for existing flexibility providers	**World D or E**	• Potentially less conducive to local (low voltage) energy markets in the short term • It takes time to implement which may impact the speed of decarbonisation in the near term
Lowest cost to implement and operate[5]	**World D**	• Potentially less conducive to local energy markets in the short term • It takes time to implement which may impact the speed of decarbonisation in the near term
Minimise structural change from today	**World B**	• Likely to lead to higher longer term costs compared to other Future Worlds • Greater complexity in system operation and dispersion of accountabilities across different actors • Potential frictional issues while co-ordination processes 'bed down'
Transparent, fair, neutral markets	**World E**	• It takes time to implement which may impact the speed of decarbonisation in the near term • Likely to lose efficiency in decision making as information needs to be exchanged back and forth to the Flexibility Co-ordinators

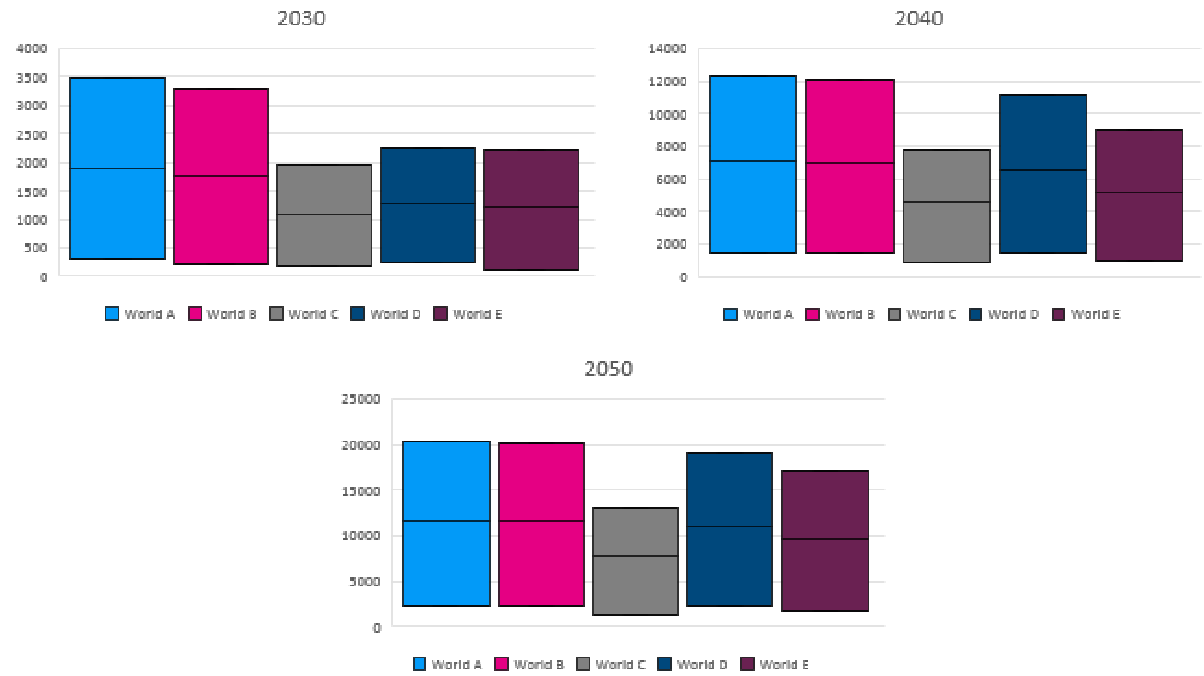
The narrower, quantitative assessment illustrated that by 2050, the performance of the Future Worlds are similar. This is explained by the fact that the available gross benefits were far higher from the mid-2030s onwards, by which point we considered most Future Worlds were capable of maturing to Stage 2 of development and delivering those benefits.[6] Consequently, the differences between the Future Worlds are largely based around their performance out to 2030, where the available benefits are lower.

Out to 2030, Worlds A and B appear to be capable of performing relatively better. This is explained by their faster development and the fact that they can exploit synergies between network and system operation at the distribution level to deliver greater benefits from access to flexible DER. Figure 1 below highlights the results of the quantitative assessment. The black line indicates the results for the central case and the coloured block around it, the range of uncertainty based on our pessimistic and optimistic assumptions.

[5] If we exclude World C on the basis that its features will effectively become a layer in all other Future Worlds

[6] We have assumed that Stage 1 of each Future World was implemented from 2018. The time when each Future World is deemed capable of moving to Stage 2 of development is different and detailed in section 3 and in more detail in Appendix D.

Figure 1 Overall net benefits[7] of the Future Worlds in 2030, 2040 and 2050 under Community Renewables FES, £m NPV (real 2018/19 prices)

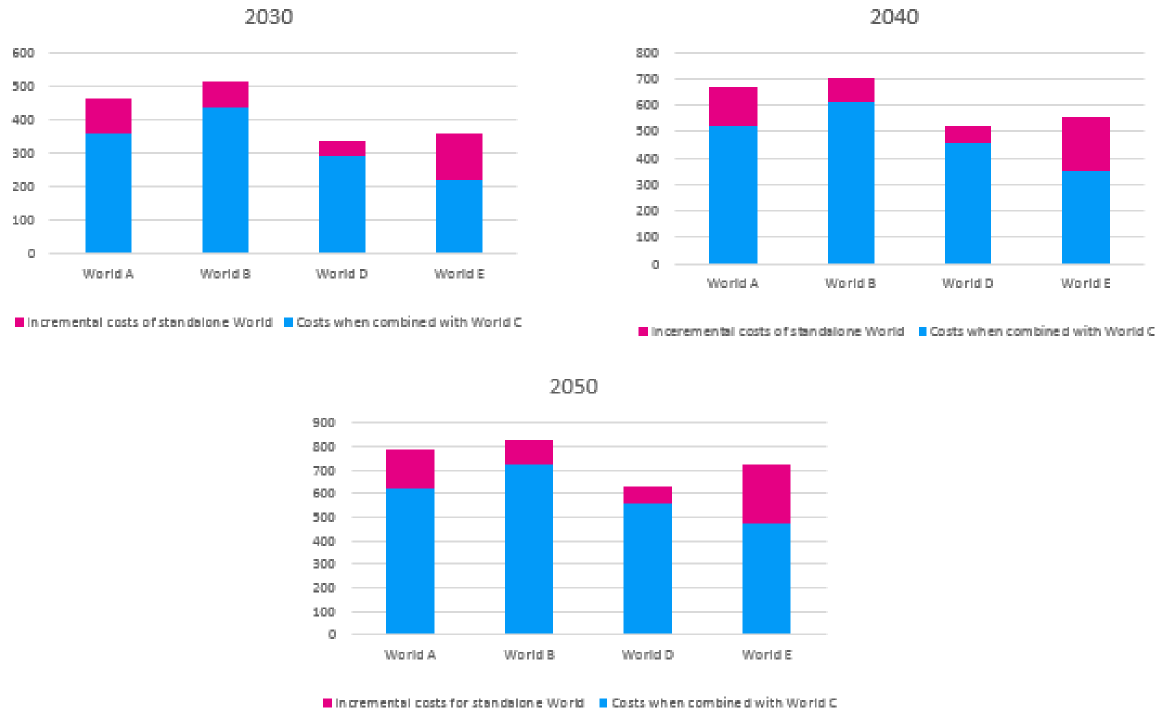


The quantitative assessment also illustrates that improved access and forward looking charging arrangements in World C can potentially deliver substantial benefits. However, on their own they do not appear to be sufficient to fully optimise the use of flexible resources. This indicates that an enduring system operation role will be required alongside reformed charging and access arrangements. We ran a sensitivity which combined World C with the other Future Worlds. We considered that treating World C in this way is more realistic as it is likely that reformed network access and forward looking charging arrangements will be a feature in all Future Worlds.

The results indicate that integrating access and charging reforms into each of the remaining Future Worlds could reduce the system and resource costs required to deliver the same level of benefit in each World.[8] Figure 2 below highlights these results. The blue block indicates the costs of each Future World when integrated with World C and the pink block, the incremental costs of delivering those benefits without integrating World C. The results show that including reformed access and charging arrangements can deliver the greatest cost reductions in those Future Worlds where there is the most duplication of system operation functions between actors (particularly World E).

[7] This is the gross benefit each Future World can deliver minus the costs of the systems, IT and resources required to deliver those benefits and the cost of paying for flexibility.
[8] The gross benefits delivered by each World were unaffected, since all other Future Worlds were able to deliver greater benefits than World C.

Figure 2 Cost impact of combining World C with the other Future Worlds, £m NPV 2018/19 prices based on central case



Conclusions and insights

The assessment indicates that all the Future Worlds are viable (particularly when features of World C are combined with the other Future Worlds). This means that there a number of potential DSO transition paths with different triggers and outcomes. Using the insights gained from the results of the Impact Assessment, we have separately[9] identified four different routes or pathways for the DSO transition (illustrated in Figure 3 below). This is designed to illustrate what is likely to drive a move to one Future World over another. Starting to understand these choices and their triggers can help network operators and network users plan more effectively for the DSO transition.

All of our identified transition paths diverge from a starting point of World B (Stage 1). This is because World B seems to align most closely to today's arrangements and the results of the Impact Assessment have not presented an obvious reason to move away from World B, at this time. From 2023, we assume that reformed access and forward looking charge arrangements become a key part of all transition paths as this combination appears capable of delivering higher overall net benefits.[10]

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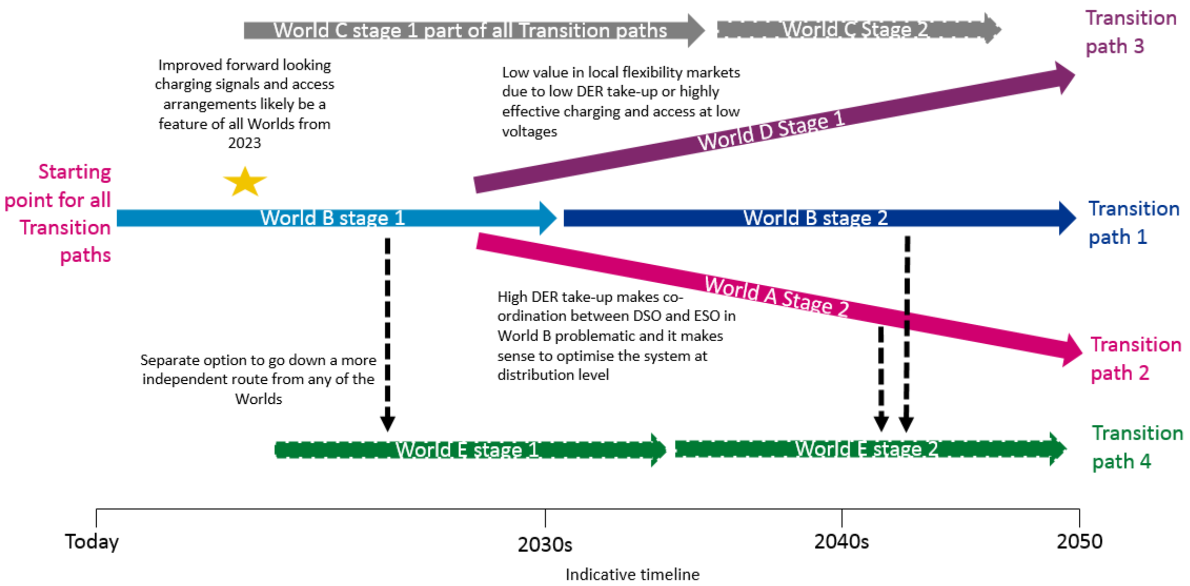
[9] For clarity these are not directly linked the quantitative assessment which modelled each Future World in isolation but use the outputs to draw insights into the different transition paths between the Future Worlds.

[10] This aligns with the timing set out in Ofgem's letter to launch of a significant code review in this area: https://www.ofgem.gov.uk/system/files/docs/2018/12/scr_launch_statement.pdf

Figure 3 Potential DSO transition paths and triggers



- **Transition path 1: Continued joint procurement and co-ordination between DSOs and ESOs (World B Stage 2)** – This is a 'least change' path and is most likely where the coordination mechanisms between the ESO and DSOs have proven to be effective and flexibility providers are able to interact with different markets and 'stack' revenues.
- **Transition path 2: Move to DSO led co-ordination (World A Stage 2)** – This is likely to be triggered by a high DER uptake scenario whereby co-ordinated procurement across the ESO and DSOs becomes problematic, and it makes more sense to prioritise optimising the system at the distribution level. This transition would only occur where there are clear benefits in operating highly local flexibility markets to avoid or defer reinforcement on the lower voltage levels of the distribution network.
- **Transition path 3: Move to ESO led co-ordination (World D Stage 1)** – This is likely to be triggered when where there is little value in running local flexibility markets. This could be due to a relatively low uptake of DER or because reformed network access and pricing arrangements have proved effective in eliciting customer responses at the low voltage (LV) and there is little value in additional procurement of flexibility. Under these circumstances, the case for benefiting from the economies of scale of extending the ESO's role to the Extra High Voltage (EHV) and High Voltage (HV) distribution networks (World D) becomes more compelling.
- **Transition path 4**: **Move to independent Flexibility Co-ordinators (World E)** – A transition path to World E would primarily be driven by concerns, real or perceived, about conflicts of interests between network operator and system operator roles. The move to this transition path could either be at an early point on the DSO transition, or a later point. An earlier move would see the creation of Flexibility Co-ordinators procuring flexibility from DER, but an ongoing role for the ESO and DSOs in dispatching it. A later move would likely involve the transition to a series of regional independent system operators.

Many of the trigger points for the transition paths are driven by the level of DER uptake. The FES which are based on delivering the Government's decarbonisation targets illustrate that this uptake is forecast to ramp up considerably in the late 2020s and early 2030s.[11] Consequently, we would expect this to be the point at which the transition paths start to diverge but it could be sooner or later depending on the actual uptake of DER. We also anticipate that there is considerable work to do in the coming years to develop new markets, platforms, operating practices, and access and charging arrangements to facilitate the co-ordinated procurement of DER flexibility, if World B (Stage 1) is the preferred pathway in the near term.

We have identified four areas for further work which can help to inform which transition path is most likely in the medium to longer term. These are based around seeking answers to the following questions:

How far can reformed access and charging arrangements go in delivering flexibility to the system?

Understanding the effectiveness of network access arrangements and price signals at providing the flexibility which system operators require can inform the volume of flexibility services required and therefore the scale of system operation functions needed. This is particularly pertinent for World B, since effective network access arrangements and price signals can reduce complexity and potentially the cost of the required coordination processes between the ESO and DSOs.

What is the value of flexibility to network operators at low voltages?

While there have been a number of trials to date on local flexibility markets, the focus has been more around testing the concepts and feasibility of flexibility products and services at a local level. Consequently, there remains some uncertainty over whether the benefits of these services (through avoiding and deferring network investment) outweigh the costs of establishing, running and operating flexibility markets at the lower voltages. Further trials, to test the economic viability of these local flexibility markets will help inform the extent to which a transition to World A remains a credible pathway.

What are the potential conflicts of interest and how can they be mitigated?

This can help inform whether a transition to World E is necessary. It would be useful to assess the potential consumer detriment which could result from network and system operations being undertaken within the same organisation. This can allow mitigation processes to be developed and tested with stakeholders prior to implementation.

How can industry arrangements facilitate a different pace of change across regions?

One of the key triggers for the transition paths is the uptake of DER. This can vary geographically. Consequently, there may be different pace of transition across different regions. Current industry arrangements are based around applying mostly uniform rules and regulations across GB. It would be helpful to start considering how industry codes and regulatory arrangements would need to change to accommodate geographical differences in the pace of the DSO transition.

Research and trials to help answer to these questions should further the understanding of the scale of DSO functions which need to be developed over the coming years to deliver the benefits we have

[11] The Two Degrees and Community Renewables scenarios

identified. The answers can also provide insights on the most likely DSO transition path. The earlier this path can be identified the more efficiently the transition to DSO can be delivered.

Further work to build on this Impact Assessment

We have identified some specific areas where this initial Impact Assessment could be developed further. One area is getting a better handle on the technology costs, and resourcing requirements, to deliver the DSO capabilities outlined in our assessment. There is still great uncertainty of the costs of IT systems and platforms to deliver the required functionality. In addition, it would useful to validate some of our assumptions over the benefits of economies of scale for different DSO capabilities with learning from real examples.

We also consider that it would be useful to define in greater detail the commercial arrangements in each of the Future Worlds and also where responsibilities and accountabilities lie. A greater understanding of how markets would interact and the commercial arrangements between parties would help to validate the operational viability of each Future World, and in turn the attractiveness to investors in flexibility. Similarly, we identified that the responsibility for system security has the potential to be fragmented across different actors in the Future Worlds. Understanding where the different accountabilities for system security sit will help to inform the required governance, code and licensing arrangements which underpin each Future World.

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Contents

1 Introduction

1.1 Context

Over the last two years, the Energy Network Association (ENA) has been running the Open Networks project to help understand the role energy networks need to play in the transition to a low carbon economy[12]. The Open Networks project is working to address network issues already arising from the increase in distributed generation (DG) in some regions, alongside planning for how to manage the forecasted demands on the networks from the decarbonisation of heat and transport.

A key part of this work is understanding the extent to which network operators need to take a more active role in managing demand and generation on distribution networks, in the same way that the Electricity System Operator (ESO), National Grid, does on Transmission networks. This is often referred to as the DSO transition. Workstream 3 of the Open Network project is specifically looking at how this transition might evolve. It has produced a DSO roadmap outlining the likely evolution towards DSO out to 2030 (Product 1). It has also set out the functional and system requirements needed for a DSO role across a broad range of network activities (Product 2).

In July 2018, Workstream 3 issued a consultation which outlined five conceptual Future Worlds.[13] These were presented as a range of stylised options for different roles and responsibilities for system operators to play in a DSO model. Alongside this consultation, the ENA asked EA Technology to model each Future World using the Smart Grid Architecture Model (SGAM).[14] This captured the role that different parties would need to assume in each Future World and the information exchanges required between parties.

There remain some fundamental questions over which of these Future Worlds (or combination) offers the most effective transition. These can be broadly summarised as follows:

- Are DNOs best placed to use their existing knowledge of distribution networks to assume the DSO role? (World A)
- Is it more efficient for the ESO to assume a DSO role, expanding on the role it currently undertakes on the Transmission system and utilising the skills and functions which it already performs? (World D)
- Can DSOs and ESO work together to implement a DSO model without the need for wide scale change to current roles and responsibilities? (World B)
- Is there a need for a new independent party to assume the DSO role, or some aspects of it, in order to improve transparency and guard against conflicts of interest for network operators in selecting between reinforcement and operational solutions? (World E)
- What role can improved network access arrangements and charging signals play in influencing consumer and generator behaviours to reduce the scope of the DSO role required? (World C)

The answer to these questions will have a profound impact on industry arrangements but, more importantly, the consumer experience over the next 20 to 30 years. Getting the answers right can help ensure that the network costs of facilitating a low carbon economy are minimised for customers

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[12] http://www.energynetworks.org/electricity/futures/open-networks-project/open-networks-project-overview/
[13] http://www.energynetworks.org/assets/files/14969_ENA_FutureWorlds_AW06_INT.pdf
[14] http://www.energynetworks.org/assets/files/Modelling-DSO-Transition-Using-SGAM_Issue2.1_PublicDomain.pdf

and that the networks have capacity to meet the growing needs of network users, while continuing to deliver safe and reliable supplies.

1.2 Scope of work

1.2.1 Independent Impact Assessment of the Future Worlds

Following a competitive tender process, in September 2018, the ENA asked Baringa to undertake a wide-ranging Impact Assessment of the Future Worlds, developed under the Open Networks project.

The Impact Assessment seeks to quantify the relative costs[15] and benefits of the different Future Worlds, alongside a qualitative assessment against a range of criteria. The ENA has been clear that this should be an independent Impact Assessment. This means that we have not been bound by the views of the ENA and its members. The results and insights we have provided stand as our viewpoint, not the ENA's. However, we have engaged with the ENA, its members and wider stakeholders throughout the process and encouraged challenge of our methodology, assumptions and emerging messages. While we have found this very useful input to the process, we have looked to ensure that the results provide an objective assessment and not influenced by pre-existing views of individual members.

1.2.2 Purpose of the Impact Assessment

The purpose of the Impact Assessment is to provide an initial relative assessment of the Future Worlds which the ENA has developed, and understand their respective costs and benefits, strengths and weaknesses. Undertaking the assessment has led to a number of insights into the Future Worlds which will help inform the nature of the DSO transition and identify what the focus of further work should be. Specifically, alongside the ENA, we set out the following objectives for the study:

- **To provide some insights into how the Future Worlds might perform**: Provide some understanding of which Future World(s) initially appear more promising than others, why and under what circumstances.
- **Identify any Future Worlds which are not operationally viable:** Identify if there are any of the Future Worlds which are not worth taking forward due to the scale of operational complexity.
- **Understand the gaps in knowledge:** Identify key gaps in how the Future Worlds might operate and the areas of greatest uncertainty for costs and benefits. These insights can be used to provide a focus for the future work programme of the Open Networks Project.
- **Understand implications for the DSO transition:** Develop an understanding of the conditions which might lead towards certain Future Worlds over others and the trigger point for these.
- **Identify the key risks and unintended consequences of the DSO transition:** Identify the risks to consumers and wider stakeholders of the DSO transition so that these can be considered as the Future Worlds are developed further over time.

It is important to stress that the purpose of the Impact Assessment was not to 'pick a winner' from the five Future Worlds, or to provide a definitive answer. The ultimate solution may have features

[15] The scope of our cost assessment was limited to the costs incurred by network operators as this was the basis of the SGAM modelling undertaken. See section 1.3 for further details.

from each of the Future Worlds, and there will be a transition pathway in order to get there. This Impact Assessment is a step towards understanding this pathway.

We are conscious that others will want to challenge, refine and build on the initial work we have undertaken. Consequently, alongside our report we have made available our spreadsheet models and key assumptions to be updated over time as more information becomes available.

1.3 Structure of this report

We have sought to provide an accessible summary of the Impact Assessment in the main body of this report:

- **Section 2** describes the Future Worlds which were set out by the ENA and how we have interpreted them for the purposes of the Impact Assessment
- **Section 3** provides a high level summary of our approach to the Impact Assessment
- **Section 4** outlines a summary of the results of the Impact Assessment
- **Section 5** sets out the insights we have been able to draw from the Impact Assessment

The appendices go into the detail of the Impact Assessment, including the full assessment of the Future Worlds against the qualitative criteria and detailed write up of the approach we have taken:

- **Appendix A:** Full assessment of the Future Worlds against the qualitative criteria
- **Appendix B:** Our approach to the benefits assessment
- **Appendix C:** Our approach to the cost assessment
- **Appendix D:** Our assessment of the timing when each Future World would mature to Stage 2 of development
- **Appendix E:** Outputs of the Unintended Consequences workshop
- **Appendix F:** Future World operating models

2 The Future Worlds

2.1 ENA Future Worlds

There are numerous different ways a Future World could be structured and operated. In its July 2018 consultation document the ENA identified five conceptual Future Worlds. The purpose of these was to set out a range of the different approaches which might be taken. Our understanding is that they were deliberately designed to act as contrasting models to cover a broad range of potential outcomes for future system operation. The five Future Worlds were described in the ENA's consultation document[16] as follows:

- **World A: DSO Coordinates** – a World where the DSO takes a central role for all distribution connected parties acting as the neutral market facilitator for all DER and provides services on a locational basis to the ESO.
- **World B: Coordinated DSO-ESO Procurement and Dispatch**- a World where the DSOs and ESO work together to efficiently manage networks through co-ordinated procurement and dispatch of flexibility resources.
- **World C: Price-Driven Flexibility** – a World where changes developed through Ofgem's reform of electricity network access and forward looking charges have improved access arrangements and forward looking price signals for Customers.[17] This World has been built with flexibility arrangements as described in World B but it is recognised that charging and access developments could be similarly progressed in other Worlds.
- **World D: ESO Coordinate(s)** – a World where the ESO takes a central role in the procurement and dispatch of flexibility services as the neutral market facilitator for DER, with DSOs informing the ESO of its requirements; and
- **World E: Flexibility Co-ordinator(s)** – a World where national (or potentially regional) third party acts as the neutral market facilitator for DER, providing efficient services to the ESO and DSO, as required.

There was additional detail in the consultation document describing the high-level arrangements for each Future World in the following areas:

- System Co-ordination;
- Network Operation;
- Investment Planning;
- Connections and Connection Rights;
- System Defence and restoration;
- Services/Market Facilitation;
- Service Optimisation, and
- Charging.

[16] http://www.energynetworks.org/assets/files/14969_ENA_FutureWorlds_AW06_INT.pdf See page 16

[17] It should be noted that since the ENA defined these Worlds, Ofgem has set out detailed arrangements on reforms of forward looking charges and access arrangements. It should be noted that since the ENA defined these Worlds, Ofgem has set out detailed arrangements on reforms of forward looking charges and access arrangements in its Significant Code Review launch. We have not included these in the assessment. These options include non-firm access rights, which would allow for active control through curtailment, or time-profiled access options. If implemented, these options could provide some primary control benefits which do not feature in the set of simple access arrangements we have assessed.

Alongside this the Smart Grid Architecture Models (SGAMs) outlined the specific roles, responsibilities and data flows for each of these functions, in each Future World. This provided considerable detail on how the Future Worlds might operate in each of the functional areas listed above.

2.2 Our interpretation of the Future Worlds

In order to undertake the Impact Assessment we needed to define certain aspects of the Future Worlds in more detail. This led to a number of questions, requiring us to make some additional assumptions.

i) **How do the Worlds develop over time?**

The Future Worlds set out by the ENA focussed on the future end state. However, for the purposes of the Impact Assessment we needed to understand how each Future World would develop over time to evolve into that end state.

To resolve this issue, we introduced developmental stages for each Future World. This comprised of an initial stage of development (Stage 1) before maturing to the end-state (Stage 2). While we have described each stage as discrete, the transition is likely to be more gradual, rather than a step change. However, the two stage approach proved to be a useful way to represent a less evolved, versus a more evolved version of each Future World. To reflect the fact that each Future World will evolve at a different pace, we proposed to have different dates for when each Future World matured to Stage 2. The details behind this assessment are set out in Section 3.

ii) **In World A what role does the DSO play in the Balancing Mechanism?**

World A introduces the concept that electricity flows will be managed by DSOs at each GSP, following a "pre-defined power exchange schedule, technically and commercially agreed with the ESO as part of whole-system balancing instructions".[18] The ENA consultation also mentioned that in World A, the DSO becomes a "balance responsible party".[19]

One interpretation of this is that the DSO is responsible for the energy balance at each GSP. There are a range of ways that this could work, some of which would require fundamental changes to the current Balancing Mechanism and which may not be compliant with current European Network Codes.[20]

The issue over the interaction with balancing arrangements appeared to be unique to World A (in all other Worlds current arrangements seemed to continue). We were concerned that this could distort the assessment. Consequently, following discussion and clarification with the ENA, we assessed World A on the basis that the DSO was required to aggregate DER under each GSP to offer flexibility into the Balancing Mechanism and Balancing Services Markets, but not responsible for energy balance at each GSP. We considered that this should avoid any issues around non-compliance with European Network Codes and removes the risk of distorting the results of the Impact Assessment.

iii) **What are the co-ordination mechanisms in place in World B?**

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[18] http://www.energynetworks.org/assets/files/Modelling-DSO-Transition-Using-SGAM_Issue2.1_PublicDomain.pdf see p18

[19] http://www.energynetworks.org/assets/files/14969_ENA_FutureWorlds_AW06_INT.pdf see p 17

[20] We are grateful to Elexon for talking us through some of the implications.

It was not clear what processes or mechanisms would be used in World B to help resolve conflicting uses of DER flexibility between the ESO and DSOs. The SGAM modelling did not go into these more commercial design details. In order to assess World B, we needed to understand how these processes or mechanisms might work, particularly to inform the level of control each system operator would have and certainty that its needs could be delivered through flexibility.

To provide some of the information we needed, we made the assumption that the DSO's needs would be prioritised, with the residual flexibility offered by DER being available to the ESO. Where the distribution networks are not constrained, the full flexibility from DER could be offered to the ESO..

iv) **Is it correct for World C to be based on a variant of World B?**

We were concerned that World C was based on a variant of World B, when in reality reformed access and charging arrangements would likely be a feature of any Future World, particularly now that Ofgem has launched its Significant Code Review.

Consequently, we proposed to assess the aspects of access and charging reform in World C separately, before combining this with all four other Worlds, and not just World B. This enabled us to consider the benefits of reformed access and charging on its own, and then to assess the additional costs and benefits of the other four Worlds on an equal footing.

We are conscious that Ofgem's significant Code Review has set out more detail on the types of network access and forward looking charging signals which could be implemented. These details were not available at the time of the modelling. We have deliberately sought to keep the definition of World C at a high level (comparable to the other Future Worlds). Therefore, the definition of World C should not be interpreted as an assessment of the reforms Ofgem has outlined in its Significant Code Review.

v) **To what network level does the ESO co-ordinate flexibility in World D?**

The ENA consultation and SGAM modelling deliberately left an open question as to how far down the distribution network the ESO would seek to co-ordinate DER flexibility. For the purposes of the Impact Assessment we needed to understand whether the intention was that there would be any co-ordination of flexible resources at Low Voltage (LV) in World D.

We took the view that in the initial stage of development, the ESO would only co-ordinate flexible DER down to HV level on the distribution network. By Stage 2, we assumed that this could then expand down to LV, if reformed access and charging arrangements prove not sufficient alone to optimise usage of the LV networks.

vi) **What is the role of the Flexibility Co-ordinator(s)?**

There are a number of potentially different interpretations of the role of the Flexibility Co-ordinator(s) in World E. In some interpretations, this could be seen as simply a platform which DSOs and the ESO use to procure flexibility resources. Or, at the other end of the spectrum, it could be seen as a full independent system operator. The ENA's consultation also posed an outstanding question over whether this was a single, national Flexibility Co-ordinator or a set of regional Co-ordinators. The answer would have important cost implications which we needed to consider in the Impact Assessment.

We have taken the view that a market platform provider could exist in any of the Future Worlds (and DNOs are already starting to use such platforms to procure flexibility from DER). Consequently, we concluded that in Stage 1, World E was more about independent parties taking procurement decision on where flexible solutions provide a lower cost alternative to capital solutions. This requires the ESO and DSOs to provide the Flexibility Co-ordinators with their network requirements and costs of capital solutions. Importantly, the Flexibility Co-ordinators do not dispatch DER in this stage.

In Stage 2 of development, we assume that the Flexibility Co-ordinators take responsibility for a number of key system operation functions, including connections and the decisions on when to dispatch DER (similar to the ESO's role at Transmission). In effect, the Flexibility Co-ordinators are regional independent distribution system operators, with clear responsibilities and accountabilities.

There was an outstanding question over the number of Flexibility Co-ordinators which should be included in the modelling. We have assumed four[21] Flexibility Co-ordinators on the basis that they are likely to evolve in regions where there are widespread network constraints. It seemed sensible to assume that these regions would be Scotland, South East, South West based on today and potentially in the North looking further head. The assumption is that the Flexibility Co-ordinators emerge in these regions and expand to cover the entire network.

Figure 4 below provides a high level summary of the definitions we have used for the Future Worlds in both Stage 1 and Stage 2. The pink text highlights the additions which we have made as outlined above. This has been deliberately kept at a conceptual level, to reflect the key differentiating aspects of the Future Worlds as outlined in the ENA's consultation document. [22]

Figure 4 Interpretation of the Future Worlds used for Impact Assessment

	Stage 1	Stage 2
World A	• DSO co-ordinates the majority of flexible DER down to LV but there remains an option for the ESO to procure services directly • The ESO provides the DSO with its residual requirements for flexibility services from DER	• The DSO becomes responsible for the co-ordination of all DER • The DSO is responsible for managing flows across the GSP to meet ESO needs (both constraints and national balancing) as part of aggregating DER into national ESO markets
World B	• Co-ordinated management of DER flexibility between ESO and DSO • DSO constraints are generally prioritised as being met first where the DSO has no alternative resources	• As per stage 1 but with more detailed rules to co-ordinate dispatch of DER and manage a greater volume of DER on the system.
World C	• Increased choice in network access products and increased time of use and locational price signals down to HV with some static time of use at LV and simple access products	• Granular, dynamic price signals flow down to and including LV substation level
World D	• The ESO co-ordinates all flexible DER down to HV • Below HV the DSO relies mainly on asset solutions to manage the network (other than ToU charging signals)	• The ESO co-ordinates all flexible resources down to and including LV
World E	• There are regional Flexibility Co-ordinators which undertake all procurement of flexibility and undertakes the assessment of the costs of flexibility compared to the asset costs provided by DSOs and ESO • The Flexibility Co-ordinators do not undertake dispatch of resources at this stage	• Regional Flexibility Co-ordinators now assume the role of dispatching DER resources to meet ESO and DSO needs • In order to optimise dispatch decisions, the Flexibility Co-ordinators take on more operational responsibility

We would stress that these are not the only interpretations of the Future Worlds and that there could be several variants. In developing these, we have tried to be as true as possible to the original intention of the ENA and the SGAM modelling. We are conscious that since our work started on the

[21] Although as explained in Section 3 we are including a single flexibility co-ordinator as part of the sensitivity analysis.
[22] http://www.energynetworks.org/electricity/futures/open-networks-project/future-worlds/future-worlds-consultation.html

Impact Assessment, Ofgem has published considerably more detail on what reformed network access arrangements and forward looking charges could look like.[23] For the purposes of the Impact Assessment we have treated World C at a conceptual level (in the same way as the other Worlds), rather than seeking to model specific arrangements. The results should be viewed in this light.

2.3 Developing the definitions of the Future Worlds further

There remain some uncertainties surrounding how the Future Worlds will operate from a commercial perspective. Understandably, the SGAMs did not go into this detail as it is a complex area and separate from how operational information will be exchanged.

This does limit the ability to really understand how the Future Worlds will operate and in particularly where risk will sit. For example, in World D, if the ESO cannot meet the DSO flexibility requirements, are there associated penalties or compensation which it needs to pay, or does that risk sit with the DSO? The answer to this question could have a bearing on the level of resilience the DSO builds into its network. We have not necessarily required this information for the purposes of this initial Impact Assessment but we consider it will be important when looking to assess the Future Worlds in greater detail and understanding where ultimate accountability lies.

[23] https://www.ofgem.gov.uk/publications-and-updates/electricity-network-access-and-forward-looking-charging-review-significant-code-review-launch-and-wider-decision

Baringa
Brighter together

3 High level approach

3.1 Summary of our approach

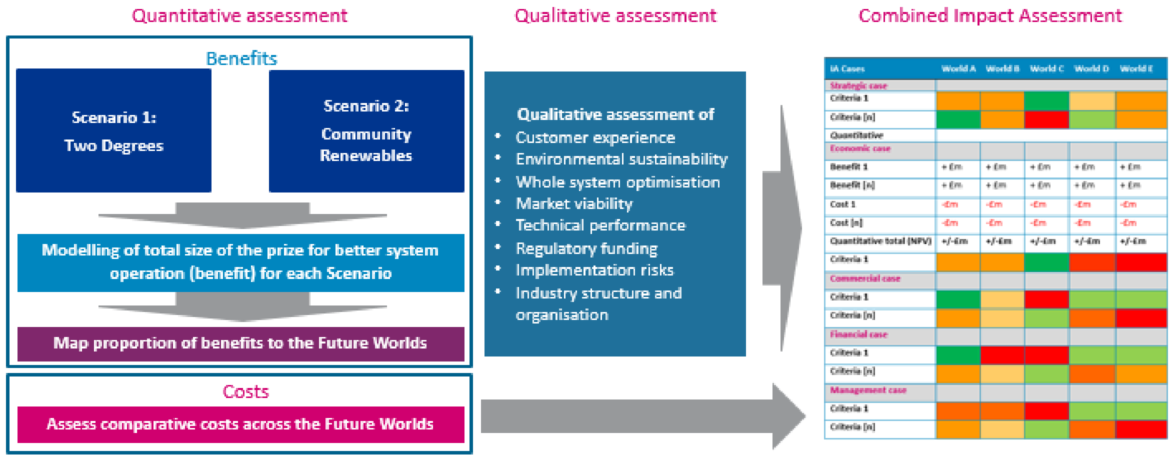
We consider that it is important that industry parties and wider stakeholder understand the approach we have taken so that they can engage with it, challenge it and build on this initial Impact Assessment. Consequently, we have looked to use as simple and transparent approach as possible and have made available the Excel models containing our calculations and assumptions for the Impact Assessment. We have sought to use publically available data for the vast majority of our assessment.

We have broken the assessment down into three separate methodologies which come together to form the overall Impact Assessment

- **Benefits Assessment**: We have looked to quantify the benefits which each of the Future Worlds can deliver. We have undertaken a high-level assessment of the quantum of benefits which might be available through improved system operation and assessed how each of the Future Worlds performs in delivering these benefits.
- **Cost Assessment**: Using a baseline of technology and resource costs, we have assessed how these vary in each Future World through the combination of:
    - The size of the different DSO functions required by different actors in each Future World;
    - The degree of duplication of functions across actors within each Future World; and
    - The economies of scale which exist for the functions undertaken by each actor within each Future World
- **Qualitative Assessment:** We have undertaken a relative qualitative assessment of how the Future Worlds perform against over 30 different criteria set out by the ENA and amended as a result of feedback from stakeholders. These include the customer experience, environmental sustainability, whole system optimisation, technical performance and industry structure and organisation.

Figure 5, below, provides a graphical summary of how these three element come together to form a combined Impact Assessment.

Figure 5 High-level summary of methodology[24]



The full detail of our cost and benefit assessment methodology can be found in Appendices B and C. Below we have provided a high level summary of each, as well as a description of how we approached the qualitative assessment.

3.2 Benefits assessment

There were two main steps in our quantitative assessment of benefits.

1) **Assess the level of potential benefits available through better system operation – the 'size of the prize'**.

We assessed the potential benefits which might be possible under two of the FES - Community Renewables and Two Degrees. These were chosen as the scenarios which both delivered Government carbon targets but through a different mix of centralised and decentralised resources, which we believe could be a key factor in determining the DSO transition.

We identified four broad categories of benefit which would form an appropriate basis to assess the relative strengths and weaknesses of the Future Worlds:

- Avoided Transmission Investment (reinforcement costs less costs of managing constraints);
- Avoided Distribution Investment (reinforcement costs less costs of managing constraints);
- Reduced Balancing Service costs (balancing services excluding constraints); and
- Avoided generation investment (due to peak demand reduction)

This step was designed to understand the quantum of benefits which might be possible through better system operation down to the distribution level, and how these benefits are proportioned across the four categories. This was important since different Future Worlds might be better or worse at delivering certain categories of benefit. We did not seek to quantify the wider benefits to the energy system as this would have added considerable complexity and required further assumptions to be made on the Future Worlds. We did not feel this would be appropriate for an initial Impact Assessment and would make it more difficult for stakeholders to engage with the

[24] Please note that for ease of reference we have not illustrated the full qualitative criteria used in the assessment

approach and challenge the results. A broader whole systems assessment may be more appropriate at a later stage, once the Future Worlds have been developed in more detail.

2) Mapping the proportion of benefit to each Future World

We used a series of assessments to map the proportion of the benefit in each of our four categories to each of the Future Worlds, in each stage of development. The basis for this assessment was the assumption that system operation will be driven by three key factors:

- Primary control (for dispatch of DER)
- Certainty of response (from DER), and
- Maximising participation in markets (reducing cost through greater competition).

We acknowledge that this is a simple approach but we consider that it gets to the heart of what system operators need to do in order to co-ordinate and manage DER effectively and is a suitable way to assess the Future Worlds at the level they are currently defined.

For each benefit category, we assessed the importance of each of the three factors in delivering the benefit. This was used to provide a weighting for the benefit available under each factor. We then assessed how each Future World performed against that factor for each benefit category. We have included an actual example in Table 2 below which is based on the assessment of the avoided Transmission Investment in World D.

Table 2 Assessment of the proportion of avoided Transmission investment allocated to World D

Benefit	Primary control	Certainty of response	Facilitation of markets
Avoided Transmission network investment (£727m[25])	Critical factor	Critical factor	Lower importance
Proportion of benefit to allocate	40%	40%	20%
Maximum benefit available per factor	£291m	£291m	£145m
World D performance			
Proportion of benefit per factor	75%	75%	50%
Benefit to allocate	£218m	£218m	£73m
Avoided Transmission investment benefit allocated to World D		**£509m**	

Our approach to assessing benefits makes a number of key assumptions. These are listed in Appendix B. The most important of these was the assumption that when Worlds A, B, D and E mature into Stage 2 of development they are all capable of delivering all of the potential benefits if well designed and effectively implemented. Instead the Worlds are differentiated by the speed by which they can achieve Stage 2 (and realise all the benefits), and the costs of getting there.

The exception to this assumption is World C. We believe that it is not possible to achieve all of the benefits through reformed network access and charging signals alone, and there will always be a requirement for a system operation function at the transmission and distribution level to a greater or

[25] Results of our modelling out to 2030, on an NPV basis under the Community Renewables scenario

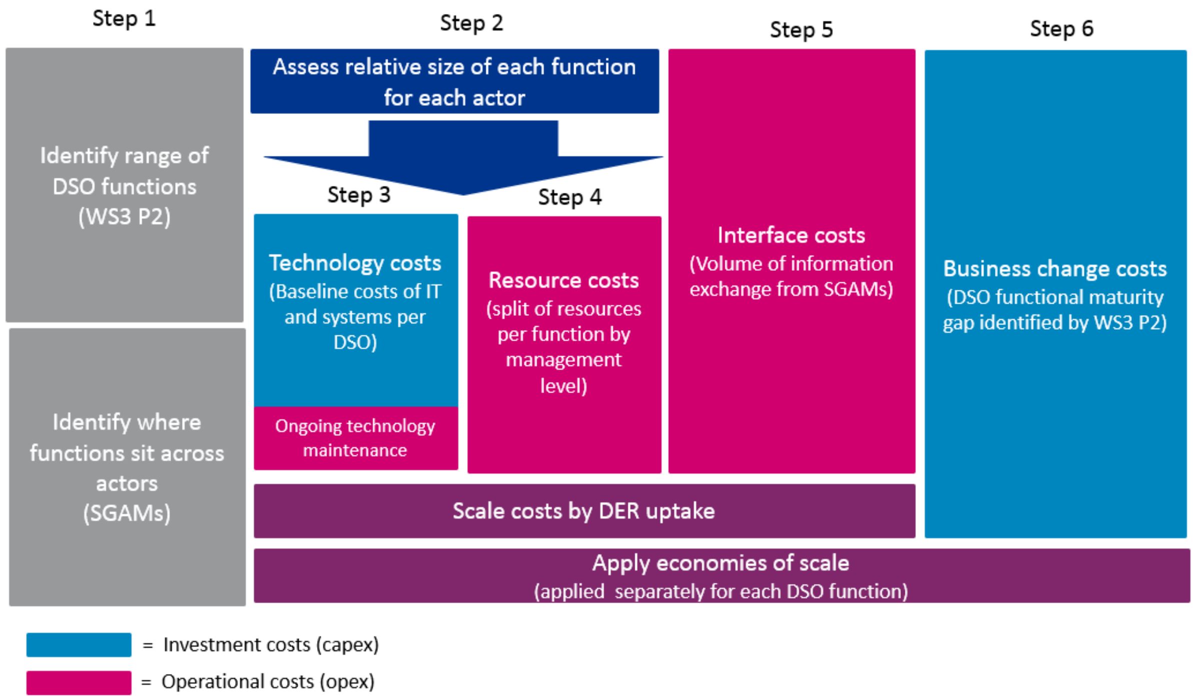
lesser extent. The question is how much can be achieved through reformed access and charging alone (and hence our assessment of World C in isolation), and how extensive with the system operation functions need to be.

3.3 Cost assessment

We used a bottom up approach to assess the costs of the Future Worlds. This approach was based around using the information within the SGAMs[26]and also the mapping of DSO functional requirements and a maturity gap assessment produced by the ENA.[27] This information focuses on the impact of the Future Worlds on system and market operators (ESO, DSO and Flexibility Co-ordinator). As part of the qualitative assessment, we have looked at the cost impact on other parties.

The cost assessment was based around the six key steps which we illustrate in Figure 6 below.

Figure 6 Summary of cost assessment approach



1) **Identify the DSO functions and where those functions sit in each Future World:** We used the list of DSO functions developed by the ENA and the SGAM modelling to understand where functions sat across different actors (DSO/ESO/Flexibility Co-ordinator) in each Future World. In some cases functions are duplicated across multiple actors. We developed operating models to depict this visually which are contained in Appendix C.

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[26] http://www.energynetworks.org/electricity/futures/open-networks-project/future-worlds/future-worlds-consultation.html

[27] http://www.energynetworks.org/assets/files/electricity/futures/Open_Networks/ON-WS3-P2%20DSO%20Functional%20Requirements-170925%20Published.pdf

2) **Assess the relative size of DSO functions for each actor in each World:** We looked at the relative size of the functions required between actors based on their role in each Future World.
3) **Technology costs:** We developed a set of baseline technology costs for each DSO function which had been outlined by the ENA in its DSO functional requirements. We issued a data request to the ENA Product Team to help validate assumptions made on these costs. The baseline costs were established on the basis that there are six separate DSOs each requiring the technology.[28] In identifying the relevant technology costs we have focussed on the technology needed, over and above initial expenditure required on monitoring equipment and communications which will be common across all Future Worlds. We scaled the baseline technology costs based on the size of the function for each actor in each World. We also scaled the costs for each function according to DER uptake.
4) **Develop resource costs for each function:** We developed a baseline resource cost for each function. These were based on the number of people and management structure required to run each DSO function. We scaled these resources in line with the functional thickness for each actor in each Future World (as per step 3) and also forecast DER uptake from the FES.[29]
5) **Assess the interface costs in each Future World:** We wanted to understand the different costs associated with information exchange and co-ordinating with other actors in each Future World. We used data in the SGAMs on the volume of information exchanges as the basis for our analysis. We scaled up these interface costs over time based on the increasing take-up of DER.
6) **Understand the business change costs associated with each Future World:** We wanted to recognise that the capex costs were not simply the technology costs but the costs of integrating that technology into the business. We used the DSO functional requirements produced by Workstream 3 as an input to understand the functional maturity gap for the different DSO functions. We applied the same methodology to assess the functional maturity gap in each Future World. We used the relative scores to inform the proportion of technology costs to allocate to business change for each function in each Future World.

Across steps 3 to 6 we looked to see where it was appropriate to apply economies of scale, on the basis that either a single party was operating a GB wide function, or that the function was split between multiple parties. We applied a different economies of scale factor for each function in each Future World to reflect the fact that the economies of scale are not uniform and that centralising functions does not eliminate all duplication of costs.

Figure 7 below provides a high-level summary of how we looked at the functional thickness, extent of duplication and economies of scale, illustrating each of these as low (L), medium (M), high (H) or very high (VH) This is a summary for each actor in each Future World. For the analysis we undertook that same assessment for every function performed by each actor, in each Future World. Appendix C outlines this approach in more detail, including the key assumptions which underpinned our cost assessment The arrows in the diagram illustrate the key changes in function size in Stage 2, compared to Stage 1.

[28] The costs are then scaled depending on which Future World they are being applied to, in order to take account of the different economies of scale

[29] Since the cost assessment was scenario agnostic, we used an average of DER take-up across both the Community Renewables and Two Degrees scenarios.

Figure 7 Key areas of cost assessment approach

Worlds	Actor	Stage 1 Functional Thickness	Stage 1 Fn. Duplication across actors	Stage 1 Dis-economies of scale	Stage 2 Functional Thickness	Stage 2 Fn. Duplication across actors	Stage 2 Dis-economies of scale
World A	DSO	H	M	H	VH ↑	M	H
	ESO	L			L		
World B	DSO	H	H	H	H	H	H
	ESO	H			H		
World C	DSO	VL	L	H	L ↑	L	H
	ESO	VL			L ↑		
World D	DSO	L	L	L	L	L	L
	ESO	H			VH ↑		
World E	DSO	H	M	H	L ↓	L ↓	M ↓
	ESO	H			L ↓		
	FC	L			H ↑		

In addition, our work has built on the SGAMs and Functional Requirements work already undertaken by the ENA. This is entirely focussed on network operators. Consequently, our quantified cost assessment is limited to how the costs of the Future Worlds will impact network operators. There is no similar detail available in the ENA's work to date to be able to model the impact of the DSO on other stakeholders in the same way. However, we captured this qualitatively and we held a specific session with stakeholders through the Open Networks Advisory Group to understand the different impact which each Future World might have on them. This has helped inform our qualitative assessment.

3.4 Assessing the timing of Stage 2

As outlined in Section 2, in order to understand the evolution of the Future Worlds, we defined two stages of development – an initial state and end state. This was designed to reflect the different rate of evolution which might be possible for each Future World. This approach required us to undertake an assessment of when each Future World might mature to Stage 2. This has an important bearing on the results, given the assumption that in Stage 2, a Future World can deliver all of the theoretical benefits available.

We identified three key drivers which would influence the timing of when a Future World could mature to Stage 2:

- **The functional maturity gap**: As part of the functional requirements work undertaken by the ENA, it produced an assessment of the maturity gap to DSO.[30] We expanded on that for the cost assessment of each Future World. We used the results to understand the maturity gap which existed to develop DSO functions from today to the start of Stage 2.

[30] http://www.energynetworks.org/assets/files/electricity/futures/Open_Networks/ON-WS3-P2%20DSO%20Functional%20Requirements-170925%20Published.pdf

We made the assumption that the larger the gap, the longer it was likely to take for a Future World to mature to Stage 2.

- **The level of business change required**: We assessed the structural changes required to enter Stage 2. This related to the complexity of implementing Stage 2 of each Future World compared to today's arrangements. This particularly focused on the level of change required within system operators. The greater the change needed, the longer it is likely to take a Future World to mature to Stage 2.
- **The level of technological change needed**: We looked at where technology would need to advance to in order to enable a Future World to deliver the full benefits in Stage 2. The greater the reliance on new, more advanced technology the longer it is likely to take to mature to Stage 2.

The results of this assessment provided us with a series of relative scores. We then looked at the potential timing of price control periods to understand the most likely dates when substantial changes to network operation could be implemented. We used these to select dates for each Future World to mature to Stage 2, based on the relative scores of the assessment. This assessment approach was not seeking to forecast a precise date for when each Future World might transition into Stage 2. It is using the results to assess the relative differences in this timing based on the likely price control periods. Table 3 below outlines the results of this assessment.

Table 3 Timing of the Evolution to Stage 2 in each Future World.

	World A	World B	World C	World D	World E
Maturity gap to Stage 2	Low	Medium	Medium	Medium	High
Business change required for Stage 2	Medium	Low	Low	V High	V High
Technology gaps to Stage2	Medium	High	High	Medium	Medium
Stage 2 implementation	**2028**	**2028**	**2028**	**2031**	**2036**

We have used these results as a key part of the quantitative assessment presented in Section 4.

3.5 Addressing the range of uncertainties in future costs and benefits

We were conscious that there are a number of areas of the quantitative assessment where we had to make assumptions around future costs and benefits, some of which are highly uncertain at this stage. In recognition of this uncertainty, we used a pessimistic, central and optimistic case for a number of important assumptions, as set out in Appendices B and C. We have only applied this range of uncertainty to the inputs for our assessment. We acknowledge that there are uncertainties over the relative performance of the Future Worlds also, but we considered that the purpose of the Impact Assessment was to provide some initial views on this which can be built on over time. Consequently, we have not applied any uncertainty ranges to the actual relative assessment of the Future Worlds at this stage.

While these cases lead to a broad range of results, we consider that this is more reflective of the uncertainties which exist. We were keen to avoid firm conclusions being drawn on the back of assumptions which are inherently very uncertain.

3.6 Qualitative assessment

The qualitative assessment was based on the criteria set out by the ENA in its Future Worlds consultation.[31] The qualitative assessment is structured around the HM Treasury's five case model for assessing business cases, which is highlighted as best practice for public sector impact assessments. The five cases are as follows:

1. **The Strategic case** – the overall rationale and objectives for the change
2. **The Economic case** – ensuring that the change will result in public value
3. **The Financial case** – ensuring that the preferred option is affordable
4. **Commercial case** – ensuring that the preferred option will result in viable outputs (in this case, markets and regulatory frameworks)
5. **Management case** – getting the incentives right to deliver the change.

The Impact Assessment we are undertaking is an initial one to compare the relative strengths of different options rather than decide on a single option to implement. However, the five cases provided useful lenses through which to assess the Future Worlds. There were over 30 criteria set out by the ENA and we have added to those based on responses to the Future Worlds consultation. Table 4 outlines how the criteria fit under each of the five cases.

[31] http://www.energynetworks.org/assets/files/14969_ENA_FutureWorlds_AW06_INT.pdf see section 6.5

Table 4 Qualitative assessment criteria

Strategic Case	Economic Case	Financial Case	Commercial case	Management case
Enhanced customer experience	**Whole system optimisation**	**Market/regulatory viability and available funding**		**Industry structure and organisation**
Choice	Supports whole system optimisation	Compatibility with regulatory funding	Market viability	Levels of rules required
Fairness	Optimises locally	Funding available to support market participation	Appropriate regulation in place	Delivers fair, neutral and transparent markets
Affordability	Brings more flexibility into the system			Complexity of operating the Future World[32]
Confidence and Trust	Manages conflicts			Difficulty to implement [33]
Consumer benefits from Markets	Avoids duplication			Future Proof
	Exploits synergies			
Greater environmental sustainability				**Technical performance**
Facilitates greater energy efficiency				Degree of safety risk
Facilitates decarbonisation of generation				Service availability and reliability
Facilitates decarbonisation of heat and transport				Physical and cyber security
More electricity consumers closer to point of generation				Resilience and recovery
				Clear dischargeable accountability

We amended a few of these criteria based on responses to the ENA's consultation. A full set of the definitions for each criteria is included in Appendix A.

[32] We assessed this from both a system operator and market participant perspective
[33] We assessed this from both a system operator and market participant perspective

Our approach was to identify the key drivers of performance against each criterion and assess each Future World against those drivers. We have described these drivers and included the detailed assessment against the qualitative criteria in Appendix A.

As part of the qualitative assessment we also looked at the risks, conflicts and potential unintended consequences of the DSO transition, which could have a detrimental impact on consumers, and sought to identify potential mitigations. We ran a workshop with the ENA's Advisory Group to help identify issues, their potential impact and possible mitigation strategies. We identified the following categories where risks, conflicts and unintended consequences are likely to arise:

- System operator conflicts;
- Gaming and market power;
- Operational integrity;
- Distributional impact on consumers;
- Network resilience and security; and
- Risk of regret.

We worked with stakeholders in a workshop to identify different issues under each category and then undertook a mapping exercise to understand which were high impact and high complexity to solve and what mitigation approach was required. The full write up of that session is included in Appendix D.

3.7 Engagement approach

We undertook considerable engagement with the ENA and broader stakeholders throughout the project. We used this engagement to test and validate the assumptions we were making and to gain data inputs to use in our modelling and assessment. This was designed to support our independent assessment through providing different perspectives and challenges, rather than being used to direct the results. We engaged with the following parties as part of the Impact Assessment:

- **ENA Work stream 3 Product Team** – weekly calls to stress test our assumptions and methodology and data request to validate inputs to the cost assessment;
- **ENA Work stream 3** – monthly meetings to present progress and validate the emerging results;
- **ENA Open Networks Steering Group** – monthly meetings to validate key strategic messages emerging from the Impact Assessment;
- **ENA Open Networks Advisory Group** – An initial meeting to validate the methodology, a specific workshop on the cost impact of the Future Worlds and a second workshop on unintended consequences;
- **Ofgem/BEIS** – Meetings to explain the overall methodology and to present emerging results.

In addition to these meetings, we undertook an in depth review of responses to Section 6 of the ENA's consultation on the Future Worlds. Section 6 specifically covered the approach to the Impact Assessment. There were no points raised by respondents that caused a fundamental change to our approach. However, we did broaden the qualitative criteria as a result of the comments and observations raised by respondents. Separate to this report, we have also developed a summary of responses to Section 6 of the ENA's consultation and a mapping exercise where we assessed how the points raised fitted against the existing criteria. This directly led to the addition of the new criteria.

3.8 Limitation of the Impact Assessment

The focus of the Impact Assessment has been to gain an initial sense of the relative differences, strengths and weaknesses of the Future Worlds. We have employed a simple methodology to do this in order that it can be fully understood, challenged and updated over time. The results we have produced need to be seen in this context.

As an example, we have focused the cost assessment only on incremental costs for network operators. This means that the results we have produced should not be viewed as the total cost of building out Future Worlds. This would need to include a number of baseline costs such as monitoring equipment, communications, smart metering data which we have not included because they are common across all Future Worlds and will make little difference to the relative assessment. We have not included these baseline costs in our assessment and consequently, the results are not at a level of detail which could support RIIO business plans. This was not the aim of the Impact Assessment and a more detailed bottom up assessment of total costs would be required.

We are aware that a number of other studies have been undertaken looking at absolute benefits which a more flexible energy system can deliver; for example the Imperial College and Carbon Trust work being the most frequently referenced.[34] These studies deployed complex whole system energy modelling which has been refined over a number of years. We have not chosen to go into this detail, partly due to the time available for the Impact Assessment. However, we also consider that this type of detailed systems modelling would not be appropriate to apply to the Future Worlds, given that they are still defined at a conceptual level. It would require a significant number of assumptions be made on the performance of the Future Worlds which would not be transparent to stakeholders. We consider it is more appropriate to take a high-level approach which provides some clear indications of how the Future Worlds might perform. We have captured this performance within simple Excel models where inputs can be amended. This allows the methodology to be tested and updated over time.

Consequently, the absolute quantified results of our high-level approach should not be compared directly to those generated from other studies which are based on more detailed bottom up modelling. We have sought to tease out the relative differences between the Future Worlds in a transparent way, and not provide a definitive view on the benefits of better system operation and flexibility across the energy system.

[34] https://www.carbontrust.com/news/2016/12/capturing-the-benefit-of-a-smart-flexible-energy-system/

4 Summary results of the Impact Assessment

4.1 Introduction to results

The Impact Assessment has produced a huge volume of results and insights which we have sought to summarise in the main body of this report. We have structured this section to first provide a high-level summary of the relative strengths and weaknesses of the Future Worlds. We then outline the results of the quantitative assessment, looking separately at the benefit and cost assessment before presenting how they combine to produce overall net benefits. Lastly, we outline the results of the broad qualitative assessment and provide a summary of performance across the HM Treasury's five cases.

4.2 High level summary

In Table 5 below we provide an overview of the relative performance of the Future Worlds against the HM Treasury Five cases and the sub-categories which sit beneath them.

Table 5 starts to illustrate that there are trade-offs between the performance of the Future Worlds. The assessment in Table 5 is designed to illustrate the relative performance of the Future Worlds, with dark blue indicating relatively strong performance and light blue indicating relatively worse performance. For clarity, a light assessment does not mean that the Future World has a detrimental impact, merely that it performs relatively less well compared to the other Future Worlds.

We have only shown the clear differences we have identified between the Future Worlds in Table 5. We would stress that this is very much a summary of the overall performance and that readers should review the rest of this section and Appendix A for a full view of the performance of the Future Worlds and the reasons driving this assessment.

Table 5 Summary of relative strengths and weaknesses against five Cases

Summary areas	World A	World B	World C	World D	World E
Strategic case					
Enhanced customer experience					
Greater environmental sustainability					
Economic case					
Whole system optimisation					
Least cost (investment and operational)					
Net financial benefits (out to 2050)					
Financial case					
Regulatory funding					
Commercial case					
Market/regulatory viability					
Management case					
Industry structure and organisation					
Technical performance					

4.3 Quantitative assessment results

Our quantitative results are comprised from both the assessment of benefits and costs. They provide a view on the performance of the Future Worlds but given the uncertainties over future costs and benefits, we highlight that the results should be viewed alongside those from the qualitative assessment in Section 4.4 which provide a broader insight into the overall performance of the Future Worlds.

4.3.1 Benefits assessment results

Overall size of the prize

Our benefits results illustrate the relative performance of each Future World in saving money across four categories:

- Avoided Transmission investment;
- Avoided Distribution Investment;
- Reduced Balancing Services costs; and
- Avoided Generation investment.

Full descriptions of each of these categories are provided in Section 3. Figure 8 below illustrates a breakdown of the overall size of the prize across each of the four benefit categories. We have shown this as a percentage to make it easier to view the proportions. .

Figure 8 Proportionate breakdown of benefits by category

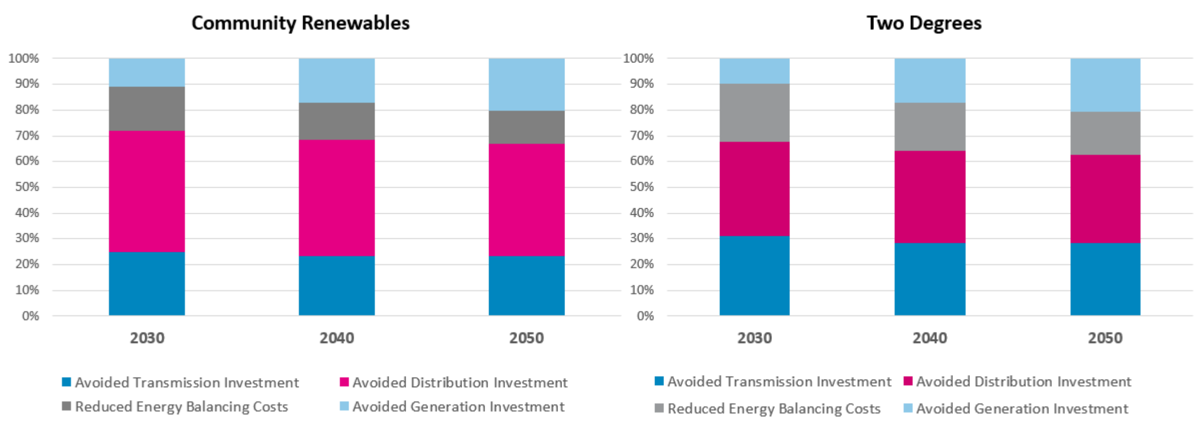


Figure 8 shows that the avoided Transmission investment and reduced Balancing Services costs comprise a higher proportion of the benefit stack under the Two Degrees scenario. This is because there is more new generation connected to the Transmission system in this scenario, and hence the greater potential for deriving benefits from avoiding Transmission reinforcement and reducing constraint costs. By contrast, under the Community Renewables Scenario, there is more DG and hence the greater potential benefits of more effective system operation are at the distribution level, by way of avoided distribution investment.

It is also worth highlighting that the benefits of reduced energy balancing costs appear to decrease over time. This simply reflects that they do not increase over time in the same proportion as the other benefit categories.

Proportion of benefit accrued in each Future World

Figure 9 below outlines the results of applying our assessment of the performance of each Future World to our benefits stack. We have not made any assumptions on how these benefits are shared between network operators and network users as this would require forecasting future regulatory arrangements. The gross benefits are presented taking into account the costs of paying flexibility providers for response (or in the case of World C the cost to flexibility providers of providing the response).[35] All investment and other operational costs are captured within the cost assessment as set out in Section 4.3.2. These are subtracted from the gross benefits to produce the net benefits as set out in Section 4.3.3.

The results in Figure 9 are based on the Community Renewables scenario. The scale of gross benefit increases in each time period. The black line illustrates the results based on our central set of input assumptions with the coloured blocks illustrating the range between our pessimistic (low benefit, high cost) and optimistic (high benefit, low cost) input assumptions.

Figure 9 Results of relative gross benefit assessment under Community Renewables scenario, £m NPV 2018/9 prices

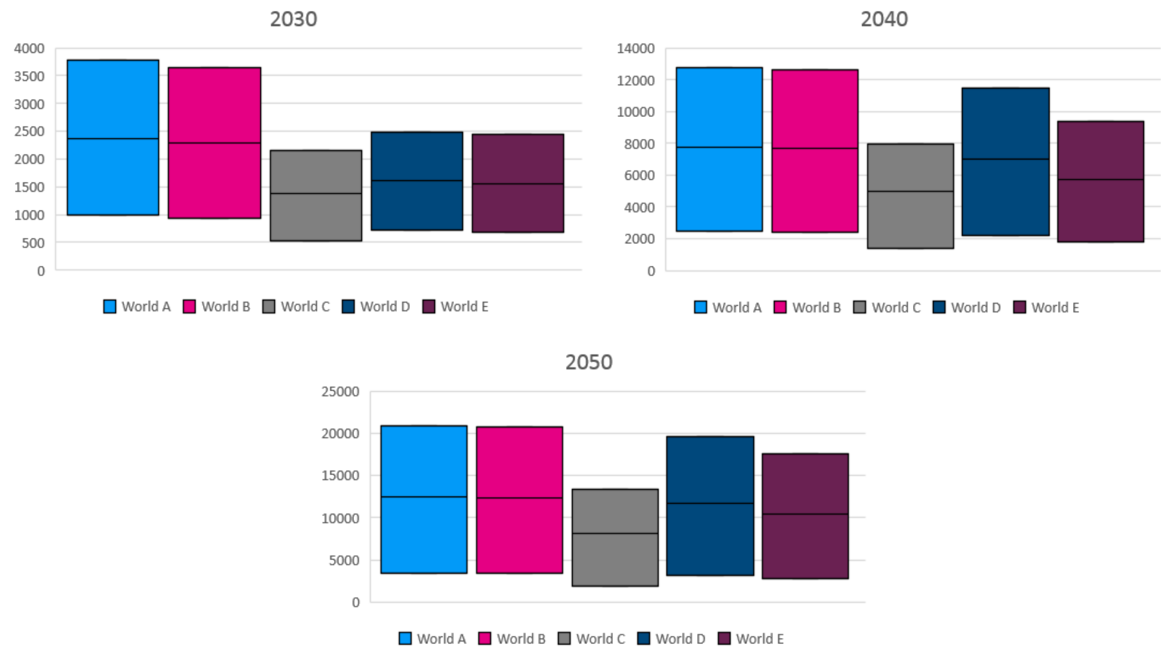


Figure 10 below illustrates the same results based for the Two Degrees scenario.

[35] We assume this is the same as the price paid for flexibility in the other Future Worlds since that price should presented the cost to the providers of changing behaviour

Figure 10 Results of relative gross benefit assessment under Two Degrees scenario, £m NPV 2018/9 prices

There is very little difference in the results between the two scenarios. The results in both scenarios highlight that by 2030, Worlds A and B are performing relatively better, but by 2050, the results across Worlds A, B, D and E broadly converge. The performance of World C indicates that reformed network access and charging arrangements can deliver significant benefits, but more evolved system operation is needed to deliver all of the potential benefits. This reinforces our assessment that some elements of World C will likely feature in any Future World, but World C in isolation is unlikely to be the preferred enduring model.

The convergence of results for the remaining Future Worlds after 2030 is a consequence of two factors. The first is driven by our assumption that in Stage 2 all Future Worlds (except World C) can deliver all of the available benefits. The second is that our assessment indicates that the majority of benefits are available after the 2030s – once we assume that most of the Future Worlds mature into Stage 2. Figure 11 below highlights the increase in benefits over time and how they are stacked towards the end of the assessment period.

Figure 11 Benefits accrued from 2027 to 2050, £m NPV 2018/9 prices (Community Renewables)

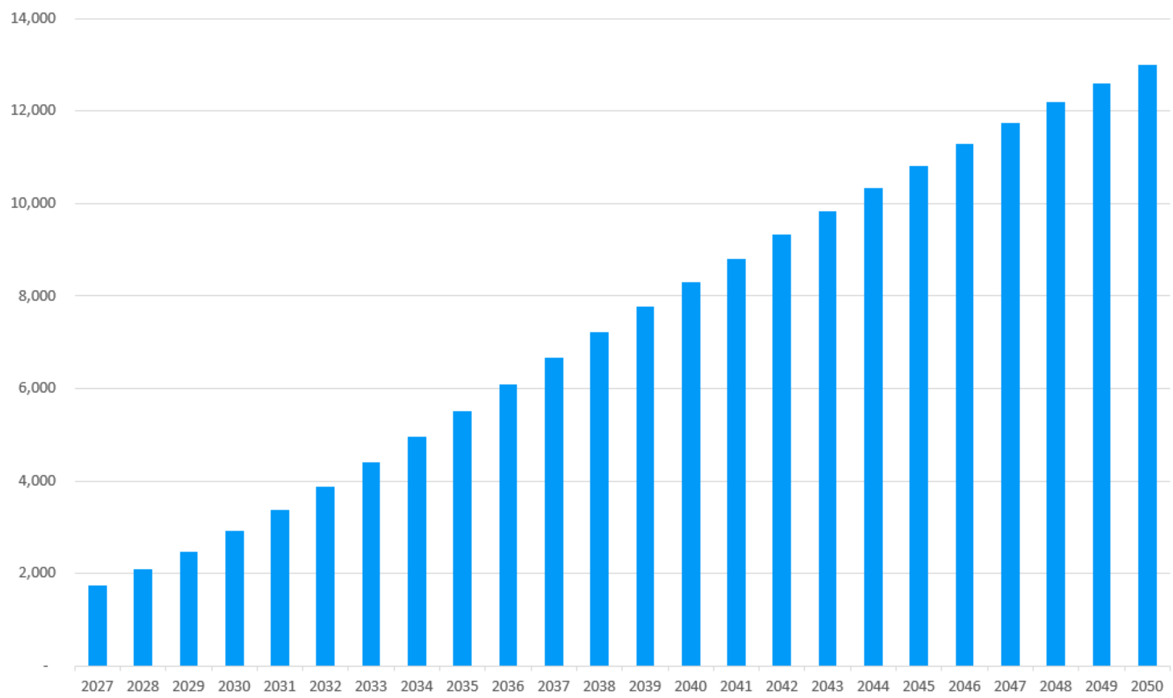
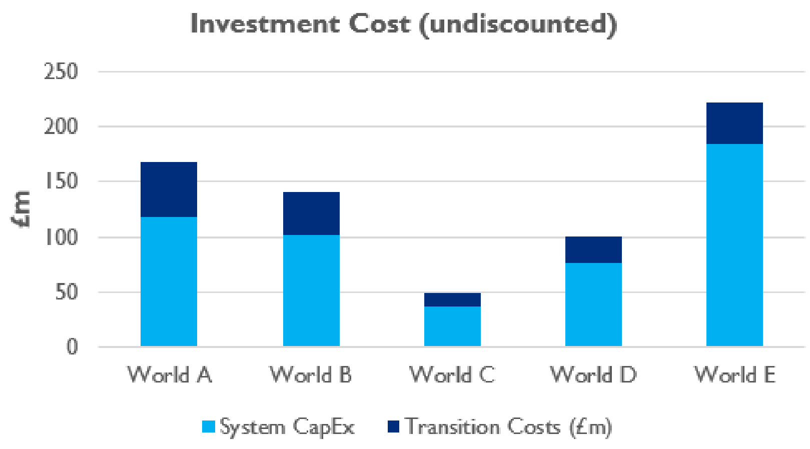


Figure 11 illustrates the extent to which the benefits are stacked towards the end of the period. Our relative assessment of the work required for each World to mature to Stage 2 has led us to the assumption that Worlds A, B and C enter Stage 2 of development and deliver all the benefits from 2028 onwards, with World D in 2031 and World E in 2036. Given that it is after these dates when the benefits are highest, it explains why by 2050, the performance of the Future Worlds is similar.

4.3.2 Cost assessment results

We undertook a separate assessment of the investment and operational costs required in each Future World to deliver the benefits outlined in Section 4.3.1 above. Figure 12 below illustrates the relative total investment costs required for each Future World out to 2050. These are based on our central case and have not been discounted, in order to illustrate the relative scale of investment required (discounted results are shown later on).

Figure 12 Overall Investment costs to 2050 across the Future Worlds[36], £m 2018/9 prices (central case)



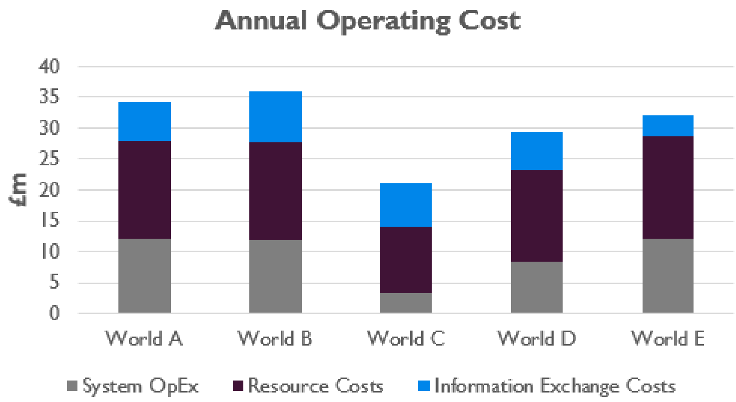
We should highlight that there is a range of uncertainty over the level of investment costs and we have chosen to show our central case here to more clearly highlight the relative differences. We have focussed on the core new costs required for the Future Worlds to understand the relative differences. Consequently, the absolute numbers should not be interpreted as overall costs of transitioning to the Future Worlds.

The results show that the standalone investment costs for World E are likely to be higher than the other Future Worlds. The costs in Worlds A and B are similar, although World A is slightly higher, mainly due to the additional investment required by each DSO in Stage 2 aggregate DER flexibility into balancing markets. Ignoring World C (on the basis that it has a different scope and in reality can be combined in all Worlds) World D appears to be lower cost to implement, driven by the fact that DSO functions are centralised under a single entity. World C appears to be the lowest cost to implement but obviously does not have the scope of system operation which the other Future Worlds do.

We have also considered the operating costs associated with each of the Future Worlds. These are based on the costs of incorporating new technology into the business, the people required to oversee the DSO functions and the costs of exchanging and processing information between different actors in each of the Future Worlds. Figure 13 below highlights the relative performance of the Future Worlds on annual operating costs. They are based on an average across both Stage 1 and Stage 2 (taking into account the duration of each Stage in each Future World).

[36] These are a combination of Stage 1 and Stage 2

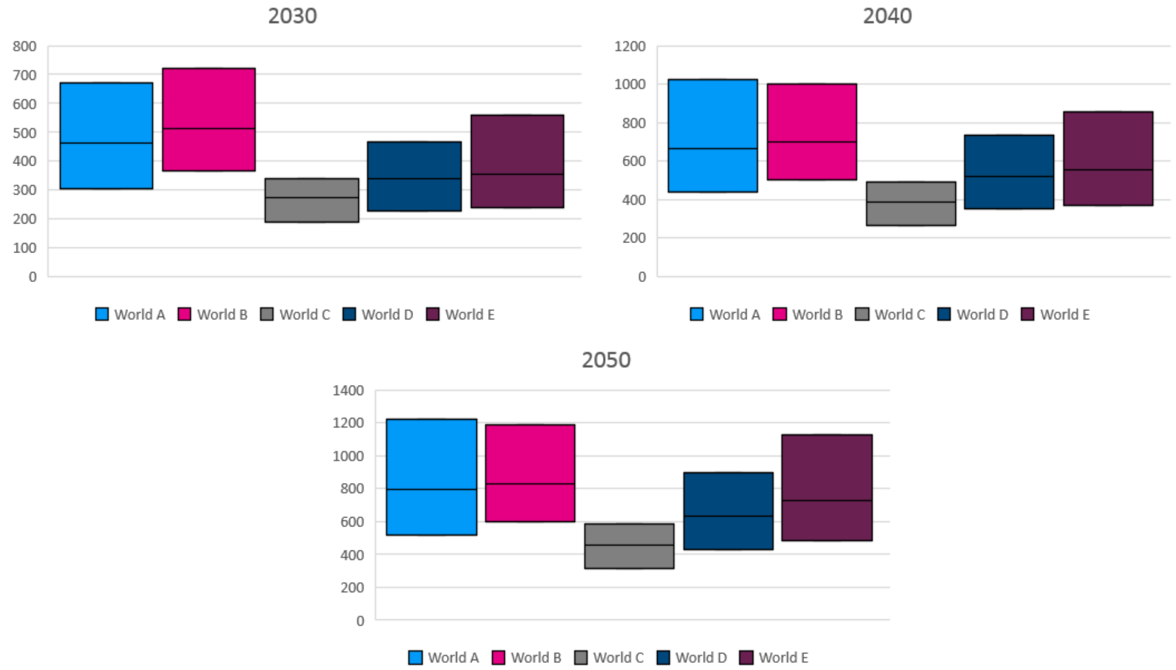
Figure 13 Annual operating costs in each Future World as an average across Stage 1 and Stage 2, £m 2018/9 prices (central case)



With the exception of World C, the level of annual operating costs are fairly similar across the Future Worlds. They appear slightly higher in World B which is explained by the fact that both DSO and ESO are running quite substantial system operation functions. For the same reason, we would have expected the annual operating costs in World E to be high. The reason for appearing lower is that information exchange costs are calculated based on the information exchange volumes outlined in the SGAMs. We understand that this may be underestimated for World E as it was assumed that much of the information exchange is internalised within the Flexibility Co-ordinator and in reality we consider that much of the information will need to be transferred from system operators. Leaving World C aside (on the basis that it will be a component in all other Future Worlds) World D is relatively lower cost due to the economies of scale associated with a single entity operating system operation functions.

Figure 14 below shows the overall results of the costs assessment once investment and operating costs have been combined and we take account of the dates in which each Future World is assumed to mature to Stage 2 of development. These are shown on a discounted net present value (NPV) basis and presented to show the range across our sensitivities, where the line in the block illustrates our central case.

Figure 14 Overall results of cost assessment, £m NPV 2018/19 prices



The results illustrate that in 2030, Worlds A and B are higher cost than the other Worlds. This partly reflects the earlier time at which they mature to Stage 2, but can consequently capture the full benefits earlier too. . By 2050, the costs of Worlds A and B are similar, this reflects the additional scope in World A Stage 2 of managing flows across each GSP. Leaving aside World C, which has a different scope from the other Future Worlds, World D has the lowest overall cost in each time period.

World E also appears to be lower cost than Worlds A and B. This seems strange given that it requires system operation functions to be built out between ESO, DSOs and the Flexibility Co-ordinator. The reasons for this are first the effects of the discounting (since we assumed that World E matures to Stage 2 of development at a later date than the other Future Worlds (2036), the investment costs are later and appear lower when discounted). The second reason is the lower information exchange costs already highlighted above.

4.3.3 Net benefits assessment

We have brought the results of the separate gross benefits and cost assessments together into an overall combined net benefit. Figure 15 illustrates the results based on the Community Renewables scenario. We have shown these as a range with our central case illustrated by the black line. All figures are discounted on an NPV basis.

Figure 15 Net benefits of the Future Worlds in 2030, 2040 and 2050 under Community Renewables scenario, £m NPV 2018/19 prices

Figure 16 below outlines the same results under the Two Degrees scenario. There is little difference between the two scenarios in relative terms. The absolute net benefits in the Community Renewables are higher, largely driven by the higher penetration of DG providing the opportunity to avoid greater distribution investment. The relative results follow a very similar pattern to the gross benefits assessment illustrated in Figures 9 and 10. This is because the absolute numbers within our cost assessment are far lower than the gross benefits, so have a limited impact on the overall results. We would caution against too much being drawn from this in terms of absolute numbers. The purpose of the assessment has been to understand the relative differences between the Future Worlds, and as mentioned above there will be additional costs for system operators common to all Future Worlds not accounted for here.

Figure 16 Net benefits of the Future Worlds in 2030, 2040 and 2050 under Two Degrees FES, £m NPV 2018/19 prices

4.3.4 Sensitivities

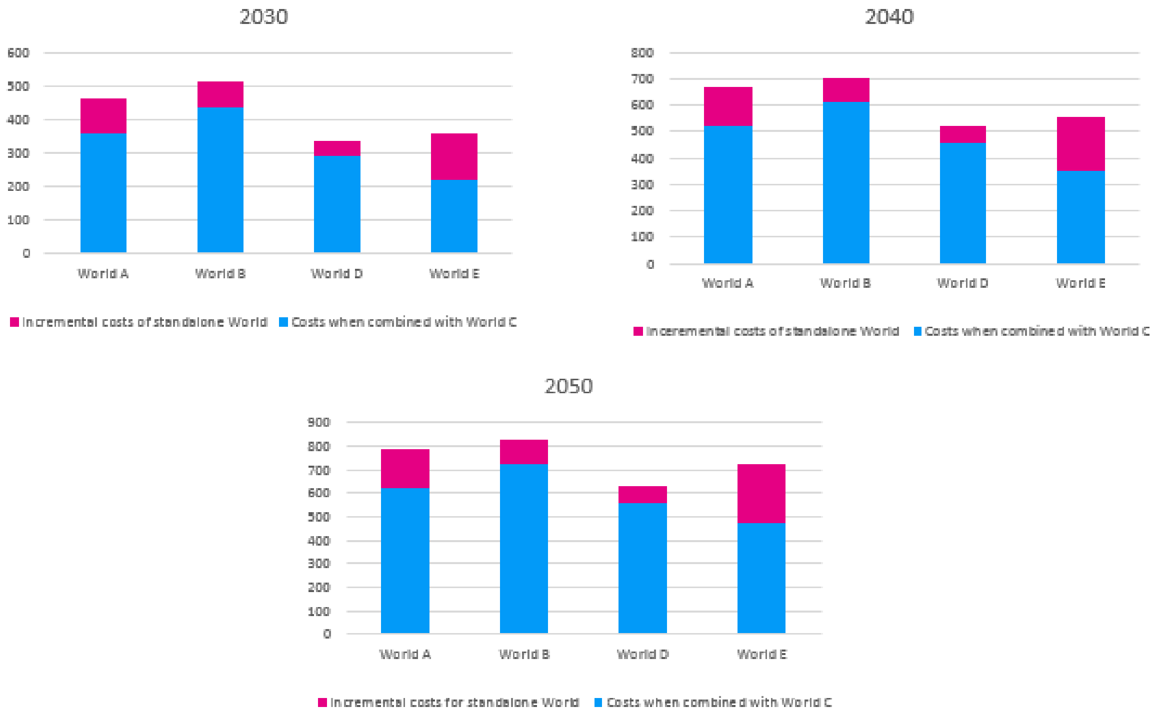
We have undertaken three sensitivities on our results to check how they might alter if we changed some of the key assumptions. We wanted to see if these made a fundamental difference to the overall results.

1) Sensitivity 1: Integrating World C into all other Future Worlds

One of our key observations has been that components of World C will likely feature in all Future Worlds. Consequently, as well as assessing the standalone costs and benefits of World C, we have assessed the net benefits that a combination of World C and each of the other Future Worlds can deliver. Our benefits assessment illustrated that there are no additional benefits which World C could deliver over and above the other Worlds. However, there are cost savings (for system operators) which can be achieved through combining World C with the other Future Worlds. These mainly stem from reducing the volume of flexibility services which need to be procured, managed and dispatched.

To run this sensitivity, we reduced the scope of the DSO functions in each Future World and added in the network access and charging features from World C. Figure 17 below illustrates the impact that this can have on the overall costs, based on our central case. The pink blocks show the reduction in costs possible by combining World C with the other Future Worlds.

Figure 17 Cost impact of combining World C with the other Future Worlds, £m NPV 2018/19 prices based on central case (Sensitivity 1)



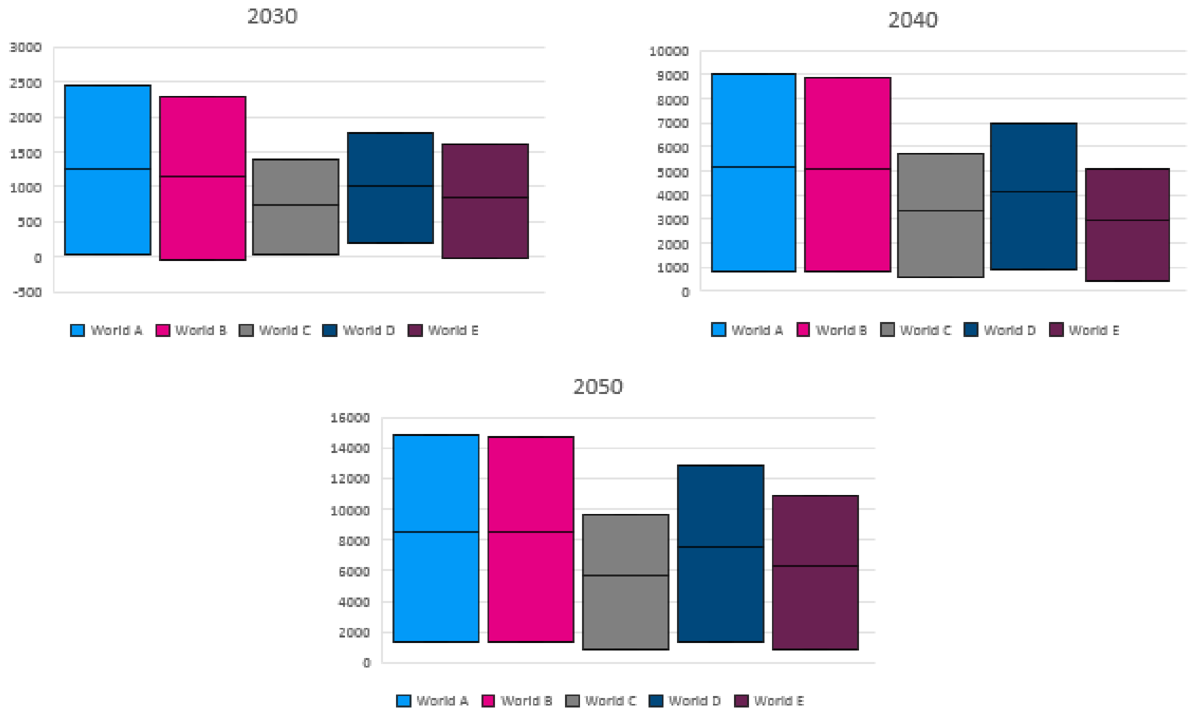
The results illustrate that the impact on costs is proportionately different in each Future World. The impact is greatest in those Future Worlds where the duplication of functions across different actors is highest, for example, World E. We would have expected to have seen a similar impact in World B but note that the proportionate cost reduction is not as high as in World E. This is best explained by the fact that the functions duplicated in World B are more the system planning, co-ordination and network operation ones. These functions are likely to be less impacted by reformed access and charging arrangements than those related to procurement of flexibility services.

2) Sensitivity 2: Different timing of moving to Worlds D and E

Our assessment indicated that Worlds D and E are likely to take more time to mature to Stage 2, compared to the other Future Worlds (for full details see Section 3 and Appendix D). For the base case analysis we set these dates at 2031 for World D and 2036 for World E (compared to 2028) for the other Future Worlds. Our analysis of the relative differences in the evolution of each of the Futrue Worlds suggested that Worlds D and E may take longer to mature. Consequently, we undertook a sensitivity to highlight the impact of taking five more years to mature to Stage 2 in Worlds D and E. This sensitivity also highlights the extent to which our results are sensitive to the timing of when each Future World evolves into Stage 2 of development.

Figure 18 illustrates the impact that this has on the relative performance of the Future Worlds.

Figure 18 **Overall net benefits of the Future Worlds in 2030, 2040 and 2050 under Community Renewables FES, £m NPV 2018/19 prices (Sensitivity 2)**



This analysis illustrates that the results are quite sensitive to the time at which a Future World matures to Stage 2. The 2030 results are identical to those in Figure 15 but there is far greater relative difference between World D and Worlds A and B out to 2040, and to 2050. It shows that the ability of a Future World to evolve quickly will be vital to delivering benefits to consumers.

Sensitivity 3: A single, national Flexibility Co-ordinator in World E

As a third sensitivity on our results, we looked at what impact moving to a single, national Flexibility Co-ordinator in World E would have on the cost assessment. This suggests that the cost reduction out to 2050 would be less than 3%. This is because many of the functions taken on by the Flexibility Co-ordinator do not have large economies of scale. For instance in Stage 2, Flexibility Co-ordinators are still be running local/regional markets and managing the connections process where operations organised geographically may be needed even within a single central body. Consequently, there appeared to be relatively few cost savings available.

4.4 Qualitative assessment summary

4.4.1 Overview

The qualitative assessment provides a broader basis through which to evaluate the Future Worlds, than the quantitative assessment. There is a wide range of criteria based around the HM Treasury's five case model which we have used to assess the Future Worlds.

The results are designed to show the relative differences between the Future Worlds. As described in Section 3, we have undertaken the qualitative assessment under both Stage 1 and Stage 2 of development and ranked how the Future Worlds perform against each of the criteria set out by the ENA, and amended based on stakeholder feedback. Figure 19 below provides a high level summary of the results against each criterion. The results are based on a relative ranking of how the Future Worlds perform against each criterion. We have colour coded the rankings to indicate the relative performance (green denotes the highest ranking and red the Lowest ranking).

Figure 19 Summary results of qualitative assessment

Case	Stage 1					Stage 2				
	A	B	C	D	E	A	B	C	D	E
Strategic Case										
Enhanced Customer Experience										
Choice	2	2	1	5	2	2	2	1	2	2
Fairness	2	2	1	2	2	2	2	1	2	2
Affordability (delivers greatest net benefits)	1	1	5	3	4	1	1	5	1	4
Confidence and trust	4	4	1	2	2	5	4	2	3	1
Consumer benefit from markets	1	1	4	5	3	1	1	1	1	1
Greater environmental sustainability										
Facilitates greater energy efficiency	2	2	1	2	2	2	2	1	2	2
Facilitates decarbonisation of generation	1	1	5	1	1	1	1	5	1	1
Facilitates decarbonisation of heat and transport	1	1	4	5	3	1	1	5	1	1
More electricity consumed closer to the point of generation	1	1	4	5	3	1	1	5	1	1
Economic case										
Financial benefits										
Cost of implementation vs benefits	1	1	5	3	4	1	1	5	1	4
Expected benefits	1	1	5	3	4	1	1	5	1	4
Whole system optimisation										
Support whole system optimisation	3	4	5	2	1	3	4	5	1	1
Optimises locally	1	1	4	5	3	1	1	1	1	1
Brings more flexibility into the system	1	1	3	5	4	1	1	5	1	1
Manages conflicts	2	4	1	2	5	2	5	1	2	2
Avoids duplication	3	4	1	2	5	3	4	1	2	5
Exploits synergies	2	2	n/a	1	5	2	3	n/a	1	5
Commercial case										
Market viability (ease of establishing new markets)	3	3	1	2	3	5	3	1	2	3
Appropriate regulation (are regulatory frameworks in place)	4	1	2	4	3	3	1	2	3	5
Financial case										
Compatibility with Regulatory funding	2	2	1	2	5	2	2	1	2	5
Funding available to support market participation	2	2	1	2	2	2	2	1	2	5
Management case										
Industry structure and organisation										
Level of rules and regulations required	2	4	1	2	5	3	4	1	2	5
Delivers neutral fair, flexible and transparent markets	4	4	1	2	2	5	4	1	2	2
Complexity of system operation	3	3	1	2	5	3	4	1	2	5
Complexity of market participation	2	2	5	1	2	2	2	5	1	2
Difficulty to implement for system operators	2	2	1	4	4	3	1	1	4	5
Difficulty to implement for market participants	4	4	1	2	2	4	5	1	2	2
Future Proof	2	2	1	2	2	2	2	1	2	2
Technical performance										
Degree of safety risk	1	1	1	1	1	1	1	1	1	1
Service availability and reliability	1	1	5	3	3	1	1	5	3	3
Physical and cyber security	3	3	1	1	3	3	3	1	1	3
Resilience and recovery	1	1	n/a	4	3	1	1	n/a	3	3
Clear dischargeable accountability	1	2	n/a	3	3	1	2	n/a	3	3

The qualitative assessment illustrates that each Future World has different strengths and weaknesses. This highlights that there are going to be trade-offs between the Future Worlds in terms of their performance against different criteria. Appendix A contains a full write up of the assessment of the Future Worlds against each of the criteria.

In undertaking this ranking assessment, we have only looked to identify the key differences between the performances of the Future Worlds. In some cases this means that there are equal ranking between the Worlds. We have included World C as a standalone World in our assessment in order to gain a sense of how improved network access and forward-looking charging signals can perform. We have already highlighted that reformed access and forward-looking price signals are unlikely to deliver the full benefits of DER flexibility and hence, in reality World C is likely to be combined with other Future Worlds. This should be borne in mind when looking at the relative performance against the qualitative criteria.

Within each of the five cases, the ENA included some sub-categories to group the qualitative criteria against. These are a useful breakdown of key topics which we have used to provide a summary view of the assessment.

4.4.2 Enhanced customer experience

We found that the main difference in the performance of the Future Worlds in this area were between the role that access arrangements and forward-looking price signals in World C can play compared to the procurement of flexibility to meet specific needs in the other Worlds. Access arrangements and forward-looking price signals can provide universal opportunities for consumers to save money from more flexible use of energy. All the other Worlds relied on contracted services for extracting value from flexibility. There is a danger that these services are procured from the very consumers who have been driving reinforcement needs on the network i.e. have EVs or heat pumps. This can lead to those customers who are driving costs, being paid to resolve them.

Appropriate access arrangements and effective price signals expose all consumers to the costs they are imposing, or the value they are creating, on the network. In addition, we found that the transparent nature of access arrangements and price signals might be able to deliver greater confidence and trust from consumers than procurement of specific services from certain consumers. In reality, we acknowledge that components of World C are likely to feature in all Worlds but it was informative to assess the World in its own right.

4.4.3 Greater environmental sustainability

The main differences we identified between the performance of the Future Worlds in this area were over their potential to access flexibility at lower voltages. It is access to this flexibility which can release additional capacity, enabling more rapid connection of low carbon technologies such as renewable generation, electric vehicles and heat pumps.

The assessment found that in Stage 1 of development, World D performed relatively less well since it does not seek to co-ordinate any DER flexibility at LV. This is likely to restrict the development of local flexibility markets. We also considered that price signals in World C are unlikely to be as effective as contracted services for accessing flexibility at the LV level (notwithstanding the fact that contracting flexibility services at LV level has not yet been demonstrated). This is particularly the case in Stage 1 of World C where only static time of use tariffs and fairly basic access arrangements are in place at LV.

There may be little difference between Worlds A, B and E in this area but one feature which we found may lead to Worlds A and B performing better is their ability to exploit internal synergies between network and system operations. For example using the understanding of how particular individual assets have been operated and performed over a number years, to assess where flexibility can provide benefits and being able to highlight the synergies between flexible markets and the connections process is likely to be more effective at stimulating flexible markets, in the short term.[37]

4.4.4 Whole system optimisation

We found that the Future Worlds which performed best in this area were those where a single party had a holistic view of the system, which could provide it with the information required to take decisions from the whole system perspective. Worlds A, D and E all have a single party with the information available to take decisions from a whole system perspective (either across a specific region, or nationally). This is largely a feature of devolving responsibility to a single party within these Worlds. While the other Future Worlds can have co-ordination mechanisms to help provide a whole systems perspective across different system operators, they require information exchange, rules and governance and could be complex to manage.

4.4.5 Market and regulatory viability and available funding

The Future Worlds which performed best under these criteria were the ones which required least change from today. All the Future Worlds will require new markets to be stimulated, new regulation and new funding. However, the extent of this change appears to be less in some Future Worlds than others.

World C can largely operate within the existing industry structure and the routes to market are already established (albeit there would need to be substantial change to current charging arrangements and investments in power system modelling to generate more granular time-of use and locational price signals). World C would also require new investments in settlement and billing systems, both for system operators and suppliers. World B is the closest to the current structure of industry arrangements. It will require new flexibility markets to be developed and stimulated. However, the regulatory arrangements and funding through price controls would not require substantial change, since the DSOs and ESO will continue to be funded through existing price controls for their respective activities (although may require new incentives).

This is not the case in World E which would require new forms of funding to be established. There is a range of forms both this and the subsequent regulation of the Flexibility Co-coordinators could take. One form could be through a separate price control from Ofgem which would enable the costs of the regional Flexibility Co-ordinators to be benchmarked against each other to drive efficiencies. Another form would be to establish the Flexibility Co-ordinators as ‘not for profit’ organisations.

Worlds A and D will require similar new markets and regulation to be established. From a regulatory perspective, new incentives may be required to help support the business case for enabling technology to be deployed by one system operator to deliver benefits to another system operator. Specifically to World A, in Stage 2 of development, some of the flexibility markets created may need to be aggregated up to GSP level and bid into national markets, which may add additional complexity.

4.4.6 Industry structure and organisation

We found that Worlds B and E tended to perform relatively less well against the criteria in this category, while the performance of the remaining Future Worlds was similar. While World B is

[37] This will obviously require suitable degree of internal separation to ensure neutral market facilitation

largely based on today's industry structure we found that there could be considerable work involved in operating the processes and systems required to co-ordinate network planning and the procurement and dispatch of flexibility services. It can be argued that in regions which have seen a higher uptake of DER, DSOs and the ESO are already starting to grapple with the issues around how the co-ordination processes envisaged in World B will work in practice.

In addition, we found that World B may be more susceptible to conflicts emerging between DSOs and the ESO, particularly over agreeing network planning options and the dispatch of flexible resources. Over time, if the volume of DER increases, it will drive a need to exchange close to real time information between DSOs (including DSO to DSO co-ordination) and the ESO. This is likely to be complex to operate and there is a risk in World B that the co-ordination mechanism put in place is not able to resolve conflicts in a timely and effective way. If this is the case it could lead to delays in connection (while the ESO assesses DSO connection applications for wider system impacts) and potentially reliability issues where there is a large reliance on DER flexibility to manage the networks.

We also identified that World E performed less well in this area, particularly in Stage 2 of development. The creation of the regional Flexibility Co-ordinators will be complex to implement and may require transfer of personnel and operational IT and communications equipment from DSOs and potentially the ESO to the Flexibility Co-ordinators. This is likely to be disruptive in the short term, during the implementation phase. As with World B, the operation of World E is likely to be complex as the volume of DER increases. This is due to the substantial information flows required between the ESO and DSOs and the Flexibility Co-ordinators to understand the network needs and where available DER flexibility can meet those needs. Again, this looks like a complex environment with scope for conflicts.

4.4.7 Technical performance

We found that that the performance of the Future Worlds against the criteria in this category largely came down to the degree of clear accountability of responsibilities between parties. World A performed well (particularly in State 2) as the DSO has complete responsibility for both distribution network and system operation. Apart from World C, all remaining Future Worlds involve either joint or split responsibilities which may impact technical performance.

In addition, the ability to exploit the synergies between network and system operations and have visibility of both under the same organisation (albeit with suitable internal separation)means it is likely to be more resilient than some of the other Future Worlds; as well as providing greater accountability of network operators to their stakeholders. Where responsibilities were either potentially unclear (as in World B), or split between network and market operation (as in Worlds D and E), then they are more reliant on clear rules being implemented and followed in a way that does not lead to conflicts. This leaves scope for the rules not to cover certain unforeseen circumstances, or be misinterpreted.

4.5 Unintended consequences and risks

As part of the qualitative assessment of the Future Worlds, we wanted to use the assessment we had undertaken to highlight where there could be unintended consequences or particular risks of the DSO transition. The unintended consequences and risks are largely 'Future World agnostic' in that they will have an impact regardless of which Future World is implemented. Consequently, they do not influence the relative assessment of the Future Worlds but can provide new insights which it will be important to consider in the design of the Future Worlds going forward.

We worked with the ENA and wider stakeholders through the Open Networks Advisory Group to test and validate the unintended consequences and risks under each of the six themes we identified.

- System operator conflicts;
- Gaming and market power;
- Operational integrity;
- Distributional impact on consumers;
- Network resilience and security; and
- Risk of regret.

This produced a long list of unintended consequences and risks which we have included in Appendix D. We have looked to group these issues into categorises under each of six themes. Table 6 below highlights these groups and provides a summary of the types of issues they cover.

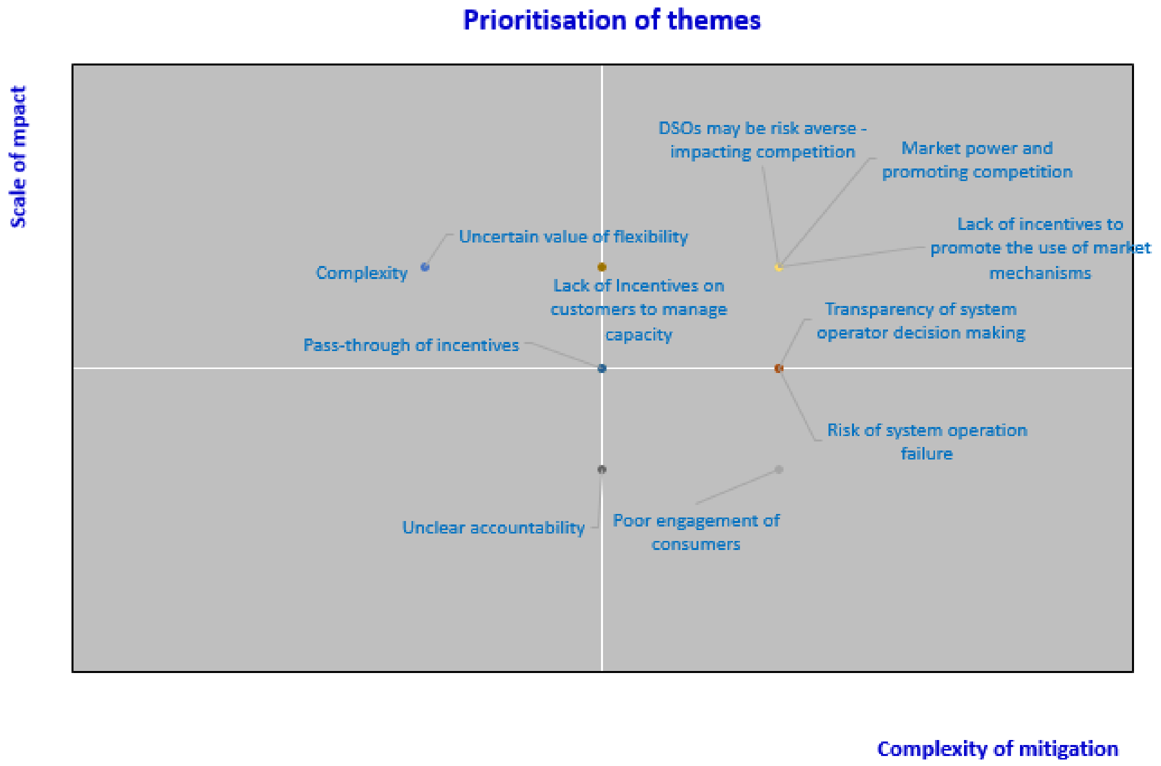
Table 6 Unintended consequences and risks key themes and categories

Market power and gaming	
SOs may be risk averse – impacting competition	Conflicts between use of 'mandated' services which are required under the terms of code arrangements or connection agreements, over market based services
Lack of incentives on customers to manage capacity	Customers who cause constraints can be paid to resolve them
Market power and promoting competition	Locational market power can drive up cost of flexibility
Pass- through of incentives	Network price signals or value is not fully passed on to end consumers (via suppliers)
System Operator conflicts	
Lack of incentives to promote use of market mechanisms	Lack of clarity over the longer term Regulatory treatment of network investment costs which are deferred or avoided through flexibility
Transparency of system operator decision making	How to provide transparency to the market on why a system operator has or hasn't opted for a flexible solution, without revealing sensitive commercial information which might compromise future flexibility tenders
Distributional customer impact	
Poor engagement of consumers	If consumers have a poor initial experience of engagement in flexibility markets and products, it may deter them from engaging in the future and reduce the benefits available
Locational price differentials	Geographically different prices may be confusing for end consumers and will require explanation

Risk of regret	
Uncertain value of flexibility	The industry is starting to plan on the basis that network operators will need to co-ordinate flexible resources to help deliver costs savings. However, there may insufficient value in flexibility to make it an economic alternative to asset solutions. This will make the Future Worlds largely redundant.
Lack of certainty	The industry is devoting considerable time and effort into developing sharper price signals and access arrangements but we do not know how effective these new arrangements will be.
Operational viability	
Complexity	How will different locational markets interact with each other and what overall impact will that have on existing national markets?
Sub-optimal economic outcomes	Existing network access rights may not be compatible with new market arrangements
System security	
Risk of system operation failure	Reduced network headroom/resilience due to reliance on market solutions
Unclear accountability	Understanding which party is accountable for network security

We used stakeholder input to assess each of these high-level issues in terms of their potential impact and how complex they were to resolve. Figure 20 illustrates the output of that work. The top right box represents the highest impact and highest complexity to mitigate, the bottom left box, the lowest impact and easiest to mitigate.

Figure 20 Prioritisation of unintended consequences/risks themes



This graphic is intended to be a starting point of identifying the issues that will need to be considered as the Future Worlds are developed further. The prioritisation highlights that there are some high impact/lower complexity issues which industry can start to work together to resolve. These include planning on how to engage with consumers for flexibility services (particularly residential consumers) and considering the co-ordination required between network operators and third parties (e.g. suppliers, aggregators etc.) to ensure that network incentives are passed through to consumers.

Many of the issues identified are in the high impact/high complexity to mitigate category. These are likely to require further work to understand the specific impacts and identify relevant stakeholder(s) who are best placed to work together to mitigate them.

5 Insights from the Impact Assessment

5.1 Performance of the Future Worlds

We have used the knowledge gained from undertaking the Impact Assessment to provide some summary observations on the performance of the Future Worlds below. These are summary conclusions and the reasons behind them can be found in Section 4 above and Appendix A.

- **Worlds A and B are likely to be the most resilient to significant DER uptake in the 2030s**

The two FES on which we have based the Impact Assessment both indicate a considerable acceleration of DER uptake in the 2030s. This means the more seamless the evolution of the Future World, the better placed it might be to manage this period in a manner which does not compromise the quality of service customers receive. The qualitative assessment suggests that Worlds A and B will be better placed to do this as they appear capable of evolving faster and do not require a substantial step change in Stage 2. Worlds D and E are likely to take longer to evolve and require substantial organisational change to move into Stage 2 (particularly in World E). Attempting this type of change during a period of accelerated DER growth is likely to add significant complexity to an already challenging situation.

- **Worlds B and E are likely to be the most complex to operate**

Worlds B and E both require complex, co-ordination across multiple actors. In the medium to longer term this is likely to drive a substantial data exchange in close to real time. Consequently, both are likely to require higher resources to operate and greater level of rules to govern that operation. This opens greater scope for operational issues to develop in these Worlds.

- **Improved network access and forward looking network charges are likely to be able to reduce the cost of the DSO transition**

The Impact Assessment indicates that a combination of each of the Future Worlds with World C, was able to deliver at least the same benefits at lower system operator costs than any standalone World. The lower system operator costs are driven by the fact that charging reforms have the potential to help provide some the flexibility needed, and reducing the volume of flexibility services which network operators need to manage. This can reduce the operational costs of managing flexibility and lead to lower costs for consumers. Although we note that in some cases these costs are simply pushed out to market participants, who may pay more for network use during periods of high network loading in certain locations, unless they adjust their behaviour to avoid these higher charges..

- **World D is likely to be the lowest cost to implement and operate**

Excluding World C, components of which we assume are included in all other Future Worlds, World D appears to be the lowest cost option to implement and operate. While the assessment has shown that it is less like to deliver the same benefits as Worlds A and B in the nearer term, it could be an effective option in the event that DER uptake is lower than expected and the majority of benefits are delivered through co-ordination of DG (not demand flexibility at lower voltage levels).

- **World E is a more natural basis to stimulate neutral markets**

All the Future Worlds are capable of providing neutral markets with the right mitigation processes put in place. However, World E provides a natural basis to act as a neutral market facilitator (without the need for additional safeguards to mitigate conflicts of interest). In the longer term, it may be easier for Flexibility Co-ordinators to take a whole system view as it is the only Future World where a neutral party has visibility of the value of flexibility to the ESO and DSOs.

5.2 Operational viability of the Future Worlds

We have identified some insights into operational viability across the Future Worlds both directly from the qualitative assessment and also from the unintended consequences and risks workshop we ran with stakeholders.

- **The DSO transition will require a significant increase in skilled people**

The Impact Assessment indicates that resource costs will be a significant driver of costs in the DSO transition across all Worlds. By the mid-2030s, our analysis indicates that between 350 and 450 additional skilled people will be needed across DSOs, the ESO or Flexibility Co-ordinators to run market and system operations. These additional people are likely to need skills and experience which combines knowledge of the networks and system operation with understanding of markets and customer facing skills to agree and manage contracts with flexibility providers.

- **Importance of market co-ordination**

New DSO markets are likely to layered onto existing market structures. This can provide a complex web of market interactions both for market participants to understand and system operators to manage. There is a risk that consequential impact of actions in different markets causes constant price oscillation between markets. Worlds A, D and E may be better placed to manage these complexities, particularly in terms of simplifying them for market participants. They each devolve responsibility to one actor, making it easy for that actor to optimise the use of resources across different markets. World B is more likely to place the emphasis on individual market participants to decide how to engage with the various different markets. This could cause different patterns of network usages which from a system operation perspective are difficult to predict and plan for.

- **Understanding where overall operational security responsibilities lie in each Future World**

At present, there is a clear responsibility on the ESO to manage overall operational security. This responsibility becomes less clear, particularly in Worlds A and E, which could involve devolving some of that responsibility away from the ESO. It will be important to clearly understand where these responsibilities sit and potentially 'war game' different scenarios across the Future Worlds to identify any potential gaps.

5.3 Other observations

- **There are likely to be different consumer experiences of the DSO transition in different regions**

The Impact Assessment has been undertaken on a GB basis. Consequently, we have used average values to help understand the benefits of the DSO transition. However, it was clear that there may be wide variations in these values depending of the specific network conditions in different areas. Consumers in some regions may be able access revenue streams through flexibility markets which consumers in unconstrained areas cannot. Equally, time of use price signals in some geographical areas may have high price differentials than in others. This may be difficult for consumers to understand and accept and will require careful communication and explanation.

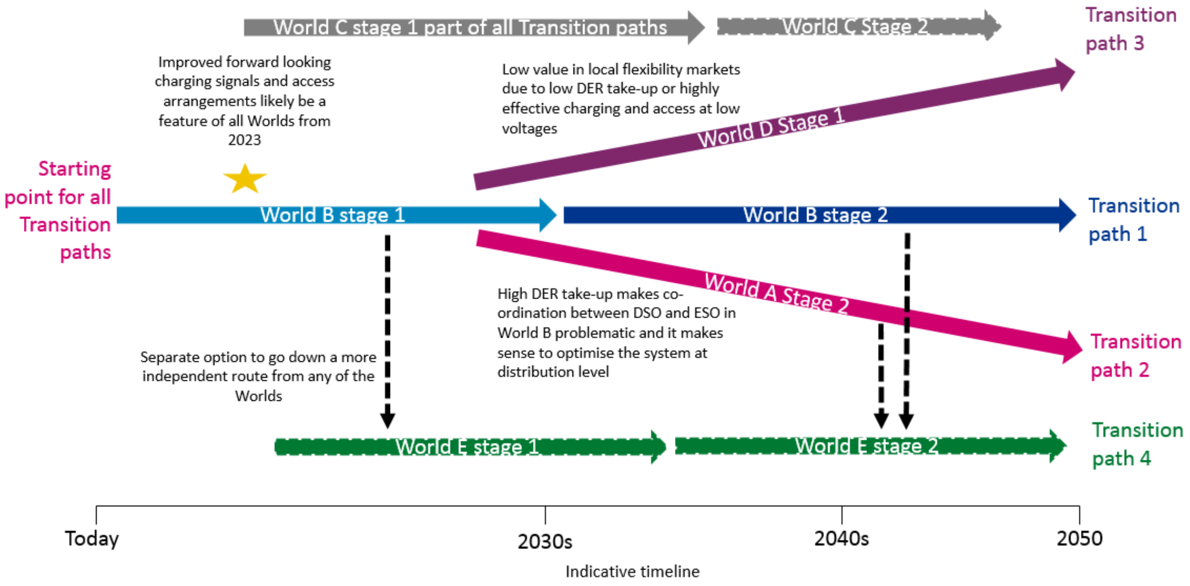
▸ **Regulatory arrangements and funding may need to change to facilitate the business case for investment**

In most of the Future Worlds a respective system operator is required to make investments in functionality which delivers benefits to a different system operator. For instance in World A, the DSOs will co-ordinate DER flexibility to deliver benefits for the ESO. This introduces a misalignment of where costs and benefits sit across network companies. This can make it difficult for any one party to make a business case for investment. Specific incentives to reflect the wider value of DSO or ESO actions may need to be implemented in order to ensure that this value can be taken into account in investment decisions. Formal regulatory incentives are likely to provide greater certainty of revenue and enable performance in delivering wider benefits to be monitored and possibly benchmarked over time.

5.4 Impact on the DSO transition

What we have learned about the features of Future Worlds (in their various stages) has provided an understanding of the ways the Future Worlds can evolve over time. Separately from assumptions used in quantitative assessment, we have used the results of the Impact Assessment to plot some of different pathways for the DSO transition and their key trigger points. We have identified four separate transition paths from today, which are summarised in Figure 21 below.

Figure 21 Potential DSO transition pathways and triggers



All of our pathways start from World B Stage 1. We consider that this is closest to today's arrangements where both DSOs and the ESO are looking to co-ordinate flexible DER. There is a range of ongoing work through the Open Networks project, Regional Development Programmes[38], code changes[39] and learning from innovation projects[40] that are starting to develop the co-ordination

[38] https://www.nationalgrid.com/sites/default/files/documents/NG_UKPN_RDP_InfoSheet%20-%20Final%20-%20Agreed.pdf

[39] Particularly the implementation of the European Network Codes: http://www.dcode.org.uk/joint-panel-working-groups.html

[40] The Power Potential project is a good example: https://www.nationalgrideso.com/innovation/projects/power-potential

processes between DSOs and the ESO envisaged in World B. While these processes are embryonic and in some cases are limited to certain parts of the country, it seems sensible to assume that World B Stage 1 will be a common starting point.

In addition, Ofgem has indicated that it is looking for reformed network access and forward-looking charges to be implemented by 2023. Consequently, we consider that these arrangements are likely to be a feature of all Future Worlds from that point on.[41] Since World B Stage 1 is the starting point, it seems appropriate to combine World C Stage 1 with World B Stage 1 from 2023 onwards. From this combination of Worlds B and C, we have identified four separate transition paths which are outlined above in Figure 21 and explained below. The explanation focuses on how circumstances and the specific characteristics of the different Future Worlds can combine to drive a particular path.

5.4.1 Transition Path 1

Under Transition Path 1, the combination of access and charging reform, and coordination in the procurement and dispatch of flexibility services provide an effective means of managing flexibility from DER. This may require an acceleration of co-ordinated approaches to flexibility procurement between now and the mid-2020s. The reforms to access and forward-looking charges arrangements have the potential to support these co-ordination mechanisms, if designed correctly. If this proves to be the case, there is no trigger to move away from World B. Over time, it may need to evolve into Stage 2 of World B. This will depend on the level of DER uptake and the effectiveness of access reform and enhanced price signals in delivering the flexibility system operators require.

This transition path is likely to suit a scenario of moderate to high DER uptake but where the co-ordination of flexibility from LV providers is driven by access arrangements and price signals.

5.4.2 Transition Path 2

Under Transition Path 2, there is a move away from World B Stage 1 to World A Stage 2. This would be driven by circumstances where a high uptake of DER cannot be operationally managed through the co-ordination mechanisms in World B. The symptoms of this would likely be where the DSO having to take numerous actions which are driven to counter the impact of DER responding to wider market signals. There may also be confusion and delay in dispatching flexibility services while the DSO and ESO need to co-ordinate on system planning. Some of these issues may sound similar to experiences in certain regions today. In this transition path, the development of World B Stage 1 and pricing signals fails to resolve these issues and they become more widespread across the country as DER uptake increases.

The decision to move to World A Stage 2 is likely to be driven by high DER uptake, where greatest value can be achieved by optimising dispatch via local flexibility markets.

5.4.3 Transition Path 3

Under Transition Path 3, there is a move away from the World B to Stage 1 of World D. This could be driven by a combination of the following circumstances:

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[41] https://www.ofgem.gov.uk/publications-and-updates/getting-more-out-our-electricity-networks-through-reforming-access-and-forward-looking-charging-arrangements

- There is little value in local flexibility markets, either due to low DER uptake, or because the benefits of running those markets do not outweigh the costs;
- Reformed access arrangements and price signals prove to be the most effective way of accessing flexibility from LV consumers; and
- The greatest requirement for flexibility from DER is to provide Balancing Services to the ESO given the level of renewables connected to the transmission system and the retirement of traditional providers.

In these circumstances, it is likely to be more cost effective to stop building out DSO functions in each of the six DSOs and centralise the co-ordination of DER flexibility under the ESO (which our assessment has indicated is more cost effective). Since the trigger to this transition path is based around a scenario where there is little value in LV flexibility (or that flexibility is best accessed through access reform and price signals), there is no need to move to Stage 2 of World D, as the ESO does not need to co-ordinate LV flexibility.

This transition path will likely result from a lower DER uptake scenario (particularly a low EV and heat pump uptake) or if market tenders indicate that there is little value in LV flexibility to network operators.

5.4.4 Transition Path 4

Transition Path 4 highlights that there is an option to move to World E both from Transition Paths 1 and 2. This would be driven by a concern that the processes in place to mitigate any perceived conflicts of interest between DSOs running both network and system operations, were not sufficient. The trigger for Transition Path 4 is likely to be a policy decision taken by Ofgem and BEIS. We do not see the move to World E being required in Transition Path 3 since the ESO is already subject to greater legal separation from the network operations under National Grid Transmission Operator.

The Impact Assessment has highlighted the extent of industry change required to move to World E (particularly in Stage 2). Both the Two Degrees and Community Renewables scenarios illustrate a sharp increase in DER in the 2030s. This is likely to pose significant operational issues for DSOs and the ESO. Consequently, any move to Transition Path 4 may need to be executed in the mid to late 2020s (to Stage 1 of World E) or in the 2040s (to Stage 2 of World E), prior to the point when operating the system is becoming more challenging.

Table 7 below provides a summary of each transition path along with the key drivers and triggers.

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Table 7 Summary of key triggers to DSO transition paths

Transition path	Key triggers
Path 1: Move to World B stage 2 (joint procurement and co-ordination)	• Low appetite to change from current industry arrangements • Co-ordination mechanisms in World B prove effective in managing DER uptake
Path 2: Move to World A stage 2 (DSOs co-ordinate)	• High DER uptake • Co-ordination mechanisms in World B lead to conflicts and complex operations • Value in local flexibility markets at lower voltages
Path 3: Move to World D Stage 1 (ESO co-ordinates)	• Low DER uptake • Little value in flexibility markets at the lower voltages • High penetration of Transmission connected renewables
Path 4: Move to World E Stage 1 or 2 (Flexibility Co-ordinators)	• Concern over perceived conflicts of interest through integrated network and system operations within a DSO

5.5 Where further work would be useful

We have identified two different areas where further work would be useful. The first area is around what is needed to help answer the key questions on the transition pathways. The second is more focussed on what new information would be required to build on this initial Impact Assessment.

We have identified four separate transition paths based on the Future Worlds. The trigger points between those pathways centre on two or three key 'unknowns'. Work to try to answer these unknowns will be crucial in understanding which transition path might be required.

- **Understanding how reformed access arrangements and forward-looking charges best support system operation functions**

Our assessment indicated that combining World C with each of the other Worlds could deliver higher overall net benefits. However, there is further work required to validate this and in particular understand how much flexibility could be delivered though reformed access arrangements and price signals and therefore what role contracted flexibility services need to play. It would seem particularly useful to trial some of the options for reformed access and forward looking charges alongside the co-ordination mechanisms in World B, to understand how they can complement each other.

- **What is the value of flexibility at low voltages to network operators?**

A key decision on whether there is a move to Worlds A or D is dependent upon the value in local flexibility markets at the lower voltage levels. Our Impact Assessment indicates that World A will be more effective at establishing and operating these markets than World D. Whether there is value in such markets will be primarily driven by the uptake and location of DER, which is largely outside the control of network operators. It is unclear whether establishing and operating flexibility markets solely to avoid LV network investment is economical.

Within the Impact Assessment, we looked at a number of different sources on both the value of flexibility to network operators and what you would need to pay providers for this flexibility. Given the uncertainties, we applied a range of values. The more pessimistic end of this range indicates that the value from demand reduction at LV may not be higher than the cost, unless it drives costs savings at higher voltage levels as well as at LV. The more optimistic assumptions suggest that LV flexibility could be a very cost effective solution, particularly in certain locations. This issue would benefit from further research.

There have been some previous innovation trials[42] which have sought to understand LV flexibility but these were a number of years ago and were focussed on testing the concept of LV flexibility rather than the economics. A greater understanding of the economics of local flexibility markets will be crucial in understanding if Stage 2 of World A is likely to be required. Further information in this area would also help to reduce the range of uncertainties placed around our quantitative analysis.

Our analysis indicates that the earlier this question can be answered, the more scope there might be for cost savings through moving to World D earlier, before the DSO fully builds out its system operation functions.

- **What are the potential conflicts of interest and how can they be mitigated?**

The Impact Assessment highlights that moving to World E is likely to require substantial structural change across network operators (both in Stage 1 and Stage 2). This is likely to lead to some teething issues which may impact network performance, system resilience and customer service. The Impact Assessment also indicates that there is quite a significant cost of moving to World E, due to the duplication of similar functions and activities required across multiple network operators.

Consequently, the only reason for moving to World E would be to mitigate any perceived conflicts of interest which surround integrated network and system operation within network operators. Given the impact on customer service and additional costs which are likely to be required under World E, it would be useful to understand what the impact of potential conflicts of interest might be. Our unintended consequences and risks session started to tease some of these out and identify mitigation measures but further work in this area might be helpful, particularly in terms of quantifying the potential impact to consider alongside this Impact Assessment.

- **How can industry arrangements facilitate a different pace of change across regions?**

Current industry arrangements are based on applying uniform rules and regulations across GB. The potential for variation in DER uptake and consequent constraints across the country suggests that the DSO transition may need to be different in different regions of the country. It would be helpful to start considering how the industry code and regulatory arrangements would need to change to accommodate this different pace of transition. This is particularly the case if one region needed to move into World A ahead of other regions.

Undertaking the Impact Assessment required us to make a number of assumptions across some key areas and in many cases apply a range of uncertainty around our inputs. This helped to identify where further work would be useful to improve the accuracy of the Impact Assessment:

[42] Low Carbon London and Customer Led Network Revolution were the two largest and well known studies.

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- **Defining the commercial arrangements for the Future Worlds**: As highlighted in Section 2, the Future Worlds would benefit from a greater understanding of how they would operate from a commercial perspective. These details were not within the scope of the SGAMs but have an important bearing on business cases and the allocation of risk will subsequently drive investment decisions.
- **Mapping the accountabilities and responsibilities in each Future World:** It may be useful to expand on the current SGAM modelling to allocate specific accountabilities and responsibilities on each actor in each World. This would be particularly useful for system security requirements and understanding the role each actor needs to play, across different circumstances.
- **A network engineering model which can forecast investment required under different load and generation growth scenarios across both Transmission and Distribution**: To assess the benefits of the different Future Worlds, we had to first understand what the benefits of better system operation might be. For this part of the assessment, it would have been helpful to know what the reinforcement costs of meeting the different FES would be. We are also aware that this is an area which the ENA is already looking at, including how to build on some of the modelling undertaken in this area in the past. Such an input would have been highly beneficial for the Impact Assessment.
- **Understanding the benefits of economies of scale across different system operation functions**: A key aspect of the assessment was the relative merits of economies of scale in World D vs the additional scope of Worlds A and B. We have made some assumptions on where system operational functions can best benefit from economies of scale but it would be useful to build on these and bring in some practical examples where possible.

A better understanding of technology costs: This was an area of considerable uncertainty in the Impact Assessment. While we accept it is difficult to get precise figures we do think that further work which technology providers to assess the likely range of costs for DSO functions would be helpful to explore. This would help narrow down the uncertainty ranges we have illustrated. We have provided the spreadsheets models which underpinned the quantitative assessment, available alongside our report. This is designed to allow others to challenge and build on this initial work, particularly as more information and greater evidence becomes available to inform the input assumptions.

Appendix A Detailed qualitative assessment

A.1 Approach for the qualitative assessment

Underpinning the summary qualitative assessment in Section 3 is a detailed assessment of the Future Worlds against each of the assessment criteria. The assessment criteria are based on those set out by the ENA in its Future World Consultation.[43] With the agreement of the ENA, we have amended some of the descriptions and scope of the criteria based on consultation responses. Separately to this report, we have provided a mapping of stakeholder comments against the original assessment criteria.

The ENA had grouped criteria under the HM Treasury's Five case model.[44] This is standard practice for public sector impact assessments. The Future Worlds are not yet defined in a way which would enable the type of impact assessment that public sector bodies would undertake ahead of implementing a decision. This is an initial impact assessment designed to start to understand the relative performance of the Future Worlds. However, the Five case models has provided a useful range of different lenses and perspectives through which to assess the Future Worlds.

We should stress that the point of this exercise was not to find a 'winning' World but to understand the trade-offs in performance between the Worlds and where advantages and disadvantages lie. As such, we would caution against reading anything into the total scores for each World across the criteria (not least because not all criteria should be ranked equally). The purpose of the assessment was to learn more about the Worlds. The breadth of the assessment criteria has meant that we have been able to draw out insights on the DSO transition which we have captured in the conclusions and insights (Section 5).

A.2 Interpreting the results of the qualitative assessment

We have assessed World C independently, even though in practice it may well be a feature of all other Worlds. This has allowed us to draw out insights into where improved access and pricing arrangements can lead to better outcomes but also where the areas where they require system operation to plug the gaps. This is important in understanding the role and scope which flexibility services need to play in the DSO transition. However, in some cases treating World C as a standalone World can lead to some 'unfair' comparisons with the other Worlds. This is particularly true on the Management Case where there is less to do to implement World C.

We have undertaken the assessment as a ranking of the Worlds. So, for example, the best performing World would be ranked 1 and the next best 2. Where the remaining Worlds performed equally, they would all be ranked 3. We have sought to base this ranking on the more obvious differences between the Worlds. This means that in some cases there are equal rankings as the Worlds are either likely to perform the same, or there is not the information available to distinguish between them.

43 http://www.energynetworks.org/electricity/futures/open-networks-project/future-worlds/future-worlds-consultation.html

44 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/469317/green_book_guidance_public_sector_business_cases_2015_update.pdf

1. Strategic case:

This case assesses how well does each model address the "case for change"?

Enhanced Customer sub-criteria:

Choice

Will assess how well each World provides both active and passive customers with relevant choices for how they interact with competitive markets. Choice is the extent to which markets remain competitive, and promote DER flexibility.

We have assessed this criterion on the basis of how each World will encourage customers to interact with flexibility markets and how many different providers there are of those markets.

	A	B	C	D	E	Justification
Choice	2	2	1	5	2	**Stage 1** New access products and price signals can provide the widest choice of participation – even at LV we can assume that by the early 2020s static ToU tariffs and basic access arrangements are in place. These will be universal products available to all consumers. The other Worlds are based around flexibility service products which consumers must actively opt into or sign up for. In Stage 1, these products may not be universally available to all customers. In World D, the ESO is not actively procuring flexible services from LV customers, reducing choice for consumers to lower their energy bills through more flexible usage. Consequently, it performs relatively less well against this criterion.
	2	2	1	2	2	**Stage 2** World C continues to perform the best as the universal access and charging signals provide an opportunity for all customers to benefit from the flexibility they can provide to the system in a way which is not possible through contracted flexibility services. However by Stage 2, all other Worlds are performing equally as in World D, the ESO is now operating flexibility markets at LV.

Fairness

How well each World achieves a level playing field for all system users and an assessment of how each World will support cost-reflective charges for all customers. This will include the following:

- *Customers that cannot react to price signals, such as those in medical situations, who might be at risk of price fluctuations that they cannot react to*
- *Customers already at risk, such as those in fuel poverty*
- *Those in geographies putting them in a situations differing to the norm.*

We are conscious that fairness can be interpreted differently depending on your perspective. We have assessed this criterion based on the extent to which of the Future Worlds provides a level playing field for network users and in that sense drive fairer outcomes.

	A	B	C	D	E	Justification
Fairness	2	2	1	2	2	**Stage 1** World C is likely to lead to the most equal treatment of consumers since new access products and price signals will be applied equally to all customers and ensure that those customers face cost reflective charges based on when they use the networks. It avoids a situation where those customers with flexible appliances (e.g. EVs) which cause network issues, are paid to help avoid the issues. This could be seen as deeply unfair as consumers with these appliances are typically higher income groups and these actions would force lower income groups to pay a proportionally higher share of network costs than they incurred. We acknowledge that price signals may lead to those consumers who are unable to shift demand paying more than they currently do. This is the nature of more cost reflective charges and there may need to be a role for social policy to help mitigate these effects.
	2	2	1	2	2	**Stage 2** We consider that the assessment is the same is in Stage 1. We note that by Stage 2 there may be further in home technology to help customers respond to price signals. This may help to mitigate some of the social issues highlighted above.

Affordability

An assessment of how well each World will enable Customers to get the services they need at a price they can afford.

We have assessed this criterion on the basis of the overall net benefit results.

	A	B	C	D	E	Justification
Affordability	1	1	5	3	4	**Stage 1** This is based on the 2030 assessment of overall net benefits. These results can be found in Table 1 in the Executive Summary.
	1	1	5	1	4	**Stage 2** This is based on the 2050 assessment of overall net benefits. These results can be found in Table 1 in the Executive Summary. .

Confidence and trust

An assessment of the transparency and predictability of future arrangements under each World. The focus on transparency will enable companies to be held accountable for decisions taken.

We have focussed our assessment on the transparency of arrangements and mitigations of conflicts of interest which might be faced by network operators. We have focussed less on accountability which is covered under a separate assessment criterion in the management case. This is simply to help reduce the overlap between different criteria. We would highlight that many of the issues around confidence and trust centre around the perception of conflict of interest though integrated network and market operation. These conflicts may or may not be real, depending on how network operators act but their perceived risk can impact confidence and trust of network users.

	A	B	C	D	E	Justification
Confidence and trust	3	3	1	2	2	**Stage 1** World C is likely to be the most transparent in Stage 1. It is based on common access products and published prices. All other Worlds rely on procuring flexibility services. There will need to be some processes in place to indicate that network operators have not favoured asset solutions over flexible ones. Worlds D and E do not require such stringent processes as they divorce the decision over using DER flexibility from the distribution asset owners.
	5	4	2	3	1	**Stage 2** The assessment is similar to the above but as the Flexibility Co-ordinator takes on the more of an ISO role it is more likely to inspire more confidence and trust as it removes any perception of conflict of interests. In World A, the expanded role of the DSO to aggregate DER into national balancing markets, may bring a higher perception of conflicts of interest which will require greater mitigation. This causes World A to perform less well against this criterion.

Consumer benefit from markets[45]

To what extent can each World create additional value for consumers through stimulating new markets for flexibility?

To assess this criterion we have looked at how the Worlds can enable all customers to access new revenue streams from markets to help reduce their energy bills.

	A	B	C	D	E	Justification
Consumer benefits from markets	1	1	4	5	3	**Stage 1** In Stage 1, Worlds A and B may be able to perform better through using the DSOs' existing relationships (through the

[45] This was an additional criteria suggested by the Open Networks Advisory Group.

	A	B	C	D	E	Justification
						connections process) and knowledge of the network to develop viable local markets and stimulate participation. In World E, the Flexibility Co-ordinators can also stimulate local markets and attract new providers but it is a new entity with whom flexibility providers and community energy schemes have no relationship. There is an argument that it can be more innovative in doing this and has greater commercial freedom than incumbent network operators. However, our assumption is that newly formed Flexibility Co-ordinators may struggle to get engagement in the near to medium term particularly from new, smaller players). World C provides the opportunity for all consumers to reduce bills through responding to price signals but these are likely to be static ToU tariffs for LV consumers. This limits the opportunity to provide other services. In World D, there are no flexibility services being procured at LV. While customers can have response aggregated to access revenue streams, the lack of consideration of LV will limit the value they can receive for their flexibility.
	1	1	1	1	1	**Stage 2** By Stage 2, consumers should be able to capture the benefits from flexibility markets in all Worlds.

<u>**Greater environmental sustainability is characterised by the following sub-criteria:**</u>

Facilitates greater energy efficiency

How well each World will support measures to achieve energy efficiency and reduce overall energy demand?

We have assessed this criterion by assessing the incentives each World is able to place on customers to reduce overall electricity demand.

	A	B	C	D	E	Justification
Facilitates greater energy efficiency	2	2	1	2	2	**Stage 1** World C may be able to encourage the greater uptake of energy efficiency measures on the basis that pricing signals are applied to all customers, even down to LV in some form. All other Worlds perform largely the same since there is a question over how well, energy efficiency can be 'bid' into flexibility markets and how this can be baselined and settled. At domestic level (where the largest size of the prize is), this could be difficult to access. There is also an issue of how to baseline energy efficiency for the purposes of verifying whether a service has actually been provided. This may impact

	A	B	C	D	E	Justification
						the ability of energy efficiency to participate in flexibility services.
	2	2	1	2	2	**Stage 2** The assessment is the same as in Stage 1, as while flexibility markets in Worlds A, B, D, and E will have developed, they are unlikely to be as effective in enabling such widespread participation of energy efficiency into markets as can be incentivised through price signals (or indeed other targeted incentives).

Facilitates decarbonisation of electricity generation

Ability of each World to support the decarbonisation of electricity generation

We have assessed the Worlds against this criteria based on how they can help make capacity available to connect new generation at both distribution and transmission level. We have not made any assumptions here on whether more low carbon generation is likely to connect at distribution or transmission level.

	A	B	C	D	E	Justification
Facilitates decarbonisation of generation	1	1	5	1	1	**Stage 1** World C performs relatively less well against this criterion as it is relying on access products and price signals alone to deploy flexibility on the network. While access products in particular can help to manage how capacity is allocated and used by different customers, it does not allow such dynamic management of the network. In addition, price signals are unlikely to provide as much certainty of response from DER as contracted flexibility. Therefore, network operators may not be willing to run the network as close to its technical limits when relying solely on price signals to stay within those limits. This reduces the capacity available to connect new generation. All other Worlds will largely be the same in that they are based on contracting flexibility through services to create capacity on the network for low carbon technologies. World D might be best at doing this on the transmission network but Worlds A and B might be best at distribution level.

	A	B	C	D	E	Justification
	1	1	5	1	1	**Stage 2** This assessment is the same as in Stage 1. While access products and price signals will become more advanced at this point, on their own they are unlikely to provide the control or certainty of response which contracted services can.

Facilitates decarbonisation of heat and transport

Ability of each World to support the decarbonisation of heat and transport.

We have assessed the Future Worlds against this criterion by focusing on the ability to make capacity available at the lower voltages of the distribution network in order to facilitate connection of electric vehicles (EV) and heat pumps (HP).

	A	B	C	D	E	
Facilitates decarbonisation of heat and transport	1	1	4	5	3	**Stage 1** Our assumption is that creating capacity at the lower voltage levels to accommodate EVs and Heat Pumps will require highly local, flexible and liquid markets, or effective access products and price signals. World D is not operating any flexibility markets to help avoid reinforcement at LV, so performs relatively less well. World C is relying solely on static time of use signals to manage the LV network along with some simple access products. As outlined in the assessment of the previous criterion, network operators are likely to build in some capacity to the network (or purchase additional flexibility) to take account of the uncertain response from price signals. World E will require regional Flexibility Co-ordinators to stimulate new flexibility markets at LV. In the early stages of development, Flexibility Co-ordinators, may struggle from a lack of understanding over how the distribution networks have historically operated. While network loading information can be easily transferred to the Flexibility Co-ordinators, knowledge of how particular network assets or customers have behaved is more difficult to pass to a new, separate organisation. However, this information could be crucial in understanding where flexible DER can provide the most benefits.

	A	B	C	D	E	
						This leads to Worlds A and B performing relatively better than World E, due to the ability to use historic knowledge of networks to help create additional headroom through flexibility and create capacity for EVs and HPs.
	1	1	5	1	1	**Stage 2** All worlds are now performing equally, as the ESO has built out capabilities at LV in World D and the Flexibility Co-ordinators have started to optimise the use of residential flexibility and have become a more established market participant with responsibility for the connection process. Price signals are likely to be sub-optimal by themselves as they do not provide the high degree of control or certainty required.

More electricity consumed closer to point of generation i.e. lower losses

An assessment of the impact each World may have on the level of technical losses in the energy system.

The focus of our assessment against this criterion has been to assess which of the Worlds can encourage more DG to connect close to demand in order to lower losses and reduce network reinforcement. We have assumed that this will be down to the ability of the World to stimulate flexibility on the distribution networks and create additional capacity for more DG to connect.

	A	B	C	D	E	Justification
More electricity consumed closer to the point of generation i.e. lower losses	1	1	4	5	3	**Stage 1** Same logic as the assessment of facilitates decarbonisation of heat and transport
	1	1	5	1	1	**Stage 2** Same logic as the assessment of facilitates decarbonisation of heat and transport

2. Economic case:

How efficiently does each model address the "case for change"?

<u>Financial benefits are characterised by the following sub-criteria:</u>

Cost of implementation versus benefits

An assessment of how efficiently each World achieves its expected benefits in terms of upfront investment. This should include the economic cost.

We have based our assessment against this criterion on the outputs of the quantitative assessment.

	A	B	C	D	E	Justification
Cost of implementation vs benefits	1	1	5	3	4	**Stage 1** Based on the results of the quantitative assessment in 2030 which can be found in Table 1 in the Executive Summary
	1	1	5	1	4	**Stage 2** Based on the results of the quantitative assessment in 2050 which can be found in Table 1 of the Executive Summary.

Expected benefits

Assessing the relative expected benefits of each World and how they relate to each actor in the system.

We have based our assessment on the outcome of the quantitative assessment of benefits. Without knowledge of future regulatory mechanisms, it is not possible to identify how these benefits flow through to different actors. However, our quantitative assessment does highlight how benefits are allocated between the four categories of benefits which we have chosen as the focus of the assessment:

- Avoided Transmission investment
- Avoided Distribution investment
- Reduced Balancing Services costs
- Avoided Generation investment.

	A	B	C	D	E	Justification
Expected benefits	1	1	5	3	4	**Stage 1** Based on the results of the quantitative assessment in 2030 and illustrated in Figures 9 and 10 in Section 4
	1	1	5	1	4	**Stage 2** Based on the results of the quantitative assessment in 2050 and illustrated in Figures 9 and 10 in Section 4.

Whole system optimisation is characterised by the following sub-criteria:

Supports whole system optimisation

Refers to degree that the World delivers whole system optimisation.

We have assessed the Worlds against this criterion on the basis that they have the information available to allow system operators to take decisions which deliver whole system benefits as opposed to benefits on a particular network. We have also assessed the incentives which will exist in each World to take decisions on a whole system basis.

	A	B	C	D	E	Justification
Support whole system optimisation	3	4	5	2	1	**Stage 1** World E may be best placed to support whole system optimisation since regional Flexibility Co-ordinators whom are fully independent have no legacy approach to system operation which may favour certain solutions over others. World E is the only Future World which can take a truly independent view across national and local needs. Similarly, in World D the ESO, as the single system operator, can take a whole system approach. However, in Stage 1 it does not actively manage flexibility on LV networks causing it to perform slightly less well than World E. In World A, the DSOs will have a fairly holistic view of distribution but only partial sight of the ESO needs at Transmission. This is because the ESO will still be running national balancing markets. This means that it is unable to optimise across the whole system in the same way that the ESO is in World D. In World B, responsibilities are split between the ESO and DSO which provides a risk that neither party has the full information available to optimise from a whole system perspective. While this can be partially mitigated through co-ordination processes it does leave open the possibility of sub-optimal dispatch of DER.

	A	B	C	D	E	Justification
						In World C, the decisions on how to optimise are left with consumers who must decide how to respond to occasionally conflicting price signals from system operators. While this can provide some degree of co-ordination, in Stage 1 these price signals are not sufficiently dynamic to reflect changing operational conditions.
	3	4	5	1	1	**Stage 2** The ranking is similar to Stage 1. The only change is that in World D, the ESO is now managing flexibility at the LV level and arguably has the same information and independence as the Flexibility Co-ordinators in World E to optimise system operation from a whole system perspective.

Optimises locally

Relates to degree that the World delivers local optimisation.

We have assessed the Worlds against this criterion based on how they can run and operate local markets at the lower voltage levels. Consequently, the results are the same as for the assessment on decarbonisation of heat and transport and encouraging generation to locate closer to demand.

	A	B	C	D	E	Justification
Optimises locally	1	1	4	5	3	**Stage 1** See the reasons under the assessment of 'Decarbonisation of heat and transport' and 'More electricity consumed closer to the point of generation'.
	1	1	1	1	1	**Stage 2** See the reasons under the assessment of 'Decarbonisation of heat and transport' and 'More electricity consumed closer to the point of generation'.

Brings more flexibility into the system

The ability of the World to attract new providers to participate in the flexibility services market and/or in the energy market and supports trading between DER.

We have assessed the Worlds against this criterion through evaluating their ability to attract new flexibility providers into markets and maximising participation. We have separately undertaken this evaluation to feed into the quantitative assessment of the benefits each World can provide (in each benefit category). The results below align with that evaluation.

	A	B	C	D	E	Justification
Brings more flexibility into the system	1	1	3	5	4	**Stage 1** Worlds A and B are able to exploit synergies of the DSOs' existing knowledge of local networks to create new local

	A	B	C	D	E	Justification
						markets and stimulate new types of flexibility providers such as community energy schemes. In Stage 1, we assume that World C is effective at HV and above but there is no dynamic price signals or access arrangements at LV to drive a dynamic response from LV providers. This limits participation. World D is not operating any markets at LV level, so performs worse as this is where much of the new flexibility providers will emerge (according to the FES).[46] Flexibility Co-ordinators in World E have the potential to stimulate innovation in recruiting customers to provide flexibility but are operating from a standing start in terms of establishing the relationship with flexibility providers and developing the required markets. As highlighted above, they may struggle initially to identify all opportunities to use flexibility as they do not have the historic understanding of how distribution networks have operated.
	1	1	5	1	1	**Stage 2** By Stage 2, all Worlds except World C will perform equally.

Manages conflicts

Relates to the degree the World is able to resolve conflict between expected/forecast/actual actions.

We have focused our assessment against this criterion in the ability of each World to provide the information required to identify a conflict and the clarity of responsibility to resolve those conflicts as efficiently as possible. The focus has been on conflicts which emerge between network and system operators.

	A	B	C	D	E	Justification
Manages conflicts	2	4	1	2	5	**Stage 1** World E is likely to lead to a greater risk of conflict between parties since the Flexibility Co-ordinators will take the decision on whether an asset or flexibility solution should be used. The DSOs and ESOs then have to implement that decision but potentially without agreeing or understanding the detailed assumptions which underpinned it. In the case of the ESO they will be dealing with four different Flexibility Co-ordinators who may all have slightly different assumptions for network planning or operations for example applying different de-rating factors to flexible resources. This could lead to conflicting

[46] Our assumption, based on the two FES scenarios we used for the quantitative modelling, is that the majority of flexibility available on the distribution system will be from network users at LV.

	A	B	C	D	E	Justification
						conclusions on where to use non-asset build options without clear responsibility on who should resolve them. World B also has the potential for conflict e.g. priority access to flexible resources at different times; impact of new connections on the network, planning scenarios. These it will require detailed rules and agreements to be reached between parties (these are not defined yet). There is also the lack of a neutral party to resolve conflicts in World B which could mean that they persist and impact the operational performance of the network. Worlds A and D are similar as there is a clear responsibility and accountability of parties to manage certain parts of the network. We consider that this makes conflicts less likely. In World C, price signals will illustrate the value of different actions to different network operators. As such it places the emphasis on customers to manage conflicts in the way they respond to the price signals. In theory this could be an effective way of managing conflicts. Although in Stage 1, they may not be sufficiently dynamic to resolve operational issues which emerge in close to real time and the ability resolve issues at LV will be very limited.
	2	5	1	2	2	**Stage 2** In Stage 2, the Flexibility Co-ordinators in World E assume more of an ISO role. This allows them to assume greater responsibility which will help mitigate the potential for conflicts. This means it performs similarly to Worlds A and D.

Avoids duplication

The degree to which the World ensures that there are no issues with duplication of flexibility services.

Our assessment against this criterion has focussed on how the extent of duplication of similar functions and technologies across the system operators and Flexibility Co-ordinators. This has formed a key part of our quantitative cost assessment and the assessment below aligns with that evaluation.

	A	B	C	D	E	Justification
Avoids duplication	3	4	1	2	5	**Stage 1** In Stage 1 all Worlds have some degree of duplication. It is arguably lowest in World C as the DSO has sole responsibility for setting distribution price signals and

	A	B	C	D	E	Justification
						the ESO sets transmission price signals. World D has little duplication since the DSO is not building out any DSO functions. World B involves duplication of a number of similar DSO functions across DSOs, while also requiring the ESO to build out functionality to manage DER flexibility into national markets. World A involves a similar level of duplication in terms of the build out of DSO functions but the ESO does not need to expand its functions to cover all DER in the same say it does in World B. Therefore, the overall duplication in World A is lower. World E requires the establishment of four new entities (the Flexibility Co-ordinators) to provide DSO and ESO needs and tender for flexibility services to meet those needs. While this avoids the DSO and ESO building out similar services they will still need to have the functions capable of identifying when to dispatch those resources, settle and bill the services. This means that duplication is likely to be highest in World E.
	3	4	1	2	5	**Stage 2** The assessment is the same as in Stage 1.

Exploits synergies

Is a measure of whether the World is able to co-ordinate actions that deliver synergies.

We have assessed the Worlds against this criterion based on how they are able to integrate new functions with existing ones to deliver the most efficiencies. We not have included World C in this assessment, because it is based on price signals and does not have any synergies with other functions to exploit.

	A	B	C	D	E	Justification
Exploits synergies	2	2	n/a	1	5	**Stage 1** World D appears to perform relatively well, since the ESO can exploit its existing system operations and expand them down to EHV and HV on the distribution networks. This enables the operations to be centralised and build on existing infrastructure and processes.

	A	B	C	D	E	Justification
						Worlds A and B perform similarly, since there are separate system operation functions at the distribution and transmission level. World E requires a new entity to be established to provide DSO and ESO requirements and take decisions on where flexibility options can meet them. This removes potential synergies between network and system operation at the distribution level, and requires a whole new set of people (with similar skills). Consequently, World E performs less well against this criterion.
	2	3	n/a	1	5	**Stage 2** The assessment is similar to above. The only change is that in World A the DSO takes on sole responsibility for managing flexibility from DER and in doing so is able to exploit more of the synergies between distribution network operation and system operation.

3. Commercial case:

How deliverable is each model – are the markets viable and regulation appropriate?

Market viability

Where elements of each World rely on market arrangements, are the markets viable and liquid enough to provide the required services.

We have based our assessment against this criterion on how easy it is to establish the required markets to deliver the services needed by DSOs and ESOs.

	A	B	C	D	E	Justification
Market viability (where a world will rely on the creation of new markets, are these viable?)	3	3	1	2	3	**Stage 1** World C requires no new markets to be created and the structures required already exist through DUoS and TNUoS charging. The one exception to this is access arrangements which may require changes to connection agreements. World D will leverage existing ESO markets and products, which are already viable and open them to new parties at distribution level. Worlds A, B and E all require new local level flexibility markets to be stimulated. Whether sufficient liquidity

	A	B	C	D	E	Justification
						can be generated in these markets at low voltages remains an unknown.
	5	3	1	2	3	**Stage 2** The assessment is similar to the above but World A now potentially needs to create more markets to enable the DSO to help aggregate flexibility from DER into national balancing markets. These could take the form of new DSO flexibility products which would need to be developed and tested and potentially standardised.

Appropriate regulation

Are appropriate regulatory frameworks available to be applied where necessary in each World?

We have assessed the Worlds against this criterion through looking at the extent to which regulatory frameworks need to change in order for the World to operate as intended. All the Worlds will require some degree of change but it is greater for some than others.

	A	B	C	D	E	Justification
Appropriate regulation (are regulatory frameworks in place?)	4	1	2	4	3	**Stage 1** World B involves the least structural change from today's arrangements and therefore is likely to more closely align with the current regulatory structure. ESO and DSO price controls may also need to be aligned in terms of scenario planning and potentially timeframes. DSOs may be required to publish information on network needs and available flexibility to remove any conflict of interest perception. There will also need to be changes to network codes to implement the co-ordination processes required but this can be done through existing processes. World C requires little structural change but would rely on new more sophisticated charging methodologies to be developed and implemented. There may need to be new regulations around how vulnerable customers, or customers who are unable to respond to price signals are treated. There may also need to be requirements to ensure that network price signals are passed on to end consumers.

	A	B	C	D	E	Justification
						World E requires a new entity to be established to act as a neutral party which procures flexibility options and evaluate whether they are better value than asset solutions. There will need to be some regulation of this entity to provide oversight and governance. Worlds A and D require the ESO or DSO to expand its system operations to cover new markets. There may need to be new incentives to encourage the DSO to meet the technical requirements set by the ESO at the GSP boundary. There may also need to be incentives to ensure that the DSO and ESO take decisions which lead to the best whole system outcomes. The current regulatory framework may not provide appropriate incentives to do this.
	3	1	2	3	5	**Stage 2** Same as above but the Flexibility Co-ordinators in World E now require substantial more regulatory oversight as they take on more system operation functions.

4. Financial case:

How viable are the funding arrangements for each model?

Regulatory funding

Where roles in each World are regulated, are they compatible with regulatory funding arrangements such as the RIIO model?

We have based our assessment against this criterion on the extent to which the Worlds require new forms of funding. All the Worlds will require new regulatory funding to a greater or larger extent, since they all require regulated entities to take on new functions or expanded roles, or create new entities to fulfil those roles. Therefore, the assessment is around which of the Worlds require least change.

	A	B	C	D	E	Justification
Compatibility with Regulatory funding	2	2	1	2	5	**Stage 1** World C may be able to align best with existing regulatory funding as all actors maintain current roles and simply rely on reformed access arrangements and price signals to manage the network. The creation of more granular access products and price signals, and settlement thereof, is likely to require new investments in these systems, particularly during the roll-out phase. Our cost assessment illustrates that this is likely to be smaller in comparison with the other Worlds. In Worlds A, B and D there could become a slight misalignment of where costs fall and benefits sit. For example, in World A, the DSO will need to install all the ICT and platforms which will be partially used to extract flexibility for the ESO to use to deliver transmission benefits. This may require a different approach to regulatory funding and how the DSO is compensated for these investments and is incentivised to consider respective cost and benefits. This challenge is common across Worlds A, B and D. World E will require new entities (the regional Flexibility Co-ordinators) to be established. These will need to be funded. This could be done by DSOs or ESOs (through additional funding in their regulatory settlement). The other option is for a separate price control for the Flexibility Co-ordinators. If this were required it would be a substantial change to regulatory funding.
	2	2	1	2	5	**Stage 2** The assessment is the same as in Stage 1.

Market facilitation

Are there funding models to support market facilitation where necessary.

We have based our assessment against this criterion on the extent to which current routes exist to fund the establishment of markets required in each World.

	A	B	C	D	E	Justification
Funding available to support market participation	2	2	1	2	2	**Stage 1** World C requires little funding to support market participation as it is based on pricing signals, although DSOs are likely to require additional funding through the price control to help generate and settle more granular price signals and manage access rights. Worlds A, B, D and E all require substantial market participation to attract the level of flexibility required. This is effectively a cost of using flexibility which needs to be traded-off against asset costs. The existing regulatory arrangements provide a mechanism for this trade-off as the TOTEX approach will encourage the use of flexibility where it is a lower cost solution to asset investment.
	2	2	1	2	5	**Stage 2** In Stage 2, World E introduces a separate actor to undertake the market participation and it is not clear how this would be funded; through DSOs and ESO or separately regulated. Consequently, World E performs relatively less well.

5. Management case:

How viable/achievable is each model in terms of complexity and alignment of responsibilities/actions with roles?

The range of criteria within the management case will provide a view on the operational integrity of the Worlds.

Industry structure and organisation is characterised by the following sub-criteria:

Rules and regulation

Relates to level of rules and regulations required for the World to function efficiently

We have assessed this criterion based on the complexity and number of new rules and regulations required in order to enable the World to function as intended.

	A	B	C	D	E	Justification
Level of rules and regulations required	2	4	1	2	5	**Stage 1** World C requires very little new rules and regulations once established. The only new rules may need to be around protecting vulnerable customers who are unable to response to price signals. Worlds A and D will require the same types of rules and regulations to inform decision making for whichever party is leading the co-ordination of DER. World B will require a

	A	B	C	D	E	Justification
						large volume of new rules and regulations to manage the co-ordination between DSOs and the ESO across system planning, co-ordination and dispatch. These same rules would need to exist in World E but, in addition, new rules around the provision of data to the Flexibility Co-ordinator and the three-way split of responsibilities between ESO, DSO and Flexibility Co-ordinator would be required.
	3	4	1	2	5	**Stage 2** In Stage 2, World B will need more rules to try and optimise the shared used of DER between DSOs and the ESO, because the volume of DER on the system will be significantly larger in Stage 2. In Stage 2, World A will require additional rules on how the DSO should aggregate DER at the GSP level into national markets. In Stage 2 World E will likely require the highest level of rules and regulations as the Flexibility Co-ordinators take on more of the system operation functions from the ESO and DSOs.

Facilitates neutral, fair and transparent markets

Is the degree that the World delivers fair and transparent flexible service markets and delivers on the objective of those markets being facilitated in a neutral manner.

Our assessment of the Worlds against this criterion is based on the extent to which actors in each World have the incentives to run neutral, fair and transparent markets. It is based on current regulation and there is nothing to prevent future regulatory changes from better aligning the incentives on parties to act in a neutral, fair and transparent way. It would be possible to undertake a separate assessment against each element included in this criterion (neutral, fair, flexible, transparent). We do not think this is the intention and have focused our assessment on how well each world can facilitate open and neutral markets.

	A	B	C	D	E	Justification
Delivers neutral fair, flexible and transparent markets	4	4	1	2	2	**Stage 1** The price signals in World C are broadly neutral to users (see the Strategic case for detailed reasons). Consequently, it performs relatively well against this assessment. Although it should be noted that protections may need to be put in place for vulnerable customers with limited flexibility in their electricity usage. The other Worlds are based around procured flexibility services. Of these, Worlds D and E are likely to be perceived to have the most neutral market facilitators since they are run by parties which are independent from network ownership. Worlds A and B are likely to require specific processes and mechanisms to mitigate any perceived conflicts of interest generated through having a single party (the DSO) running integrated network and system operation functions.
	5	4	1	2	2	**Stage 2** The assessment is similar to the above but in World A, the DSO now becomes the single procurer of DER flexibility. As the single buyer (which also has interests in network operation) there is the potential for the flexibility markets to become less transparent in the absence of the requisite regulatory oversight. This is the only change in the rankings from Stage 1.

Complexity of operating the system

Refers to level of complexity of the World and is a measure of the difficulty for industry participants to operate in the World.

We have assessed the Worlds against this criterion based on the level of operational complexity which would exist in each. As such, it has a similar assessment to the criterion around the levels of rules and regulations required as these are mainly a function of complexity.

	A	B	C	D	E	Justification
Complexity of system operation	3	3	1	2	5	**Stage 1** World C is based on reformed access products and pricing signals and once set up, should be fairly easy to operate from a network perspective. It will require continued monitoring of the network to provide the inputs for any dynamic time of use tariffs. There will also need to be monitoring access arrangements. World D may also be relatively easy to operate once established, particularly as the ESO is only operating down to the HV networks in Stage 1, although the DSOs will need to provide the ESO with a view of its network needs and for the ESO to interpret these correctly. World A is likely to be more complex to manage than Worlds D and C, as the DSO will be running local markets which may have many different requirements and participants. World B is similar in Stage 1 and so performs the same. In World E, the ESO/TOs and DSOs will need to provide the Flexibility Co-coordinators with their system operation needs and the costs of asset solutions. This is likely to be complex, particularly at LV and may require a lot of information going back and forth between these parties and Flexibility Co-ordinators to fully understand operational needs.
	3	4	1	2	5	**Stage 2** In World A, the DSO now assumes responsibility for co-ordinating all DER flexibility with clear technical guidelines to aggregate flexible DER under each GSP into national markets. This can help to reduce some of the complexity seen in Stage 1. Consequently, it is likely to perform relatively better than World B (impacting the rankings). In World E, the Flexibility Co-ordinator has become more of a regional system operator. It will require far more network information from both DSOs and the ESO to help inform network planning, connections and to optimise the dispatch of DER.

We have repeated the assessment above from the perspective of a DER flexibility provider. This draws on the feedback and insights which stakeholders on the Open Networks Advisory Group provided us with at a workshop on 1 November 2018. This highlighted differences of opinion between smaller flexibility providers and larger, more established market players. We have tried to reflect these differences in the assessment below.

	A	B	C	D	E	Justification
Complexity of market participation	2	2	5	1	2	**Stage 1** World D is more likely to lead to standardised DER flexibility products. Existing, larger market players operating across GB are likely to find this beneficial compared to having different regional products (as might be the case in Worlds A, B and E). Although we note that such products may not suit smaller, more local flexibility providers and community energy schemes have highlighted that they may prefer to interface with Worlds A, B and E Worlds A, B and E all involve the relevant system operators looking to maximise the use of flexibility across different ESO and DSO markets. This means that those providers do not need to engage as closely with separate markets, helping to reduce the complexity. This is particularly the case for new, smaller players who may not have the knowledge to manage assets across multiple markets. World C performs relatively less well, particularly for new, smaller flexibility providers as it requires monitoring of network charges and evaluating how to respond to different price signals from the ESO and DSO. While this empowers consumers and promotes choice, when operating multiple assets, this could be complex.
	2	2	5	1	2	**Stage 2** The assessment is the same as in Stage 1.

Implementation for System Operators

Is the measure of the difficulty to implement the World for System Operators.

We have assessed the Worlds against this criterion in terms of the level of change required compared to today. This has focused on the level of organisational change required by system operators for each World to become operational.

	A	B	C	D	E	Justification
Difficulty to implement for system operators	2	2	1	4	4	**Stage 1** Implementing each of the Future Worlds is likely to require substantial work from system operators. World C is potentially the least difficult to implement. While, it requires more sophisticated charging methodologies to be agreed and implemented and access rights to be defined, these can be done through existing

	A	B	C	D	E	Justification
						industry codes and requires little change to the respective roles of system operators, outside of bolstering forecasting capabilities to understand how network users will respond to price signals. While this is still likely to require substantial work, it is likely to be less difficult to implement than the broader organisational and market changes required in the other Worlds. Worlds A and B require less organisational change than the other Worlds. The main change would be to develop and implement the co-ordination mechanisms needed for planning and system operation which can be implemented through existing industry codes (particularly in World B where the need will be greater), although, this may still require considerable resources from both an ESO and DSO perspective. Worlds D and E are likely to be relatively more difficult to implement. This is because they require new roles to be developed and existing responsibilities to be split between different parties. For instance in World D, the ESO would need to start to understand flows on the higher voltages of the distribution network and interpret the reinforcement needs of DSOs. The same is true of World E where Flexibility Co-ordinators would need to understand how flexibility providers can meet DSOs' network needs. This will potentially require the transfer of resources over to the ESO or Flexibility Co-ordinators and some rules to be established on the provision of data from the DSOs. This may require new industry codes (or new sections in existing codes) and potential trialling, before implementation.
	3	1	1	4	5	**Stage 2** We have taken account in this assessment that Stage 2 would build on the capabilities and functions already established in Stage 1. The transition to Stage 2 appears to involve the largest step change in World E. It requires the transfer of functions and operations from both the ESO and DSOs into the Flexibility Co-ordinators. This potentially involves the transfer of existing communications and IT assets as well as resources and potentially contractual arrangements, such as connections. This is likely to be a significant undertaking.

	A	B	C	D	E	Justification
						Similarly, World D requires quite a large step change for the ESO to assume responsibility for co-ordinating all DER flexibility down to LV. As in World E, this may require transfer of IT communications systems and potentially resources to the ESO. However, other functions like connections, and system planning will remain with the DSOs and so the change to implement is likely to be less than in World E. The main other step change in Stage 2 is potentially the commercial arrangements in World A. In Stage 2, the DSO becomes responsible for aggregating flexible DER under each GSP into national markets. This would require changes to the balancing and settlement arrangements. However, its relative ranking remains unchanged from Stage 1.

Difficulty to implement for market participants

Is the measure of the difficulty to implement the World for market participants.

We have looked at the question of how difficult it is to implement each Future World from the perspective of flexibility providers looking to participate in DER markets. We have drawn on feedback provided at the Open Networks Advisory Group workshop held on 1 November 2018 to inform the assessment against this criterion.

	A	B	C	D	E	Justification
Difficulty to implement for market participants	4	4	1	2	2	**Stage 1** World C is arguably the easiest to implement for market participants (particularly for existing participants who are used to assessing the cost/value of network charges). It requires no new contractual arrangements (although new access arrangements may be implemented in changes to existing connection agreements) but may need more resources to forecast more sophisticated network charges and advise on the best way to manage assets to reduce those charges. All of the remaining Future Worlds require more complex commercial arrangements with the respective SO. Of these, Worlds D and E are arguably easier to implement for market participants since they involve contracting with a single party to access a range of different markets. These Worlds are also more likely to have standardised flexibility products which will be easier for those participants with a number of flexible DER assets to manage.

	A	B	C	D	E	Justification
						Worlds A and B in Stage 1 both have an element of requiring interaction with both the ESO and DSO. World B, in particular, will require DER providers to stack different flexibility services from the DSO and ESO. This is likely to require more complex commercial arrangements.
	4	5	1	2	2	**Stage 2** The assessment in Stage 2 is similar to Stage 1. The main difference is that in World A, the DSO is now aggregating flexible DER under each GSP into national markets . This allows DER flexibility providers to have a single contractual party for all flexibility services from an individual asset (in the same way as in Worlds D and E). However, there will still be six DSOs and the products may still differ across regions. In World B, there is still emphasis on the flexibility provider to work across different markets to stack revenue, rather than have a single system operator to contract with. This means that World B, performs relatively less well in Stage 2.

Future proof

Is the degree to which the World can facilitate change with ease.

We have focussed the assessment on this criterion on the adaptability of each World to new developments, in terms of the time and costs of adapting to change.

	A	B	C	D	E	Justification
Future Proof	2	2	1	2	2	**Stage 1** World C is likely to be highly adaptable because price signals can be adjusted to different circumstances. Apart from changes to the methodology, it would not require substantial changes to industry processes, planning, commercial arrangements or regulation. World C can also more easily deal with regional differences in DER penetration. It is technology neutral and avoids the needs to adapt flexibility products to new types of flexibility providers. All of the remaining Worlds would likely require equal change to adapt to a different future as they are all based around contracted services based on complex rule sets which would take time to change. Equally, all remaining Worlds require significant investment in system operation functions which could lead to sunk costs if scenarios or circumstances change.

	A	B	C	D	E	Justification
	2	2	1	2	2	**Stage 2** The assessment is the same as above.

__Technical performance is characterised by the following sub-criteria:__

Safety risk

Is the degree to which the World facilitates safe operation of the electricity network, particularly where this relies on co-ordination between network operators.

We have assessed performance of the Future Worlds against this criterion by looking at what could drive safety risk. We consider that safety risk is driven by control (or lack of it) over assets and the ability to identify network issues quickly and take immediate actions to rectify them.

	A	B	C	D	E	Justification
Degree of safety risk	1	1	1	1	1	**Stage 1** The Future Worlds mainly assess how DER flexibility can be co-ordinated and managed. While some of the Worlds have the potential to do this more effectively than others, we do not think there is any evidence that the way in which this flexibility is managed can drive greater safety issues. Consequently, we have scored all Words equally.
	1	1	1	1	1	**Stage 2** The assessment is the same as in Stage 1.

Service reliability and availability

Is a measure of the reliability and availability of electricity experienced by customers, including the degree to which each World can maintain national security of supply.

We have based our assessment of the Future Worlds against this criterion through assessing how quickly a network operator can react to make network capacity available to maintain reliability of supply. We have not specifically looked at national security of supply in this criterion as we believe that is slightly different and covered in part of our unintended consequences conclusions in Section 5. Ultimately, all Worlds can be designed to ensure a high degree of service reliability, and the question may come down to the amount of redundancy required in the networks in order to achieve this.

	A	B	C	D	E	Justification
Service availability and reliability	1	1	5	3	3	**Stage 1** Network users' response to price signals is uncertain in World C (at least initially) and hence a higher degree of redundancy is required. As a result this World performs relatively less well. Worlds D and E involve a division of responsibilities between network and system operation. This could cause

	A	B	C	D	E	Justification
						delays in decision making which may impact service availability. Worlds A and B are set up in a way to enable DSOs to exploit the synergies between network and system operation. This may be able to allow faster response to network issues through utilising flexibility resources.
	1	1	5	3	3	**Stage 2** The assessment is the same as in Stage 1.

Security

Is a measure of the physical security of network assets, and the cyber security of both operational and non-operational IT and communications infrastructure.

We have assessed the Future Worlds against this criterion based on the extent to which the critical IT, communications equipment and data analysis to operate the networks is decentralised. Our assumption is that decentralised systems are likely to be more vulnerable to attack as it is more difficult to secure multiple points of weakness. We would stress that a successful attack on more centralised system, while less likely, would arguably have a greater impact. All the Worlds are potentially vulnerable to cyber attack from behind the meter i.e. outside the reach of system operator systems; for example, attacks on home automation systems.

	A	B	C	D	E	Justification
Physical and cyber security	3	3	1	1	3	**Stage 1** In World D, more of the systems are being centralised under the ESO, which means that there are fewer vulnerable points of weaknesses and that security can be focussed on these few sites. However, a successful attack at one of these sites is likely to have a greater impact. World C is also likely to have a highly centralised system for network charging. This could use existing infrastructure like the Data Transfer Network. As with World D, this may lead to fewer vulnerable sites where security can be focussed. In Worlds A, B and E, there are likely to be numerous critical systems across each DSO region. The decentralised nature of these systems may mean that security is less sophisticated at each site, making them more vulnerable to attack. Hence, the impact of any successful attack is likely to be lower.
	3	3	1	1	1	**Stage 2** The assessment is the same as Stage 1, although the impact of a successful attack is likely to be worse in Stage 2

	A	B	C	D	E	Justification
						as there will be more DER on the system which need to be managed.

Resilience and recoverability

Is a measure of how resilient the system is to failure, and how safe and recoverable it is in the event of widespread system failure and in the event of special events such as large storms.

We have assessed the Future Worlds against this criterion based on their ability to deal with shocks (such as large storms) and then the ability to restore the system (and consumers' quality of service) in the wake of these shocks. We have not included World C in this assessment as we do not think it is valid to evaluate how access arrangements or price signals could add resilience or recoverability as they are not designed with that purpose in mind.

	A	B	C	D	E	Justification
Resilience and recovery	1	1	n/a	4	3	**Stage 1** There is clear responsibility in Worlds A and B for network outages at the distribution level, which is likely to provide greater network resilience and recovery. Both of these Worlds can exploit the synergies between system and network operations to help restore supplies quickly in the event of system failure. In World E, during a storm event, the Flexibility Co-ordinators role would be limited to identifying where flexible providers can help restore supplies quickly. There could be some delays or confusion as information was relayed between the DSO/ESO and the Flexibility Co-ordinators on the precise network conditions and therefore which flexibility options are most useful. Word D performs similarly to World E but there would be limited flexible resources to use at LV to help restore supplies more quickly following a shock incident, limiting the role which flexibility providers can play in providing network resilience.
	1	1	n/a	3	3	**Stage 2** The assessment is the similar to Stage 1. However, World D now covers LV meaning that is performs similar to World E.

Clear dischargeable accountability for technical performance

Is the degree to which the World ensures that all parties have clear visibility of and accountability for performance, and the network owner/operator is capable of addressing and managing performance risk i.e. is able to manage the risk either of non-provision or over provision of flexibility services.

We have undertaken this assessment based on the clarity of responsibilities between network operators and ability to be in control flexibility on their own networks. We do not think it is valid to include World C in this assessment since it does not include procurement of flexibility services. We have interpreted accountability to mean both clear responsibility and clear tools to effect change in those areas of responsibility.

	A	B	C	D	E	Justification
Clear dischargeable accountability	1	2	n/a	3	3	**Stage 1** In World A accountability rests with the DSO for managing DER, although DER can still provide services directly to the ESO. This still provides clear accountability to the DSO. World B performs slightly less well than World A as it has greater emphasis on the co-ordination processes in place, which have the potential to blur lines of responsibility unless designed in a very clear way, which is transparent and understood by network users. World E takes accountability for the decision over whether to use DER flexibility away from network operators. This means that network operators can be less accountable for the performance of the network as they are not responsible for some of the decisions which will impact their network. This is similar for World D (from a DSO perspective) and so these Worlds both perform similarly against this criterion.
	1	2	n/a	3	3	**Stage 2** The assessment is the same as in Stage 1 but the step change in World A assigns clear responsibility for co-ordinating DER to DSOs. This allows for greater accountability than in World B which is still reliant on co-ordination mechanisms which have the potential to blur accountabilities unless designed in a very clear and transparent manner.

Appendix B Benefit assessment Methodology

B.1 Context

In undertaking the Impact Assessment we have sought to try and understand the relative strengths and weaknesses of the different Future Worlds which the ENA has developed. Much of this has been through our qualitative assessment, but we also wanted to assess the Future Worlds quantitatively, in terms of the costs and benefits they can potentially deliver.

The timeframe available for the Impact Assessment and fact that the Future Worlds are defined at a conceptual level, means that we chose to take a high-level approach. What we have produced is not a final Impact Assessment to inform implementation but an initial assessment to help inform thinking about the DSO transition. Consequently, the absolute numbers we have produced should not be directly compared with other more detailed studies on the benefits of DSO. We chose not to undertake a whole-system, dynamic assessment of the Future Worlds as we consider that it would require complex modelling which would not be appropriate for an initial impact assessment seeking to identify the relative strengths and weaknesses of the Future Worlds. We are also conscious that such modelling would largely be opaque to stakeholders and make it difficult to challenge and build on the work we have undertaken.

We have had to make a number of assumptions in order to produce the results. We have been clear and transparent where we have made these assumptions and highlighted the basis for them. In some cases they are highly uncertain and we have chosen to present them as ranges in the results. We have provided the spreadsheet model alongside this report which will allow any interested party to change the assumptions and see how they impact the relative assessment of the Future Worlds.

We have taken a two-stage approach to assessing the range of benefits which each Future World can deliver:

1. Assess the 'size of the prize' which is available from more effective deployment of flexibility from better system operation of Distributed Energy Resources (DER) in system operation, which we have termed the benefit stack;
2. Map the proportion of those benefits which accrue to each World, across two time periods up to 2050.

The remainder of this appendix has the following structure:

- Section B.2 explains our approach to developing the potential range of benefits from effective deployment of DER for system operation
- Section B.3 then summarises the key assumptions in our approach and the justification for them. In cases where our assumptions are likely to be highly uncertain over time, we have chosen to include a range (high, central and low)
- Section B.4 then outlines how we assessed the proportion of benefits that each World could realise.

B.2 Assessing the benefit stack

Our quantitative analysis of potential benefits focused on four broad categories which could be delivered through better system operation of DER:

- **Avoided Transmission Investment**: avoided reinforcement costs caused by locational constraints;
- **Avoided Distribution Investment**: avoided reinforcement costs caused by locational constraints;
- **Reduced Balancing Services costs**: reduced cost of Balancing Services (Fast Frequency Response, Enhanced Frequency Response, Balancing Mechanism, etc); and
- **Avoided Generation Investment:** generation plant[47] that does not need to be built due to access to greater flexibility on the demand side.

Our approach for assessing the three avoided investment areas follows broadly the same four stages:

1) The unit value of the avoided investment
2) The value of avoided investment over time
3) The assets capable of providing the flexibility services that can avoid investment
4) The price which needs to be paid for flexibility services.

We have outlined the overall approach for each stage below and then specifically the method we followed for each of the three avoided investment benefit categories. We then explain the separate approach we have used to assess avoided Balancing Services costs.

B.2.1 Understanding the unit value of the avoided investment

The starting point of our approach is to understand what the value of avoided investment is. To ensure it is comparable across the different benefit categories, we have looked to do this on a pounds per kilowatt per year (£/kW/year) basis.

Transmission

We have looked at three different areas of value from avoided Transmission investment.

1) Avoided GSP reinforcement due to demand reduction

At Transmission level, we made the assumption that the main avoided reinforcement costs which can be delivered through accessing flexible DER are those at the Grid Supply Point (GSP). National Grid has set out a value of £3.33kW/year for avoided GSP infrastructure (AGIC) in its forecast TNUoS tariffs.[48] The AGIC is a component of the Embedded Export Tariff, paid to 'exporting demand' at the time of Triad. While is it paid to DG it is effectively represents the value of generation at point of peak demand. This has the impact of lowering net demand at the GSP and helping to avoid the reinforcement of GSPs. We consider that is reasonable to assume that demand reduction would have the same impact as it would reduce net demand at the GSP.

2) Reduced Transmission constraint payments

[47] This could be DG or larger Transmission connected plant. It is simply an assessment of the lower supply needed at peak due to demand side response at peak.
[48] https://www.nationalgrideso.com/sites/eso/files/documents/Forecast%20from%202019-20%20to%202023-24_1.pdf

We have also looked at how greater competition provided by flexible DER can help reduce Transmission constraint payments (which we have included as part of avoided investment). The annual spend on Transmission constraint payments is forecast to be £321m in 2018/9.[49] To gauge the potential for competition from DER to reduce constraint costs we looked at the impact of distribution connected storage on the Firm Frequency Response (FFR) market. According to National Grid's monthly Balancing Services summaries, FFR prices dropped between 20-30% from 2015 to 2017. We think it is reasonable that similar savings could be possible in constraint payments as both rely on similar market structures. Consequently, we have assumed that 20% of annual Transmission constraint costs can be saved through greater competition provided by DER and access to new technology.[50] We appreciate that that there is uncertainty around these savings. Therefore, we have applied a range with a low (of 10% savings and high of 30% savings. We profiled this so that the level of savings gradually accrue from 2018 with the full benefit achieved by 2030.

3) Avoided investment for voltage and reactive power issues

We are conscious that the Transmission constraint payments only cover thermal constraints. One of the benefits which DER flexibility can provide is helping to reduce or resolve voltage and reactive constraints on the Transmission network. The benefits which this can provide are being actively trialled under National Grid and UKPN's Power Potential innovation project.[51] The business case submitted to Ofgem for the Power Potential project included forecast potential investment savings for 2030, 2040 and 2050. Consequently, we have used these values as an additional benefit which DER can provide. Table B1 below illustrates these values.

Table B1 Potential benefits from DER to reduce Transmission voltage and reactive power constraints[52]

	2030	2040	2050
Trial area benefits £m NPV	10.6	18.3	26.0
GB wide benefits, £m NPV	155.7	269.3	382.8

We applied a linear equation to extrapolate the benefits in Table B1 across all years from 2018 to 2050.

Distribution

Similar to our approach for Transmission, we have looked to the distribution (DUoS) charging methodology to provide a proxy for the value of distribution avoided investment. The Common Distribution Charging Methodology (CDCM) models distribution tariffs which are based on the incremental expansion costs of adding 500MW of demand onto the distribution system at the point of maximum demand. Each CDCM model contains the £/kW/year 'yardstick' values of these expansion costs across all voltage levels.

Table B2 below provides an average of these yardstick values which we have weighted by the demand in each DNO. The CDCM yardstick breaks out these values across all assets and transformers. For simplicity, we have summarised them into three voltage levels – LV only, HV only and EHV only.

[49] See National Grid MBSS March 2018: https://www.nationalgrideso.com/balancing-data/system-balancing-reports
[50] We note that the 20% savings seen mainly come from storage providers which are a good example of a new technology.
[51] https://www.nationalgrideso.com/innovation/projects/power-potential
[52] https://www.ofgem.gov.uk/ofgem-publications/107804

Table B2 DNO demand weighted average of CDCM yardstick

	LV only	HV only	EHV only
Weighted average of yardstick values in the CDCM (£/kW)	£29.52	£34.24	£39.55
Proportion of value assumed for LV flexible asset	100%	33%	33%
Proportion of value assumed for an HV flexible asset	0%	100%	33%

We used the demand weighted yardstick values to represent the annual value to DSOs of a kW reduction at local peak demand, where assets are already demand constrained.[53] We are conscious that these values will differ significantly across different locations and depending on the size of the asset. However, for the purposes of this impact assessment, we needed to generate a single national average value. We acknowledge that the CDCM is not a perfect source to use for these values. Therefore, we have applied a range around them under a high and low case to illustrate the uncertainty. This is detailed in Section B.3 below.

For clarity, we have assumed that the value of the transformer between voltage levels is included in the lower voltage level, for example the LV/HV transformer is included in the LV yardstick value. This is on the basis that it is demand at the lower voltage level which will drive reinforcement of the transformer. The EHV value includes 132kV assets for those DNOs which have them.[54] We used these values as a proxy for network expansion costs for both demand and generation.

We acknowledge that they are demand driven values but we would expect the costs of expanding a constrained network for generation to be similar given the similar nature of the assets required. We have been advised by the DNOs that generation is connected to a different engineering standard to demand which could reduce the costs required. We also understand that in some cases, there may be some additional costs of network expansion for generation because generation reinforcement can often be driven by fault level reinforcement which is more expensive. Since we are applying a range to our values of avoided distribution, we consider that these issues will be picked up as part of the higher and lower end of the ranges we are using.

To understand the full value of flexibility at distribution, we also had to make an assumption around the upstream impact of LV demand on HV and EHV reinforcement. For instance if you pay an LV connected asset a price to avoid LV reinforcement, that can also help avoid HV and EHV reinforcement in some (but not all cases). We have sought to take account of this in our assessment. Again, the best available representation of the split of incremental reinforcement costs would appear to be the CDCM yardsticks which look at where the costs of adding 500MW of demand fall across voltage levels (as illustrated in Table B2). These values broadly show an even split across voltage levels. On this basis, we have assumed that where a flexible asset is used to avoid reinforcement, it delivers 100% of the value at the voltage level it is connected at and 33% of value at the voltage levels above.

In addition, we also had to make some assumptions over the voltage levels where flexible resources will be available. For Electric Vehicles and Heat Pumps this is predominately the LV level. However,

[53] By this we mean that they require reinforcement to accommodate any additional demand
[54] In Scotland 132kV assets are owned by Transmission Operators, not Distribution Network Operators

we needed to make an assumption over where providers of flexibility services will be located. For simplicity, we assumed that these are all HV connected. For DG, we assumed an equal weighting of connections between voltage levels. We recognise that today the majority of DG volume is connected at HV and EHV but going forward we would expect DG at LV to increase.

Avoided generation investment

For avoided generation we simply used the Capacity Market prices as being representative of the value of avoided generation build, since if the generation requirement reduces, this represents the main source of savings to customers.

We took an average of the last four years of the Capacity Market T-4 price which equates to £17.92/kW/yr. We held this price constant in real terms out to 2050.[55]

B.2.2 Profiling the value over time

The steps outlined above provide a value for flexibility based on a fully constrained Distribution and Transmission network. Consequently, in order to understand the volume of avoided investment it is possible for the Future Worlds to deliver, we needed to assess how constrained the networks are, on average across GB, both today and out to 2050. A detailed engineering study of current and future constraints would be a helpful resource to use to understand the level of future constraints. In its absence, we had to use the best available data and make some assumptions around how the level of constraints on the network will change from today out to 2050.

Transmission

We have three different areas for avoided Transmission investment. We took a different approach in each of the three areas.

For avoided GSP investment, we did not profile the value over time. This is because it is based on tariffs reflecting the current level of constraints on the network. We acknowledge that National Grid is forecasting some increases to the AGIC over the next five years within its forecast TNUoS tariffs. We believe that applying a high range (£6/KW/year) will take account of this.

For reduced constraint costs, we had to make some assumptions around how Transmission constraints might increase out to 2050. To do this we looked at the FES data to calculate the percentage increase in Transmission connected generation (compared to today). We then increased the 'pot' of Transmission constraint payments by this percentage in each year.

We assumed that the Power Potential CBA includes appropriate profiling of voltage constraints over time.

Distribution

For avoided Distribution investment, we looked to profile both the demand and generation constraints out to 2050. This is because the yardstick values we took from the CDCM are pure incremental cost values i.e. they represent the cost of adding 500MW of demand to the distribution network when it is fully constrained. This is different from the Transmission tariffs which simply

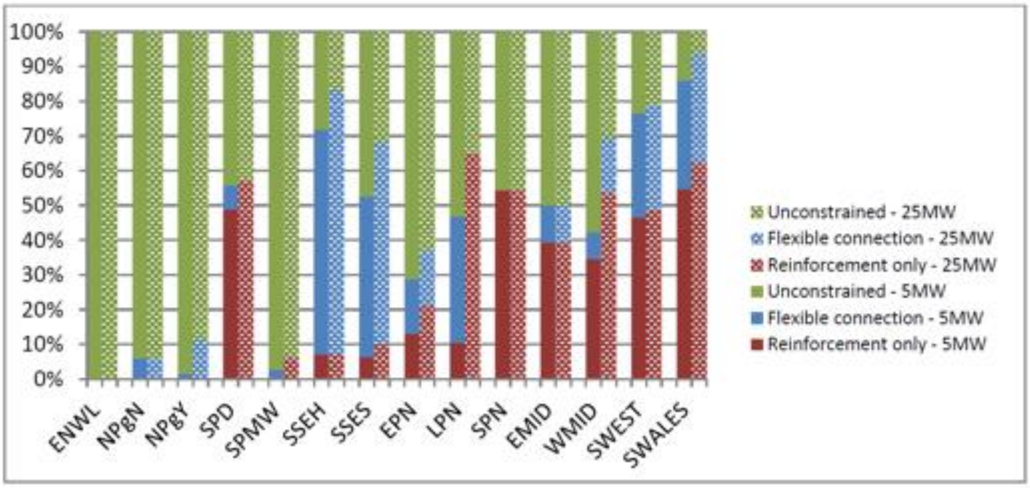
[55] For consistency, all prices used in the assessment are 2018/19 real prices.

reflect the value of a kW of demand at a certain location (based on current loadings). For this reason, we thought it appropriate to apply a different profile for demand and generation constraints.

Generation

To profile the value of avoided generation related reinforcement, we looked at data to give an indication of how generation constrained the distribution network is. The best publically available data we could find in this area was in some information Ofgem published in 2016 based on an information request made to DNOs.[56] This data showed the proportion of GSPs under which a DNO could connect either a 5MW or 25MW generator without the need for either reinforcement or where only a flexible (constrained) connection was possible. Figure B7 illustrates the results which Ofgem published.

Figure B4 Proportion of GSPs which are generation constrained[57]



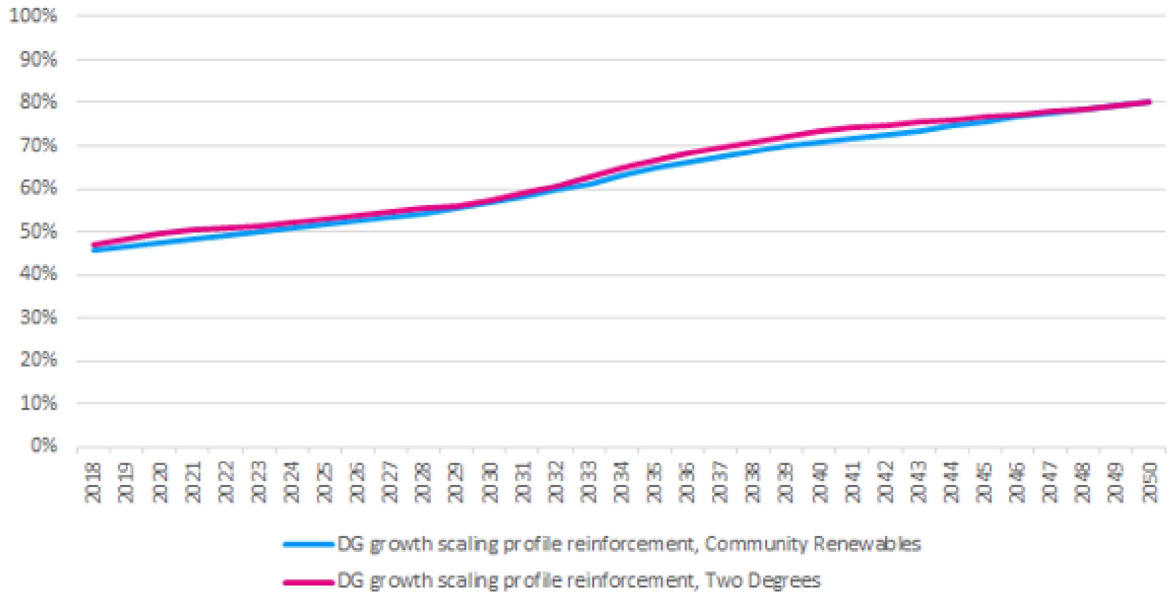
We were unable to obtain the underlying data behind this chart published by Ofgem but were able to recreate the chart to gain a sense of the level of constraints. This illustrates that under roughly 40% of GSPs, there is not sufficient distribution capacity to provide an unconstrained connection without undertaking reinforcement. There is obviously a mixed picture across different DNO regions. The modelling we undertook is based on a GB average but this underlines the point that there will be significant regional differences.

We took this starting point and profiled it over time based on the forecast DG volumes under the Two Degrees and Community Renewables scenarios. This is to illustrate that constraints will increase as more DG seeks to connect. There was a question over what the maximum level of a constrained network might be. It seems fair that it would never be 100% as DSOs are unlikely to manage every part of their network under ANM to its operational limits. However, there is little data available on what this level might be. Consequently, we assumed a level of 80% as a reasonable threshold and included a range either side to highlight the uncertainty surrounding it. We validated this with the ENA's Product Team as a reasonable assumption in the absence of other evidence. The details of this

[56] https://www.ofgem.gov.uk/system/files/docs/2017/02/unlocking-the-capacity-of-the-electricity-networks-associated-document.pdf
[57] https://www.ofgem.gov.uk/system/files/docs/2017/02/unlocking-the-capacity-of-the-electricity-networks-associated-document.pdf

range is set out in Section B1.3. Figure B8 below, highlights the profile of generation constraints we have assumed in our central case.

Figure B8 Profile of generation constraints out to 2050



Demand

On the demand side, we wanted to understand what proportion of the value of avoided distribution investment that can be delivered through demand flexibility. We found little data in this area, particularly as DNOs do not currently report the loading of assets at LV and HV networks. We looked at Load Indices which DNOs produce to illustrate the loading of primary network assets[58] but found that these were not a useful indication of the potential for LV and HV reinforcement triggered by EVs and Heat Pumps.[59]

In the absence of firm data, we took a slightly different approach. We looked at studies which illustrate the avoided reinforcement costs which can be delivered through demand flexibility to gain an idea of the proportion of flexible resources which might be able to deliver avoided reinforcement. Specifically, we looked at the My Electric Avenue study which considered the benefits of smart charging of EVs.[60] We used the results of that study to understand the proportion of reinforcement which can be avoided.[61] To do this we looked at the number of LV feeders on which reinforcement can be avoided using smart charging, indicated at 312,000 in the My Electric Avenue Study. We looked at the cost of reinforcing LV feeders based on data published by UKPN in its RIIO-ED1 RIGs.[62] Comparing our results to the benefits estimated through My Electric Avenue illustrated that it was possible to avoid 26% of reinforcement through smart charging.[63]

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[58] Typically at the higher voltage levels
[59] The figures illustrated that the primary network was less than 3% constrained.
[60] http://myelectricavenue.info/
[61] The study indicated that 312,000 LV feeders would need reinforcement due to EV growth. Taking figures from UKPN's published ED1 RIGs we looked at the costs of LV feeder reinforcement. This came to around £8.5bn. The claimed benefits of My Electric Avenue were quoted at £2.2bn – so roughly 25% of the total costs incurred
[62] http://library.ukpowernetworks.co.uk/library/en/RIIO/Ofgem_RIGs_Data_Tables/
[63] The actual figure was 25.7%

We used this calculation as a basis as to understand how the volume of flexible assets might convert into an avoided reinforcement. This is a blanket assumption which we used in the absence of other reliable data. While the data has come from an EV trial we note that the majority of flexible demand resources are at LV, and it also provides an indication of the potential value which flexible resources can deliver. We consider that this area is where engineering studies on the future reinforcement of networks would be a helpful input to the analysis. In recognition of this broad approach, we applied a low and a high range on this proportion which we have outlined in Section B3.

Avoided Generation investment

We based the values of avoided generation investment on an average of the T-4 capacity market auction clearing prices. While this value may well change in future years, this could be down to a range of factors, all of which are outside of the influence of network companies and the Future Worlds. While you could look to model these differences, we felt that it would be a significant distraction from the rest of the analysis and was not worth the time investment given the timeframe to complete the analysis and recent announcements by the European Commission Court of Justice. Instead, we chose to apply a range of values to reflect this uncertainty. These values are based on the range of T-4 capacity market auction clearing prices seen to date. That is, the highest and lowest T-4 auction clearing prices. These are outlined in Section B.3.

B.2.3 Types of assets to provide services

The next step in our methodology was to understand what services would be needed to help avoid investment and the assets capable of providing those services. Table B3 below provides a summary of the types of the technical services required and the assets likely to be capable of providing these services. We are aware that there may be other technologies which can provide similar services, both today and certainly within the future. We have focused on the below because they form the vast majority of assets which can provide services today and to be consistent with National Grid's Future Energy Scenarios (FES) which we used to look at the volume of those assets available.

Table B3 Summary of assets capable of providing flexibility to avoid investment

<table>
<tr><th rowspan="2">Benefit category</th><th colspan="2">Demand driven investment</th><th colspan="2">Generation driven investment</th></tr>
<tr><th>Demand turn down</th><th>Generation turn up</th><th>Generation turn down</th><th>Demand turn up</th></tr>
<tr><td>Avoided Transmission investment</td><td rowspan="3">Flexible EVs (smart charging), Heat Pumps, flexible I&C customers[64], Storage, household appliances</td><td rowspan="2">Flexible DG[65], Storage[66]</td><td>n/a[67]</td><td>n/a[68]</td></tr>
<tr><td>Avoided Distribution investment</td><td>All new DG[69]</td><td>n/a</td></tr>
<tr><td>Avoided generation investment</td><td>n/a</td><td>n/a</td><td>n/a</td></tr>
</table>

We used the data set out by National Grid in its 2018 FES to assess the volumes of DER on the network which can provide these services. The FES includes an 'engagement index' for I&C DSR assets and smart appliances to illustrate what proportion will be willing to provide flexibility services. We applied these indices to the assets to understand the proportion which will be participating in flexibility markets. We then applied a separate de-rating factor to reflect the availability of those assets across the year. These de-rating factor are those used in the most recent T-4 capacity market auction.[70] This provided us with a volume of flexible resources on the system in each year out to 2050 which are capable of providing the flexibility services required to deliver avoided investment. We then applied these volumes of assets consistently across our benefit categories.

B.2.4 The price paid for flexibility services

After determining the value of avoided investment, we needed to assess the price to pay for flexibility services. This is one of the more difficult areas to assess as DER flexibility markets are still nascent and information about the price being paid to specific providers is often commercially sensitive. In addition, the price offered for a specific service will depend on how a provider is stacking different services. We have looked at a number of ways to calculate these prices.

1. Assess the 'missing money' from other services

We undertook some analysis looking at the annual required revenue (£/kW/year) to cover investment and operating costs for typical new DER such as storage assets and reciprocating gas

[64] This includes behind the meter generation
[65] Thermal plant capable of generation turn up
[66] We have not included Vehicle to Grid (V2G) in the assessment of generation turn up as there is uncertainty over what volumes will be available at times of peak demand. Once there is greater evidence from trials, it would be useful to add this to the assessment.
[67] Covered through assuming 20% savings on Transmission Constraints through access to DER including storage
[68] As above
[69] We have only assessed New DG on the basis that only new DG is likely to be connected under ANM and be able to provide generation turn down
[70] We considered that these were reasonable approximations to make for the availability of flexible resources to provide services when called.

engines. We then looked at the £/kW/year revenue they might earn through existing markets (wholesale, Capacity Market, Balancing Services, Balancing Mechanism, etc).[71] We assessed the revenue shortfall the asset to break even, on the basis that this could be a proxy for what DER require as a price for providing a flexibility service to the DSO.

2. Existing assumptions in CBA projects

We looked at some of the CBAs used for innovation projects and the assumptions used in those on what price was paid for flexible services.

3. Current flexibility prices

We also looked at current prices being paid for DER flexibility. This includes the prices being paid to DER for FFR and EFR services and WPD's flexible power prices for their 'secure product'. In both cases we had to make assumptions around the utilisation of flexibility to produce a £/kW/year price.

Based on the above and reflecting the uncertainty around these prices, we used a central case of £26/kW/year with £6/kW/year on the low side and £45kW/year on the high side as a price paid for flexibility. There is an argument that our central case prices will fall over time as the volume of flexibility providers increases (through increased competition). Through presenting the prices as a range, we think this takes into account how prices may change going forward.

Price paid for demand reduction for avoided Transmission GSP investment and avoided generation services

For both avoided GSP investment at Transmission and avoided generation investment, we assumed for the purposes of this analysis that these are essentially 'free' on the back of flexibility services procured by the DSO to operate the distribution system.

B.2.5 Reduced Balancing Services costs

To assess the potential savings from Balancing Services cost, we deployed the same approach as for Transmission constraint payments. This results in an annual saving of 20% under our central case, with a low range of 10% and high range of 30% (see Section B.3 for details).

In addition, we needed to make some assumptions around how the volume of Balancing Services actions might increase over time. We assumed that this will be driven by the proportion of intermittent generation which is connected to the system. We looked at how Balancing Services costs (excluding transmission constraint costs) have increased since 2005 as the level of intermittent generation has increased. We calculated the average increase in Balancing Service costs for each percent of increase in intermittent generation. This was calculated at £1.8 million a year for each 1 percent increase in renewables.

We then profiled the percentage of intermittent generation out to 2050 in both the Two Degrees and Community Renewable scenarios. This allowed us to apply the increase in Balancing Services costs to each year out to 2050. We applied our percentage savings due to increased competition in each year out to 2050. As with the Transmission constraints, we profiled these savings gradually, so that they ramp up to the assumed values by 2030.

[71] This assumed that Capacity Market payments were in place and that current embedded benefits were removed by 2022.

B.3 Summary of key assumptions and ranges

This section provides a summary of the key assumptions we have made and the justification for these. Where there is considerable uncertainty over how those assumptions will change over time, we have included them as part of a range.

Our ranges are based on a low (pessimistic), central and high (optimistic) case. The low case includes all the most pessimistic assumptions across both costs and benefits. The central case contains our best estimate on those key assumptions and the high case, a more optimistic take on the assumptions.

We have split out the key assumptions below into different areas of the assessment.

Avoided Transmission investment

We looked at where access to flexible resources connected on the distribution network can lead to avoided investment on the Transmission network. As with the avoided distribution investment this is a difficult area to assess, particularly as Transmission investment tends to be lumpy and for specific projects. The sections above describe the approach we took. Table B4 below highlights the key assumptions which underpin our analysis of Avoided Transmission Investment.

Table B4 Key assumptions to assess avoided transmission investment

Area	Central Assumption	Justification	Range used
Value of avoided Transmission investment	£3.33/kW	National Grid five year TNUoS forecast[72]	Pessimistic: £2/kW/yr Optimistic: £6/kWyr
Level of constraints on the Transmission network	That the value of locational demand tariffs indicate the expansion costs at the GSP	The tariff reflects the actual value to the Transmission Operators	n/a
Benefit from DER in Transmission constraint markets	20% saving on costs		Pessimistic: 10% Optimistic: 30%
Payment needed for flexibility services from DER	That no payment is needed for flexibility which avoids GSP investment	This flexibility will be a by-product of the flexibility which is contracted by DNOs at lower voltage levels. The value is too low (£3/kW) for it to be made a specific services	n/a

[72] https://www.nationalgrideso.com/charging/transmission-network-use-system-tnuos-charges

Avoided Distribution investment

This was a key area of the assessment as it is the largest areas of benefits for the Future Worlds. Our approach first required us to understand the potential size of benefits available due to avoided distribution investment. These are summarised in Table B5 below which provides the justification for those assumptions and where we felt it necessary to include a range.

Table B5 Key assumptions to assess avoided distribution investment

Area	Central case	Justification	Range
Value of avoided distribution reinforcement	£53.87/kW/yr at LV £47.29/kW/yr at HV	These are based on the incremental cost of building out the distribution network according to the CDCM	Pessimistic: 20% less Optimistic: 10% more
Proportion of flexible capacity that can be assumed to contribute to avoided reinforcement	26%	This is calculated using some of the results of the My Electric Avenue study on the proportion of reinforcement that can be avoided. We consider it the best available proxy for the conversion of flexible resources to avoided reinforcement	Pessimistic: 15%[73] Optimistic:-36%
Proportion of upstream reinforcement assumed to be avoided through access to flexibility	33% at each voltage level above the voltage of connection	This is based on the split of reinforcement costs within the Distribution Reinforcement Model used to produce the yardstick costs in the CDCM	n/a
Price paid for flexibility	£26/kW/year	We undertook a range of assessments to understand the likely prices which flexibility needs to be paid. WPD's flexible Power 'secure' prices fall in the middle of this range. We kept this range constant through time in real terms	Pessimistic: £45/kW/yr Optimistic: £6/kW/yr

[73] We have applied a 40% upside and downside from our central assumption

Area	Central case	Justification	Range
Current level of generation constraints	44% of the distribution network is currently generation constrained	This is based on data published by Ofgem in 2016 on the proportion of constrained GSPs. Given the time gap of the data, we think it is valid to apply a range	Pessimistic: 35% Optimistic: 50%
Upper threshold of generation constraints managed through flexibility	80% of the newly connected DG is being managed through ANM[74]	There is little data in this area. We took an assumption based on conversations with the ENA's Product Team and applied a broad range	Pessimistic: 60% Optimistic: 90%
Generation offsetting demand reinforcement	We did not take account of any reduction in demand driven reinforcement due to local generation	We found little data on which to base a national assumption over the proximity of generation to demand and the co-incidence of that generation to peak demand	n/a
From what date are smart EV/HP charging solutions available	That flexibility from EVs and heat pumps is not available until 2023	This is based on the start of the next distribution price control and provides time to build out smart charging infrastructure and new access arrangements are due to be in place	n/a

Avoided Balancing Services costs

As part of our approach, we looked at how Future Worlds can enable greater access of DER into Balancing Services markets, to increase competition and potentially lower prices. We had to make some assumptions around the value of Balancing Services out to 2050 and the benefits which competition can provide. These are summarised in Table B6 below.

[74] Active network management

Table B6 Assumptions for avoided balancing services costs

Area	Assumption	Justification	Range
Value of balancing services out to 2050	That this will increase in line with the volume of intermittent generation on the system	Greater balancing actions will need to be taken when there is a more intermittent generation on the system	n/a
Potential benefits of competition and new technology	20% savings each year	That the recent fall in FFR prices due to battery storage provides evidence for the reductions which can be achieved in wider Balancing Services (10-30%)	Pessimistic: 10% Optimistic: 30%

Avoided generation investment

We looked to include the benefits of reduced peak demand under the Future Worlds, in order to reduce the generation capacity needed to meet that demand. We outline the key assumptions used in Table B7 below.

Table B7 Assumptions for avoided generation investment

Area	Assumption	Justification	Range
Value of avoided generation investment	That the Capacity Market T-4 auction is a good indicator of the marginal cost of adding additional generation capacity to the system (£17.92/kW/year)	We consider that it is appropriate to include a range in our assessment given the future uncertainties in Capacity Market prices. The range is based on the lowest and highest Capacity market prices in the last 4 years	Pessimistic: £8.65/kW/year Optimistic: £23.47/kW/year
What price is paid to flexibility providers to reduce generation capacity requirement	No price needs to be paid since peak demand reduction is a consequence of flexibility actions taken by the DSO and ESO	There is no specific service available for generation adequacy (outside of the Capacity Market). SOs will not be paying DER separately for it.	n/a
How quickly can savings through competition be realised	That the full savings through increased competition are not seen until 2030; we profile them up to that level	It will take time for some the DER numbers to increase and for markets to develop, particularly to access balancing services	n/a

B.4 Mapping the proportion of benefits to the Future Worlds

The second aspect of our benefit methodology was to take the overall size of prize for benefits from better system operation and see what proportion could be mapped across to each of the Future Worlds based on their performance.

We assessed how well each Future World would perform against three critical factors for system operation:

- **Primary control**: The extent to which a system operator has control over the decision to dispatch DER
- **Certainty of response**: What certainty does a system operator have that once the decision to dispatch has been taken, it will be met
- **Maximising participation**: The extent to which a system operator can maximise participation in flexibility markets to increase competition.

At a high level, we considered that performance against these three factors would drive the benefits which each Future World could deliver. We were conscious we would need to assess these three factors for each of our benefit categories. Consequently, we first looked to establish how important each factor would be in delivering each benefit category. This is indicated in Table B8 below.

Table B8 Importance of the factors in each benefit category

Benefit	Primary control	Certainty of response	Maximise participation	Notes / Justification
Avoided Transmission Investment	High	High	Low	Maximising participation is not critical for transmission system operation because of the wide range of potential Balancing Services providers across the system. However, once dispatched, the ESO will need a high level of certainty that the response will be delivered. The ESO will also need a good deal of control over the timing of the dispatch of DER to deliver the flexibility required
Avoided Distribution Investment	High	High	High	Distribution network needs are highly locational. There will need to be a high level of participation to deliver the liquidity in markets at specific locations. In addition, once a decision has been taken not to invest in assets and rely on flexibility, there are few alternatives but to rely on that flexibility (from very specific assets). This makes certainty of response equally important. Primary control is also an important factor as the

Benefit	Primary control	Certainty of response	Maximise participation	Notes / Justification
				DSO needs to have control over the decision to dispatch in order to obtain the flexibility required
Reduced Energy Balancing Costs	Medium	High	High	The main driver for reduced Balancing Services costs is greater competition from DER and hence maximising participation is important. The ESO/ Flexibility Co-ordinator will still require certainty of response. The primary control of dispatch is slightly less important
Avoided Generation Investment	n/a	n/a	High	SOs do not have responsibility for avoided generation investment and there are no specific services for it. The benefit will be driven as a by-product of flexibility services used by system operators (especially DSOs) for constraint management, where those services help to reduce overall system peak demand. Consequently, the benefits will be realised by maximising participation in flexibility markets, rather than control over dispatch and certainty of response. The higher the access to flexibility the greater the peak reduction is likely to be.

We used this assessment to allocate the total benefit in each category to each of our factors. This was done on the basis of the relative importance allocated to each factor for each benefit area. This is illustrated in Table B9 below.

Table B9 Proportion of available benefit in each factor

Benefit	Primary control	Certainty of response	Maximise participation
Avoided Transmission Investment	40%	40%	20%
Avoided Distribution Investment	33%	33%	33%
Reduced Energy Balancing Costs	20%	40%	40%
Avoided Generation Investment	0%	0%	100%

Having established the available benefit for each factor per benefit category, we wanted to assess how each Future World performed in delivering that benefit. For example, in World A, how much of the benefit of avoided transmission investment could the ESO capture without primary control of DER.

Our assessment was based around a qualitative assessment of the proportion of benefit which each Future World could deliver in each category. There were five options depending on how well a Future World performed:

- 0% - Very poor performance
- 25% - Poor performance
- 50% - Average performance
- 75% - Good performance
- 100% - Excellent performance.

The series of tables below illustrate the results of that assessment. As highlighted in Section 3 of the report, a key assumption was that by Stage 2 of the development each Future World, with the exception of World C, would deliver 100% of the benefits. Consequently, we only illustrate the Stage 1 results for Worlds A, B, D and E. The percentages illustrated in these tables were applied to the benefits available in each area to produce the overall gross benefit which each Future World could deliver.

These tables are repeated (along with the justification) in the spreadsheet model which sits alongside the report.

Table B10 World A Stage 1 assessment

Benefit	Primary control	Certainty of response	Maximise participation
Avoided Transmission Investment	25%	75%	75%
Avoided Distribution Investment	75%	75%	75%
Reduced Energy Balancing Costs	25%	75%	75%
Avoided Generation Investment	n/a	n/a	75%
Notes/Justification	Primary control is low for Transmission since the ESO must rely on the DSO to dispatch and this will be dependent on distribution constraints. The same is true for Balancing Services where DER are being used. Control for Distribution is high since the DSO will have autonomy on dispatch decisions. There are no specific services that SOs have to help avoid generation investment so primary control is not applicable.	Certainty of response is high throughout since contracted services should be able to deliver a high certainty of response. Since there are no specific services for avoided generation investment, certainty of response is not applicable.	Maximising participation from DER will be high since the DSO will be able to define bespoke, local markets down to LV which will help bring new sources of flexibility to the market. These sources can be used for a range of services across T & D.

Table B11 World B Stage 1 assessment

Benefit	Primary control	Certainty of response	Maximise participation
Avoided Transmission Investment	50%	50%	75%
Avoided Distribution Investment	75%	50%	75%
Reduced Energy Balancing Costs	50%	50%	75%
Avoided Generation Investment	n/a	n/a	75%
Notes/Justification	World B prioritises distribution dispatch needs over Transmission, so the DSO has a high degree of control on dispatch. For the same reason, the ESO has less control because it cannot be sure if its decision to dispatch a DER will be 'overruled' by the DSO.	The certainty of response falls compared to World A because market participants are stacking revenues from different sources. This means that they may choose to incur non-delivery penalties on DSO services, in order to provide more remunerative ESO services and vice-versa.	Market participation remains high, as in World A because the DSO is stimulating local markets down to LV which can also be accessed by the ESO.

Table B12 World C Stage 1 assessment

Benefit	Primary control	Certainty of response	Maximise participation
Avoided Transmission Investment	0%	50%	50%
Avoided Distribution Investment	0%	50%	50%
Reduced Balancing Services Costs	0%	50%	50%
Avoided Generation Investment	n/a	n/a	50%
Notes/justification	Price signals provide no control for system operators and may not be dynamic enough in Stage 1 to reflect changing system needs in real time.	Price signals can only provide a medium level of certainty of response and users of the network may chose not to change behaviour in response to price signals. The level of response can be studied over time and built into forecasting tools.	More granular price signals can generate high participation, but in Stage 1 we assume that they only apply down to HV which means that participation at LV will be limited to ToU tariffs and simple access arrangements, Potentially limiting participation from LV customers.

Table B13 World C Stage 2 assessment

Benefit	Primary control	Certainty of response	Maximise participation
Avoided Transmission Investment	0%	75%	100%
Avoided Distribution Investment	0%	75%	100%
Reduced Energy Balancing Costs	0%	75%	100%
Avoided Generation Investment	n/a	n/a	100%
Notes/justification	Price signals provide no control for system operators and are not dynamic enough to reflect changing system needs in close to real time.	Automation of domestic appliances with price signals should improve certainty of response, compared to Stage 1.	The expansion of granular, dynamic price signals down to LV will increase participation to all customers.

Table B14 World D Stage 1 assessment

Benefit	Primary control	Certainty of response	Maximise participation
Avoided Transmission Investment	75%	75%	50%
Avoided Distribution Investment	25%	75%	25%
Reduced Energy Balancing Costs	75%	75%	75%
Avoided Generation Investment	n/a	n/a	50%
Notes/Justification	World D provides a reasonably high degree of control for Transmission related services. However, the DSO has little control in World D and there is no control of LV flexibility in this stage.	World D provides a high degree of certainty since contacted services should be able to provide a high degree of response.	World D relies upon centralised procurement of flexibility services by the ESO. These may work well for larger providers which are key for avoided Transmission investment and Balancing Services cost reduction but may not attract the more local providers who can provide distribution level services. In Stage 1 of World D, we are assuming limited services at LV, which impacts the amount of avoided distribution investment that is possible.

Table B15 World E Stage 1 assessment

Benefit	Primary control	Certainty of response	Maximise participation
Avoided Transmission Investment	75%	50%	50%
Avoided Distribution Investment	75%	50%	25%
Reduced Energy Balancing Costs	75%	50%	50%
Avoided Generation Investment	n/a	n/a	50%
Notes/Justification	Primary control is high because the decision to dispatch still resides with the ESO for transmission related services and DSO for distribution services.	Certainty of response will be similar to World B because at this stage, flexibility providers are stacking revenues from both ESO and DSO and therefore might chose to take penalties on non-delivery on one service to provide a different more remunerative service.	Flexibility will be procured centrally and hence the level of participation is assumed to be similar to World D with slightly lower participation in Balancing Markets due to the Flexibility Co-ordinator being a new (unknown) party.

Appendix C Cost assessment methodology

C.1 Summary of approach

The cost methodology utilises the existing work undertaken in the SGAM modelling and within the Open Networks project to understand the relative differences in costs between the Future Worlds. To do this we have focused on the following elements:

- The degree to which DSO functions (and subsequent resources) are duplicated across actors within each Future World
- The volume of information exchanges required between actors in each Future World
- Where economies of scale can reduce the costs within a Future World.

To tease out how these areas impact the relative costs of the Future Worlds, we have used the high level methodology outlined in Figure C1 below.

Figure C1 Summary of costs assessment methodology

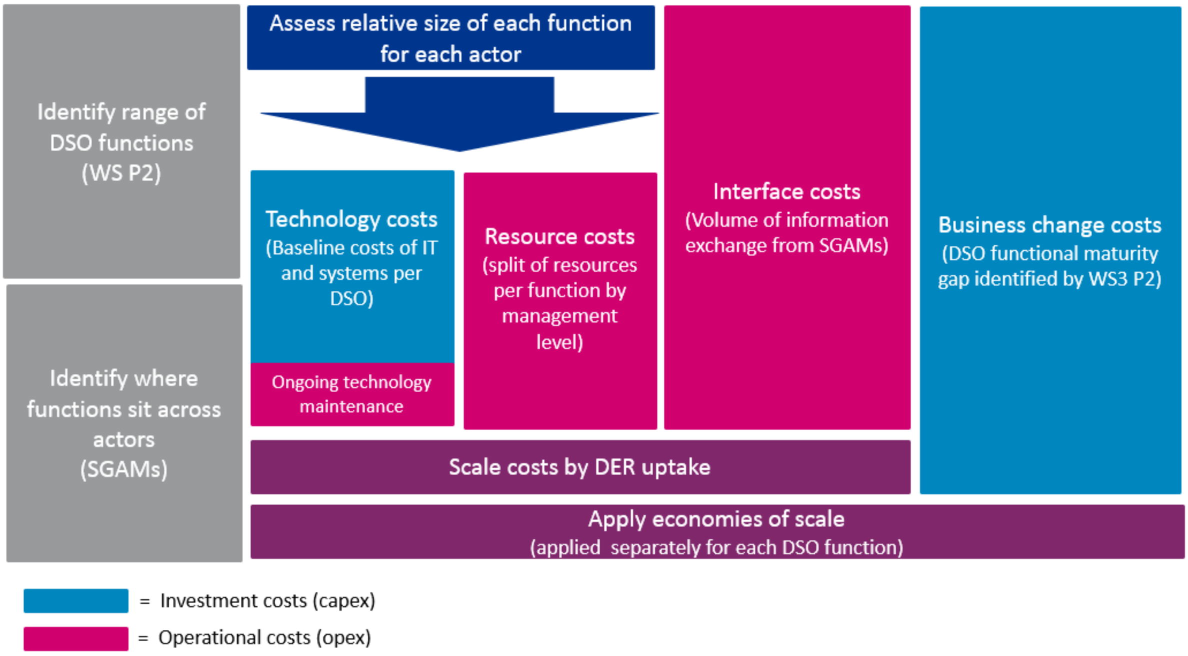


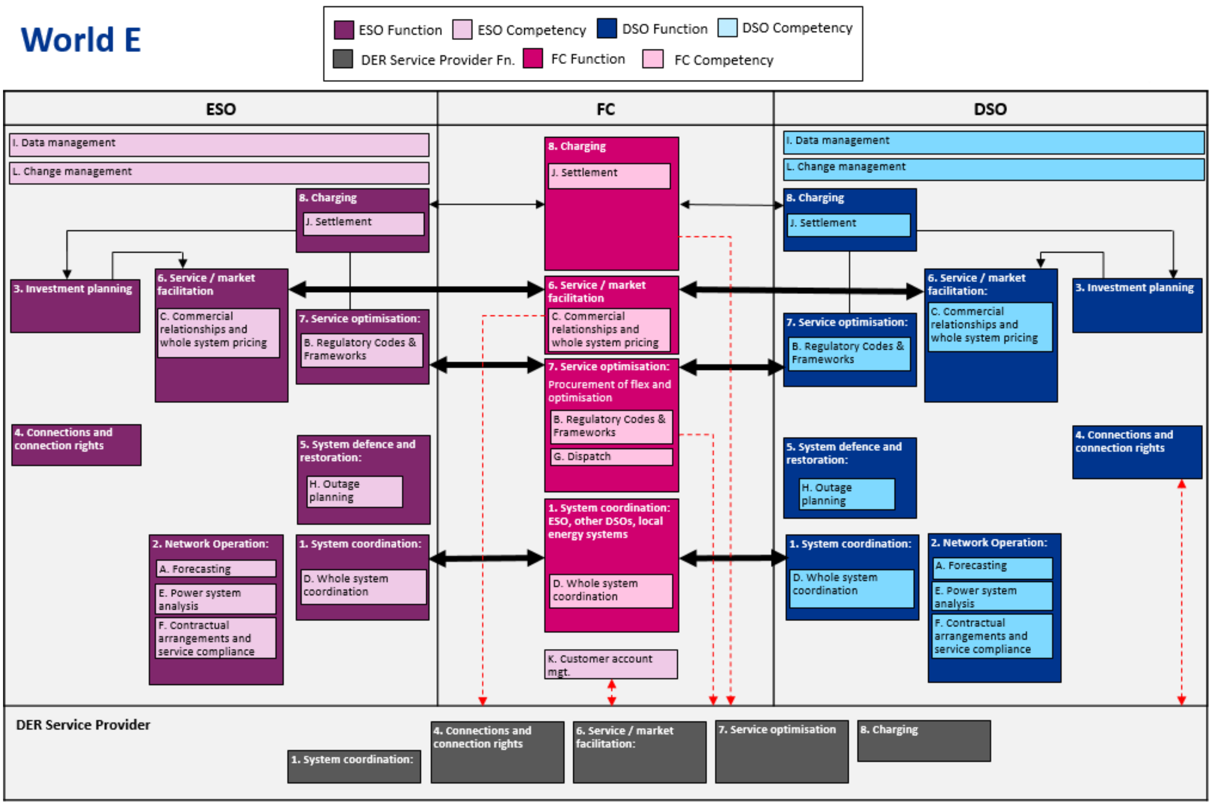
Figure C1 highlights the key areas of the assessment. We describe each of these in turn below and provide a summary of the key assumptions at the end of each section.

C.2 Identifying DSO functions and where they sit in each Future World

We wanted to understand the drivers for cost within the Future Worlds. As a starting point, we were able to use the work undertaken by Work Stream 3 Product 2 of the Open Networks Project which identified the key functions required for DSOs.[75] This Product identified the key DSO functions required, which we adapted and applied to each Future World. This included working with the ESO to understand its maturity gap for DSO functions.

The SGAM modelling used these same DSO functions as its basis. This allowed us to take the outputs of the SGAM modelling to understand where different DSO functions sat across different actors in each Future World. We captured these in high level operating models. As an example we have shown in Figure C2 below, the operating model for World E to highlight where functions sit across the different actors and the information exchanges between each other and with DER providers. Appendix F includes the operating models for all of the Future Worlds.

Figure C2 Example of Future World E operating model



C.3 Assessing the relative size of the DSO functions

The operating models as in Figure C2 gave us a sense of where functions would sit between actors but we needed to understand how large or 'thick' these functions were for each actor in each World. For instance in World A, both the ESO and DSOs are likely to have some system co-ordination functions but those are likely to be much thinner in the ESO than in the DSO, since the volume of activity which the DSOs need to co-ordinate is greater. Consequently, we used the definitions of the Future Worlds to judge where functions would be a Very high, High, Medium, Low, or Very low scale. This assessment feeds directly into the technology and resource costs as described below.

[75] http://www.energynetworks.org/assets/files/ON-WS3-P2%20DSO%20Functional%20Requirements.pdf

C.4 Technology costs

We identified a set of baseline technology costs required to run each DSO function outlined in the WS3 Product 2 report. Importantly, we excluded some enabling technologies from this assessment such as smart metering systems, active network management (ANM) systems, remote monitoring and communications equipment. The basis for this is that these costs would be required regardless of the Future Worlds.

For the technology costs we did assess, we sought to identify a typical cost for the required systems on a per DSO basis. We found that there was considerable uncertainty over many of these costs, as in many cases these would be bespoke systems which are not available 'off the shelf'. This was particularly apparent when trying to assess them further out for Stage 2 of each Future World. Given this uncertainty, we applied a range around the baseline figures we used. The lower end of the cost range fed into our Optimistic set of assumptions and the higher end fed into our Pessimistic set of assumptions. Table C1 below outlines the baseline technology costs, the DSO function they relate to and the range of uncertainty we applied.

Table C1 Baseline technology costs and ranges

		Stage 1	*Stage 2*	*Uncertainty Range*	
Cost Item	**Relevant DSO Function**	**Capex**	**Capex**	**Pessimistic**	**Optimistic**
Flexibility/capacity market platform	6. Service / Market Facilitation	£5,000,000	£1,000,000	100%	50%
DER asset register	1. System Coordination	£1,000,000	£250,000	50%	50%
Flexibility contract management systems	1. System Coordination	£750,000	£187,500	50%	25%
DER customer information management systems	1. System Coordination	£1,500,000	£375,000	50%	25%
DSO/ESO interface for system operation	1. System Coordination	£1,000,000	£250,000	100%	50%
DNO/TO interface for planning information	3. Investment Planning	£500,000	£125,000	50%	25%
Planning systems - optimisation of traditional vs. smart solutions for specific sites	3. Investment Planning	£1,000,000	£250,000	100%	50%
DNO/TO interface for connections	4. Connections & Connection Rights	£500,000	£125,000	50%	25%

		Stage 1	Stage 2	Uncertainty Range	
Cost Item	Relevant DSO Function	Capex	Capex	Pessimistic	Optimistic
DNO/TO interface for protection and boundary planning	5. System Defence & Restoration	£500,000	£125,000	100%	50%
DERMS - flexibility	7. Service Optimisation	£4,000000	£1,000,000	100%	50%
Power system modelling (price signal generation)	7. Service Optimisation	£5,000,000	£5,000,000	100%	50%
Flexibility/capacity market platform (billing and settlement)	8. Charging	£2,500,000	£1,000,000	100%	50%
Enhanced billing capability for price signals	8. Charging	£1,000,000	£4,000,000	100%	50%
Billing and income management (settlement with DSO/ESO)	8. Charging	£1,000,000	£250,000	100%	50%
DER Platform to manage flows across the GSP	7. Service Optimisation	£0	£2,000,000	200%	50%

We took these baseline costs and scaled them to take account of the functional ‘thickness’ for each actor in each Future World. In practice, we understand that many of the cost items above could be combined with each other into single systems. We have separated them out here for transparency and to ensure that we can illustrate the cost impact of duplicating specific functions across different actors. We used the assessment of the scale of function size for each actor to understand the capex costs for actor in each Future World. We assumed that these costs would be recovered over a ten year period. The Stage 2 costs are incurred at the starting date for Stage 2 in each Future World. Table C2 below shows the scaling factor used to take account of the functional thickness.

Table C2 Scaling factor applied to technology costs for function size

Function thickness	Ratio of technology costs applied
Very High	1.5
High	0.8
Medium	0.5
Low	0.2
Very Low	0.1

We also scaled these costs to take account of DER uptake over time.[76] This is because the volume of DER will drive different scales of functions. We applied a different level of scaling to each technology cost. For instance, Service and Market facilitation costs have a higher weighting (75%) of scale than System Defence and Restoration costs (0%).

In addition, since the baseline costs have been assumed as being on a per DSO basis, we applied economies of scale to each function for each actor. This takes account of where that function is performed by the ESO (as a single actor) or the Flexibility Co-ordinators (four actors). We do not scale each function directly to the number of parties, as we recognise that different functions will have different national economies of scale. For example, we expect more common (centralised) industry solutions for the charging function, than for the system operation functions.

Finally, we assumed that 10% of these technology costs would be required to cover ongoing system refreshes and maintenance. This takes account of the fact that many of these costs will be IT and communications system which have annual and biennial upgrades. For Stage 2 of each Future World, these costs are based on 10% of the combined technology costs for Stage 1 and Stage 2.

C.4.1 Detailed assumptions on technology costs

Below we outline our key assumptions for compiling the technology costs and how they can be amended within the spreadsheet model:

- We have defined a "Unit" cost for each technology required in both Stage 1 and Stage 2 of each Future World (this formed part of the data request)
- The unit costs are apportioned between actors based on their "function size", e.g. a high function accounts for 80% of the unit cost and a low function for 20%. There is a spectrum of function sizes within the modelling to reflect the differences between Future Worlds e.g. medium and very low. This is an option which can be altered via the assumptions tab
- "BAU" system costs have been excluded as these do not differ between the Future Worlds e.g. ANM, smart metering, network visibility, TO costs. The baseline DSO costs are estimated to be £120 million to the end of RIIO-ED2 (as informed by WPD) but are not included within our analysis
- Annual system opex is assumed to be 10% of system capex
- There is an additional system opex which relates to DER uptake. The systems which are expected to "scale" with DER have been identified. A "DER weighting" has been defined

[76] DER scaling modelled according to an average of both FES scenarios which we are using (Two Degrees and Community Renewables).

which scales the system opex costs with the DER uptake (average of the two FES) within the time-frame being considered i.e. we have assumed the same costs, regardless of DER uptake scenario

- Incremental system capex has been included at the start of Stage 2 to represent the step change in functionality
- System depreciation has not been included, as the annual system opex is assumed to be sufficient to maintain systems and allow for incremental change
- IT capex and business transition cost has been annuitised over a 10 year period
- Some systems have zero cost when they are not relevant to a Future World.

C.5 Resource costs

The starting point to understand the resource (staffing) costs was to allocate a management structure to each of the functions. This was based on three levels of skill types with different salary levels. We looked at the proportion of each skill type which might be required for each function. For instance, market facilitation has a higher mix of lower level skilled resources than network operation.

We assessed the number of people required to operate each function, both in Stage 1 and Stage 2 of each Future World. We split this number of people according to the management level structure identified for each function. We then scaled the number of people in each function according to the function sizes we have developed, as outlined in Table C3 below. Different scaling factors were used for the ESO compared to the DSO to take account of the different respective roles.

Table C3 Scaling factors applied to resource costs based on function size

DSO function Size	Scalar	ESO function Size	Scalar
DSO VL	*0.25*	ESO VL	0.25
DSO L	*1*	*ESO L*	1
DSO M	*1.5*	*ESO M*	2
DSO H	*2.5*	*ESO H*	3
DSO VH	*3*	*ESO VH*	3.5

Table C4 below highlights the management structure split per function and the extent to which the resources for each function are then scaled by DER uptake.

Table C4 Resource cost management structure

Function	Skillset Ratio / Function			DER Weighting
	Skill Level '1'	*Skill Level '2'*	*Skill Level '3'*	*Highlights which functions resources will scale with DER*
1. System Coordination	0	2	0.25	50%
2. Network Operation	0	2	0.5	50%
3. Investment Planning	0	2	0.25	25%
4. Connections & Connection Rights	2	1	0.25	50%
5. System Defence & Restoration	0	1	0.25	0%
6. Service / Market Facilitation	2	1	0.25	25%
7. Service Optimisation	1	1	0.25	25%
8. Charging	2	1	0.5	50%

As with technology costs, we also apply economies of scale depending on which actor the function sits with. These are the same as applied to the technology costs. Table C5 illustrates the summary of results for total resources across the Future Worlds in both Stage 1 and Stage 2.

Table C5 Summary of resources required in each Future World

	Stage 1			*Stage 2*		
"Whole World" Resources	**Total DSOs**	**Total ESO**	**Total FC**	**Total DSOs**	**Total ESO**	**Total FC**
World A	222	122	n/a	322	109	n/a
World B	221	128		269	155	
World C	147	61		217	110	
World D	129	175		168	268	
World E	161	132	72	143	97	209

As with the technology costs, we recognise that there is some uncertainty around the future resource costs required to operate different DSO functions. Consequently, we applied an uncertainty range around those costs of 25% higher for our pessimistic set of assumptions and 50% lower on our optimistic assumptions. The reasons for the asymmetry is that we think the scope of future efficiencies facilitated by technology is greater than the risk of resourcing requirements being higher than anticipated.

C.5.1 Key assumptions on resource assessment

- We defined three levels of skill-sets, with varying annual salaries.[77] This is designed to reflect the typical management structure for specific functions.
- The resource numbers (people required) are scaled according to function size and the actor type (detail provided within the model).

[77] These were based on our experience of working with network operators and were validated by the network companies.

- Additional resources have been assumed for functions which scale with DER. A "DER weighting" was defined for each function (detail provided within the model). These resource numbers scale with DER uptake at the specified time frame (e.g. average of the FES scenarios).
- We scaled resources separately from other opex in line with DER uptake.

C.6 Interface costs

We wanted to understand how the costs of data exchange and co-ordination vary in each Future World. To do this, we looked at the information in the SGAMs on the types and volumes of information exchange. We considered that these acted as a useful reference for the interface and co-ordination costs. The SGAMs included four different types of information exchange:

- SCADA
- Gateway
- Publish
- Contract.

We made some assumptions on the costs of each type of information exchange based on data provided by the ENA's Strategic Telecoms Group on SCADA costs.[78] This provided us with a basis to understand the proportionate costs of each type of data exchange as shown in Table C6 below.

Table C6 Data exchange unit costs

Data exchange type	Cost (£k)
SCADA	600
Gateway	120
Publish	30
Contract	60

This provided a baseline cost per unit of the different data exchanges. We then applied this to volumes of the different types of information exchange outlined in the SGAMs. We did have some concerns that these volumes in World E appeared to be lower than expected. We noted that EA Technology in its report highlighted this and explained that it was due to much of the required information exchange being internal to the Flexibility Co-ordinator.[79] Consequently, while we have retained the results of the SGAM for consistency, we do think that it underestimates information exchange in World E.

As with the technology and resource costs, we have scaled up the interface costs in line with DER uptake. We have applied a different weighting of DER scaling factor in each functional area, as already outlined in Table C4. For instance, the data exchanges linked to System Co-ordination have a higher scaling factor than those linked to System Defence and Restoration. This DER scaling drives

[78] The STG provided the SCADA costs and we used this to make proportionate assumptions for the other information exchange types.
[79] http://www.energynetworks.org/assets/files/Modelling-DSO-Transition-Using-SGAM_Issue2.1_PublicDomain.pdf see Section 5.3

the key differences between the assessment in Stage 1 and Stage 2 of each Future World. We have also applied economies of scale to the interface costs.

C.6.1 Key assumptions on interface costs

- The volume of interface exchanges per World was taken from SGAMs (they therefore include BAU interface exchanges).
- Interface types split into SCADA, Gateway, Publish, Contract as set out in SGAMs.
- Interface set-up costs are included within the technology capex costs, therefore interface costs purely refer to interface opex.
- Individual unit cost assigned to each exchange type, scaled off cost of SCADA system from data given by the ENA's Strategic Telecoms Group.
- Individual unit costs then multiplied by the volumes to produce costs of interface change.
- Interface volumes are then scaled in proportion to DER.

C.7 Business transition costs

We wanted to recognise that the costs of the DSO transition were not simply just the investment costs in new technology but also in integrating that technology into the business and aligning with existing system and operational functions.

We were aware that under the ENA's Open Network project the Workstream (WS)3 Product 2 set out required DSO functions and assessed the current "as is" development state of those functions through allocating a score out of 5 for each function and activity. The Product Team also developed a score out of 5 for the "to be" development state of each function and activity required for a DSO. This was done prior to the development of the Future Worlds and so is 'World agnostic'. This allowed us to use those outputs to assess numerically the maturity gap required to move to DSO.

We took this assessment a stage further by first working with the ESO to identify the maturity gap for ESO functions which relate to the DSO transition. Second, we then assessed how the maturity gap would vary by function and actor in each Future World. This was based on the size of the function each actor was undertaking. For instance, in World A where the 'thickness' of DSO functions tended to be High, we applied the full maturity gap identified by the ENA, but for the ESO functions in World A, we lowered the maturity gap.

This produced overall scores for the maturity gap which existed for each Future World at a functional level. We used these relative scores to allocate a High, Medium or Low ranking for each function, for each actor in each Future World. We used these rankings to allocate different percentages of the technology capex cost to represent the business change costs. These are shown in Table C7 below.

Table C7 Ratio of capex costs applied as business change costs

Maturity Gap	Ratio of Capex to Business Transition Cost:
H	1
M	0.5
L	0.25

Table C7 illustrates that where a specific function in a Future World was assessed as having a High maturity gap, we allocated 100% of the capex costs for that function as business transition costs. Where a function was assessed as having a Low maturity gap, we allocated 25% of the capex costs for that function to business transition costs.

C.7.1 Key assumptions for business transition costs

- The maturity gap assessment is used to inform the business transition costs. The business transition costs are a function of IT capex, and the ratio is defined by the maturity gap.
- The as-is DSO maturity was defined as part of WS3 Product 2, and the ESO "as-is" was created by National Grid ESO as part of this Impact Assessment. We have made our own assumptions around the functional build out required for the Flexibility Co-ordinator in Stage 2 of World E. These are largely similar to those for the ESO in World D.
- A "to-be" score has been defined for each actor for each world. We assumed a different split of maturity gap between Stage 1 and Stage 2 in each Future World, depending on the evolution of each Future World. For Worlds A, B and C this equated to a 50% split of the maturity gap between stages. For Worlds D and E this was 30% in Stage 1 and 70% in Stage 2 in recognition that much of the development occurs in Stage 2.

Appendix D Assessing the time for each Future World to develop into Stage 2

D.1 Background

A key assumption for the quantitative assessment was that all Future World (except World C) were capable of delivering all of the available gross benefits once they reached a more mature development – Stage 2. As highlighted in the main report, this was designed to ensure that the focus of the assessment was on the development of the Future Worlds over time and the associated costs, rather than seeking to pre—judge a 2050 end state.

This assumption means that the point in time when each Future World is considered as capable of maturing into Stage 2 is a key driver of performance in the quantitative assessment. We set out in Section 3 our high level approach to assessing the timing of when each Future World matures to Stage 2. We set that out in more detail in this Appendix.

D.2 Summary of approach

We used a mixture of quantitative and qualitative data to assess when each Future World could be capable of maturing to Stage 2 of development. There were three key drivers which we considered would influence the timing of when a Future World matured to Stage 2.

- **The functional maturity gap**: As part of the functional requirements work undertaken by the ENA, it produced an assessment of the maturity gap to DSO.[80] We expanded on that for the cost assessment of each Future World. We used the results to understand the maturity gap which existed to develop DSO functions from today to the start of Stage 2. We made the assumption that the larger the gap, the longer it was likely to take for a Future World to mature to Stage 2.
- **The level of business change required**: We assessed the structural changes required to mature to Stage 2. This related to the complexity of implementing Stage 2 of each Future World compared to today's arrangements. This particularly focused on the level of change required within system operators. The greater the change needed, the longer it is likely to take a Future World to mature to Stage 2.
- **The level of technological change needed**: We looked at where technology would need to advance in order to enable a Future World to deliver the full benefits of Stage 2. The greater the reliance on new, more advanced technology the longer it is likely to take to mature to Stage 2.

We used a combination of the assessment in each of these areas to understand the relative differences between the development stages of each Future World. The purpose of this assessment is not to forecast a firm date on when each Future World might mature but to assess the relative

[80] http://www.energynetworks.org/assets/files/electricity/futures/Open_Networks/ON-WS3-P2%20DSO%20Functional%20Requirements-170925%20Published.pdf

differences in the development of each Future World and understand how to reflect that in the quantitative assessment.

D.3 Functional maturity gap

The functional maturity gap is effectively looking at the advancements required in the capabilities of system operation functions, in order to support Stage 2 of each Future World. The ENA Product Team has previously identified a list of functions and capabilities which would be required for DSO (agnostic to the Future Worlds). These were described as follows:

DSO functions

- System co-ordination
- Network Operation
- Investment Planning
- Connections and Connection rights
- System Defence and Restoration
- Service/Market facilitation
- Service provision
- Charging

DSO competencies

- Forecasting
- Regulatory Codes & Frameworks
- Commercial relationships and whole system pricing
- Whole system co-ordination
- Power Systems analysis
- Contractual arrangements and service compliance
- Dispatch
- Outage planning
- Data management
- Settlement
- Customer account management
- Change management

The ENA Product Team undertook an "as is" assessment of each competency against each function and provided a score for each out of 5 to indicate the level of maturity (5 being the most mature).[81]

[81] The maximum available score would be 480 for a single actor (12 competencies across 8 functions, each with a mark out of 5.

They then ran a separate "to be" assessment which assessed what maturity would be required to move to a DSO. The difference between the scores represented the maturity gap identified.

We expanded on the "to be" assessment to apply it to the Future Worlds. This required a separate assessment for each actor (DSO, ESO and Flexibility Co-ordinator) in each of Future Worlds. This gave us a set of scores for each actor in each Future World to compare to the "as is" scores developed by the ENA Product Team.[82]

These were used to produce the maturity gap which formed part of the broader cost assessment methodology (see Appendix C). Table D1 below highlights the results of the maturity gap assessment from the "as is" state to the "to be" state for each Future World. We assumed that the "to be" state is indicative of Stage 2 of development. Consequently, the higher the score for each actor, the greater the maturity gap and the longer time is likely to take to mature to Stage 2 of development.

Table D1 Maturity gap assessment

		World A	World B	World C	World D	World E
Maturity gap from today to Stage 2	DSO	240	238	196	147	147
	ESO	-24[83]	155	110	156	152
	FC	n/a				261
	Total across all actors	216	393	306	303	560
	Overall	**L**	**M**	**M**	**M**	**H**

Our assessment of the time taken to reach Stage 2 is based on the overall results across all actors. We used the following scale to apply a High/Medium/Low rating.

- High = 400+
- Medium = 250- 400
- Low = 0-249

D.4 Business change gap

The business change gap effectively looked at the level of organisational change required to reach Stage 2 of each Future World. This was more of a qualitative assessment based on the change in roles and responsibilities for different actors.

Table D2 provides the results of the assessment with some summary justification.

[82] As part of this assessment, we engaged with the ESO to develop an "as is" maturity assessment as the ENA Product Team had not developed this.

[83] Since the ESO is devolving some of its functions to the DSOs in World A, it achieves a negative sore

Baringa
Brighter together

Table D2 Business change gap assessment

	World A	World B	World C	World D	World E
Business change gap	DSOs start managing flows across the Grid Supply Point (GSP). This will require aggregation of distribution flexibility resources at GSP level into ESO markets	Little change from today apart from building out DSO and ESO functions to a more advanced level (largely picked up in maturity gap)	Little business change required from today apart from greater emphasis on power flow modelling and integrating real time data to set dynamic price signals	A significant change from today which would require transfer of expertise in distribution system operation to the ESO and integration of DSO monitoring data into the ESO	A significant change from today, requiring many system operation functions to be transferred to regional flexibility co-ordinators
	M	**L**	**L**	**V High**	**V High**

The results are presented on a relative basis and indicate that Worlds D and E are likely to result in much higher levels of business change. This is mainly because they involve new parties (either the ESO or Flexibility co-ordinator) taking commercial decisions which will impact operations and planning on the distribution network. To have the experience and data to take these decisions may require transfer not just of data but also people to the ESO or Flexibility Co-ordinators.

D.5 Technology gap

The technology gap assessed which of the Future Worlds was likely to have a greater reliance on technology development to mature to Stage 2. This is separate from the functional maturity because it focuses on where deployment of new technology is likely to be required to manage the complexity of operating each Future World. Table D3 below outlines the results of the qualitative assessment.

Table D3 Technology gap assessment

	World A	World B	World C	World D	World E
Technology gap	Technology will be focused on integrating real time data into network management systems and seeking to optimise the use of flexible resources for distribution and transmission	In addition to the requirements of World A, additional technology will be required to monitor conflicting actions between ESO and DSO and take real time decisions on the optimum solutions. This is likely to be complex to manage and require highly sophisticated technology running in close to real time	Sophisticated technology will be required to set localised dynamic price signals, relay these to customers, settle and bill against them. Residential customers may also require advanced in home technology to help them respond to price signals without active engagement	Similar to World A, technology will be focused on integrating real time data into network management systems and seeking to optimise the use of flexible resources across Transmission and Distribution	Similar to World A, technology focus will be on integrating real time data into network management systems and seeking to optimise the use of flexible resources across Transmission and Distribution. There may be added complexity with the volume of data coming from DNO and ESO but this should not drive fundamental differences
	M	**H**	**H**	**M**	**M**

All of the Future Worlds are likely to rely on technological developments to operate efficiently but it seems likely that Worlds B and C will have the greatest reliance on technology to support the operation of the Future World.

D.6 Mapping the results to years

The steps outlined above provided a series of relative High/Medium /Low scores for the different elements of our assessment. For the purposes of the quantitative assessment, we still needed to convert this into a specific year in which each Future World will mature to Stage 2.

To do this we looked at potential dates through understanding price control periods over the next 20 years. It seemed appropriate to assume that a move to Stage 2 would likely coincide with the start of a new price control period. Table D4 below highlights the likely price control period start dates based on 5 year price control periods. [84]

Table D4 Likely Transmission and Distribution price control periods

	RIIO-2	RIIO-3	RIIO-4	RIIO-5	RIIO-6
Distribution	2023	2028	2033	2038	2043
Transmission	2021	2026	2031	2036	2041

We used these dates as potential options for Stage 2 implementation and used the average of the three assessments to judge which would be an appropriate date from these options. In arriving at these dates we were conscious that it is likely to be infeasible to move to Stage 2 during the RIIO-2 price control period given their proximity. Equally, it would require strong evidence to suggest that a Future World could not be fully implemented in the next 25 years.

Table D5 provides the overall summary and subsequent dates we judged as aligning to the relative scores.

Table D5 Summary table of assessment of time taken to reach Stage 2

	World A	World B	World C	World D	World E
Maturity gap from today to Stage 2	L	M	M	M	H
Business change gap to stage 2	M	L	L	vH	vH
Technology gap to stage 2	M	H	H	M	M
Average	**M**	**M**	**M**	**H**	**H**
Stage 2 implementation based on analysis	**2028**	**2028**	**2028**	**2031**	**2036**

Determining these dates is not an exact science and we acknowledge that there are arguments that each Future World could mature to Stage 2 sooner or later. However, we think that the relative balance between the Stage 2 implementation dates is a good basis for the quantitative assessment. We did feel that the scores for Worlds D and E might suggest a later implementation date for Stage 2. Consequently, we ran a sensitivity for the quantitative assessment where World D and E took five years longer to mature to Stage 2.

[84] Ofgem's latest RIIO-2 consultation seems to indicate a return to 5 year price control periods: https://www.ofgem.gov.uk/publications-and-updates/riio-2-sector-specific-methodology-consultation

Appendix E Outputs of unintended consequences and risks workshop

E.1 Scope of Unintended Consequences and risks workshop

To help identify the unintended consequences and risks across the Future Worlds, we held a workshop with the ENA's Open Networks project Advisory Group on 4 December 2018. We used this workshop to:

- Validate an initial list of unintended consequences and risks which we had developed
- Identify any other unintended consequences and risks to the list
- Assess the impact and complexity of each unintended consequence and risk
- Start to consider mitigation strategies for each unintended consequence and risk.

Prior to the workshop we identified six key themes of unintended consequences and risks. These are largely agnostic to the Future Worlds and so the outcomes do not feed into our assessment. It is designed to highlight areas which require further work, regardless of which Future World is implemented. The following sections include summary tables illustrating the output in each theme. The table is structured around the following columns:

- Scale of Impact of the issue
- Scale of complexity of the issue
- Qualitative description of the impact of the issue
- Potential mitigation measures

The tables below should be viewed as the broad output of the workshop.

E.2 Distributional Customer Impacts

Distribution customer impacts sought to examine how consumers may be impacted by new markets, where the value is likely to vary by location and where the ability to participate may depend on the ability to change energy consumption patterns.

Table D1 Distributional Customer Impacts unintended consequences

Item	Impact	Complexity	Description of the impact	Mitigation
Unequal opportunities for customers to participate in flexibility markets				
Inability for customers to participate due to lack of technology or specific assets	High	High	Some customers may be unable to change patterns of electricity (or wider energy) usage and may face higher network bills as a result (or be unable to access new revenue streams through flexibility services)	• Potentially Government social policy to protect vulnerable customers unable to respond to price signals
Locational price differentials				
Move away from 'vanilla' pricing	High	High	Is there political acceptance for network tariffs which vary by location? Varying network tariffs may not align well with the retail price cap.	• Potentially greater information provided to consumers around the basis of network charges • Dialogue with Ofgem and suppliers around interaction with the price cap
Different implicit values of lost load	Low	Low	There are implicitly different values of lost load (VoLL) in the system today e.g. different compensation for network outages versus VoLL used to calculate the generation capacity requirement. As the system becomes more integrated, from a customer perspective all outages are the same regardless of reason and it becomes increasingly perverse that the signals to avoid outages are different in different parts of the system.	• More co-ordination between different flexibility products and incentive values of lost load such as those used in the Interruptions Incentive Scheme (IIS)

Item	Impact	Complexity	Description of the impact	Mitigation
Geographical differences in network costs	Medium/High	High	Costs of serving rural communities may increase faster than urban if there is a not a concentration of flexibility available to manage new loads and generation. This may not be politically acceptable.	• Policy impact assessments may need to include distributional analysis as standard • Network charges may need to be more visible on consumers' energy bills to explain the costs they are paying
Poor engagement of consumers				
Third party intermediaries do not act in consumer interest	Medium/High	Low	Consumers may not see the full value for their services. Consumers may be locked into long term deals through mis-selling of products. Poor consumer experience could reduce the levels of engagement.	• Third parties need to be subject to some form of regulation or binding code of practice
Engagement with residential customers is undertaken too early	Medium/High	Medium	Poor engagement or lack of value might discourage residential customers from engaging in flexible response. This would reduce the benefits which can be delivered.	• Careful planning and potentially regulation of engagement with residential customers alongside continued trialling
New customer interactions are required	Medium	Medium	Customers may not want to engage with new parties and this could restrict liquidity in flexibility markets and reduce the benefits to consumers.	• Need to ensure that there are multiple avenues for consumers to realise the value of flexibility they are providing to the system • Need to make engagement easy and have a clear incentive

Item	Impact	Complexity	Description of the impact	Mitigation
Treatment of costs				
Operational costs of DSO socialised	Medium	Medium	The operational costs of running a DSO will be socialised across all customers while some of the benefits will accrue directly to some connecting customers.	• Explore how connectees who trigger investment and operational costs face the appropriate costs that they are imposing on the system
Value of flexibility				
Insufficient value in services to stimulate the market	High	Medium	The cost of the low carbon transition could increase if networks need to rely more on asset solutions. Risk of spending time and resources developing flexibility markets which do not deliver benefits.	• Undertake some detailed research on the value of avoided reinforcement costs to network operators (particularly at LV) • Assess what benefits charging signals can provide before investing heavily in flexibility services

E.3 Risk of regret

The risk of regret category was designed to challenge some of the assumptions on which we are basing decisions or actions today, by assessing the impact they can have in the future.

Table D2 Risk of regret unintended consequences

Item	Impact	Complexity	Description of Impact	Mitigation
Policy decisions discourage flexibility providers				
Flexibility providers may not be available when the DSO needs them	High	Medium	There may not be sufficient numbers of flexibility providers to produce liquid markets when DSOs need them and this results in reinforcement which 'locks out' flexible options for another 20-30 years.	• Consider the future impact of policy decisions which negatively impact the business model for flexibility providers

Item	Impact	Complexity	Description of Impact	Mitigation
Lack of clarity on future market design and arrangements delays or prevents investment	High	Medium	Network investments may be delayed while there is uncertainty on future flexibility available. Flexibility providers may be held back in developing business models because there is uncertainty of value. Technology providers may not be making investments in R&D.	• Network companies can provide a sense of direction and list future products and services • Strategic plan on market design • Reforms to industry governance to speed up decisions
Lack of certainty				
Network companies spend money building out SO functions which are not needed in the medium/long term because better network access arrangements and charging signals are in place	High	Medium	Costs to customers increase unnecessarily due to sunk assets. Market participants will make investments on the back of SO services which could be redundant.	• Further market testing and trialling to understand the role reformed network access and price signals and charging can play
Little financial return for SO taking on new risk associated with DSO	Medium	Medium	Network operators revert to asset solutions to provide certainty of meeting outputs.	• Regulation recognises the additional risk
Value of flexibility				
Sudden technology advances drastically change assumptions on which decisions are made e.g. cheap in-home storage makes flexibility very cheap	Medium	High	Risk of stranded flexibility contracts result in network consumers overpaying.	• Shorter duration of flexibility contracts (but balanced against the needs of providers to make

Item	Impact	Complexity	Description of Impact	Mitigation
				investment case for new assets)
Industry is too focussed on markets				
Industry is too focused on markets and overlooks the benefits of technological solutions	Medium	Low	Some lower cost ways of managing increased load and generation are missed because there is an assumption in industry that markets deliver the lowest cost solution.	• Continued trialling of different technological solutions

E.4 Operational viability

The operational viability category is designed to understand where new interactions with DSO markets can pose operational issues for network operators.

Table D3 Operational viability unintended consequences

Item	Impact	Complexity	Impact	Mitigation
Sub-optimal economic outcomes				
Market oscillation	High	High	Different timeframes for markets and (increasingly dynamic) price signals, could lead to instability and requirement for SOs to take multiple corrective actions (potentially causing costs to increase for consumers).	• Need to better understand how markets will interact and impact on system operation • Consider how markets could be better harmonised through standard rules and principles • Ultimately may need more formal co-optimisation either centrally or hierarchical (layered)

Item	Impact	Complexity	Impact	Mitigation
Sub-optimal dispatch	High	Medium	Conflicting price signals and different time horizons could lead to sub-optimal dispatch decisions.	• Understand the interaction between markets through 'war gaming' different market scenarios
Conflicting signals from control systems	High	Medium	Where DER is providing multiple services to different SOs it is possible that control systems are sending conflicting dispatch signals.	
Conflicts between firm and non-firm connections	High	Medium	Those on non-firm connections typically have no guarantee over the level of curtailment they can expect. This could effectively become a free resource for DSOs.	• Greater standardisation of flexible connection approaches, and potential changes in connection boundaries, incentives on DSOs etc.
Sub-optimal economic outcomes				
Existing access rights may not be compatible with new market arrangements	Medium	Medium	Grandfathering principle of existing access rights could create a barrier to more efficient market design.	
How to assess generation adequacy in a world of decentralised energy and flexible demand?	High	Low	With more 'fluid' supply and demand, and less visibility given the small scale nature of decentralised energy it may become increasingly difficult to define what is the appropriate amount of generation on the system - this could lead to over- or under-procurement in the Capacity Market.	• Map out where responsibilities and accountabilities sit for the various aspects of system security and test how this would work in practice
Lack of incentives for innovation in technological solutions	Low	Low	Much of the innovation is focused on market solutions, at the risk that technological innovation is de-prioritised.	• Broaden out innovation to technological solutions
Complexity				

Item	Impact	Complexity	Impact	Mitigation
How will peer to peer trading interact with underlying physical system?	Medium	Medium	Risk that peer to peer trading does not respect underlying physical nature of system leading to network congestion and costs for other users. Issue could be particularly acute where peer to peer trading is occurring in local areas that span more than one DNO licence area.	• Need to better understand how markets will interact and impact on system operation • Consider how markets could be better harmonised through standard rules and principles • Ultimately may need more formal co-optimisation either centrally or hierarchical (layered)
Does proliferation of different markets/platforms become untenable?	High	High	If new markets are added alongside existing markets, all required to interface, there is a risk that it all becomes too complex.	
Impacts of local markets on liquidity, competition and consumer choice	Medium	Medium	There is a risk that local energy markets, perceived to be good for supporting decarbonisation, might actually negatively impact consumers by reducing choice and competition, leading to higher price outcomes.	

E.5 System security

This category is designed to identify the implications of new more active DSO markets on the overall security of the system.

Table D4 System security unintended consequences

Item	Impact	Complexity	Description of Impact	Mitigation
Lack of certainty				
Uncertain response to price signals	High	Medium	SOs do not know how much they need to over procure flexibility in order to get the response required.	• Need to better understand how markets will interact

Item	Impact	Complexity	Description of Impact	Mitigation
Arbitraging of different non-delivery penalties	High	High	Flex providers may prioritise services that have higher penalties for non-delivery, and some penalty regimes currently are benign and may not accurately reflect the cost of non-delivery.	and impact on system operation • Consider how markets could be better harmonised through standard rules and principles • Ultimately may need more formal co-optimisation either centrally or hierarchical (layered)
Accountability				
Accountabilities across DNO/DSO and TO/ESO	High	Medium	As the energy system becomes more integrated, but more complicated, it is not always clear who is ultimately responsible for network and wider system security. This could lead to reduced resilience in the system and sub-optimal investment decision making.	• Assess current accountabilities • Identify gaps/ambiguities • Assign appropriate accountabilities • Licence changes
Who is accountable for network security is becoming less clear	High	Medium		
Accountability				
Who is responsible for cyber security	High	Medium	Some of the biggest risks will be cyber security attacks from behind the meter, outside of the scope of the SOs. Who is ultimately responsible for this?	
System operation failure				
Increasing reliance on communications infrastructure	High	Medium	New operational solutions are increasingly reliant on high availability communications infrastructure. Comms failures will increasingly become the biggest risk to security of supply.	• Assess current accountabilities • Identify gaps/ambiguities • Assign appropriate accountabilities • Licence changes

Item	Impact	Complexity	Description of Impact	Mitigation
Is focus only on thermal constraints by DSOs putting wider system at risk	High	High	The ESO takes a holistic view of system and energy balancing in the actions it takes. There is a risk that DSOs may not fully understand the consequence of their actions on the wider energy system if they are only procuring flexibility for specific needs such as managing thermal constraints.	• Integrating DSO activities within central market arrangements
Impact of gaming in system security	High	High	Gaming potentially has an impact on system security (in addition to the economic impact) since it can lead to behaviours that the SOs are not expecting.	• Effective contracting to reduce scope for gaming
Reduced headroom as a result of efficient markets	Medium	Medium	The ability to deploy flexibility will reduce headroom, which would save on investment costs but could lead to less resilience in the system for dealing with shocks.	• Adaptation of security standards
Lack of visibility at D level	Medium	Low	Inefficient investment decisions due to lack of information.	• Investment in network monitoring equipment and communications infrastructure

E.6 System Operator conflicts

This category was designed to understand where conflicts of interest might emerge if system operators were responsible for both network and market operations.

Table D2 System operator conflicts unintended consequences

Item	Impact	Complexity	Description of impact	Mitigation
Transparency of decision making				
Transparency of Opex/Capex investment decision making and the ability of DSOs to take risks in determining the right solution	High	Medium	Risk of inefficient investments due to not giving flexibility solutions full consideration.	• Transparency of how decision are made in the planning process e.g. the NOA process • Network operators should publish their methodology, inputs and outputs • Ofgem needs to set the requirements on the process
DNO / TO connection timelines can erode the business case for services	High	High	DSOs / ESOs providing long timescale connection offers may prevent the emergence of alternate services which can help resolve the very constraints on the network which are preventing them from connecting. This can lead to overall higher investment costs.	• Incentive to accelerate connections in certain areas • Greater collaboration regarding locations / flexible connections
DNO / TO provision of services from funded assets may impact competition	High	Medium	The use of funded assets or capabilities developed through "seed funding" for innovation may require the customer to "pay twice" for services. It also leads to an incumbent advantage for DNOs that might inhibit the development of markets.	• Ofgem will need to specify how funded assets should and should not be used in delivering services • If such services are lowest cost to the customer, there should be a mechanism for use

Item	Impact	Complexity	Description of impact	Mitigation
				• Treatment of revenues / incentives
Consideration of IDNOs				
IDNO revenue driven by demand so no incentive exists to encourage alternate solutions	Low	Medium	IDNOs "opt out" and do not engage with the emerging market space. Customers on their networks cannot benefits from flexibility services.	• Regulatory framework for IDNOs may need to be considered
DSOs may be risk adverse- impacting competition				
Conflicts between "mandated" vs. "procured" flexibility (i.e. DSO market power due to flexible connections agreements)	High	Medium	Those on non-firm connections typically have no guarantee over the level of curtailment they can expect. This could effectively become a free resource for DSOs e.g. reactive power / power factor specifications in connections agreements may drive additional market requirements and influence prices that service providers can deliver. This may compromise efficient operation of the market.	• Greater standardisation of flexible connection approaches, and potential changes in connection boundaries, incentives on DSOs etc • Commercial incentives to release capacity • Customer opt-outs
DNO ability to step in and interrupt the market in a "control-led" way when network thresholds are breached	High	High	Risk of inefficient “market override” actions due to overly risk-averse practices. May lead to consumers not receiving the full value for flexibility used in these ‘override’ situations.	• A market first / last resort mentality should be adopted • Visibility of decision-making hierarchy and reporting • Clear thresholds and rules published in advance • Compensation for curtailment • Commercial incentives to release capacity

Item	Impact	Complexity	Description of impact	Mitigation
Lack of incentives to promote the use of market mechanisms				
Regulatory claw-back of asset allowances / funding for flexibility procurement	High	Medium	Erodes revenue streams paid to flexibility providers which means that network operators need to revert to asset solutions. This means consumers are at risk of ‘double funding’ a network solution.	• Clear policy on the regulatory treatment of assets deferred through flexibility

E.7 Market power and gaming

This category was designed to assess where new markets could be open to gaming from market participants, or where they could be vulnerable to market power.

Table D6 Market power and gaming unintended consequences

Item	Impact	Complexity	Description of impact	Mitigation
Transparency of decision making				
Ability to neutrally frame network needs in order to avoid excluding new technologies and players	Medium	Medium	Failing to present network needs in a transparent way, may reduce the scope for flexibility providers to engage in new markets.	• Best practice guidance/binding code requirements
Risk of existing mandatory requirements becoming “paid services” (e.g. ROCOF / power quality) therefore increasing costs to consumers	Medium	Medium	Risk to consumers of rising costs and/or abuse of existing provisions to undercut developing markets.	• Clear regulation and clarity within code requirements
Transparency of decision making				

Item	Impact	Complexity	Description of impact	Mitigation
Changes to system needs driving contract "regret" with low utilisation of contracted service assets	Medium	Medium	Consumers could become locked into paying the costs of flexibility contracts to DER which are not needed by system operators.	• Consider the length of flexibility contracts and the split between utilisation and availability payments
Market Power and promoting competition				
Locational market power - how to ensure fair service pricing and cost	High	Medium	Where a flexibility provider is the only asset capable of helping to avoid a specific, locational investment, it can increase its prices i.e. game locational service procurement which will increasing costs to consumers.	• Design of market framework and means to discover efficient prices • Promote increasing number of participants and/or simulated competition
Incumbent power e.g. existing funded assets, existing connections, largest voices, market expertise	High	Medium	System operators are used to running the network in a certain way. This increases the risk of persisting with the status quo.	• Stakeholder engagement through market framework definition
Lack of incentives on customers to manage capacity				
Providing parties with visibility of emerging constraints can provide them with the ability to trigger those constraints which they are then paid to resolve	High	High	Ability for customers to game the system, driving higher costs for other customers.	• Can be addressed via market design, charging arrangements, connections processes, licence conditions • Requires joining up of Ofgem's Charging Review with Open Networks project • Sub-metering / baselining may also provide a solution

Item	Impact	Complexity	Description of impact	Mitigation
Lack of incentives on customers to manage capacity				
Customer inertia and legacy connections / capacity hoarding inhibiting transition to flexibility	High	Medium	Slows the DSO transition and holds back system evolution / efficiency.	• Commercial incentives to release capacity • Ofgem's reform to access arrangements may also provide a useful mitigation
Pass through of incentives to the end customer				
Third party pass-through of ToU prices and incentives to customers	High	Low	Loss of behavioural incentives on customers which may inhibit the desired responses and lead to higher costs for consumers. Customers not gaining the benefits of improved network constraint management.	• Regulatory oversight likely to be required to ensure that network price signals and incentives are passed through to consumers

Appendix F Future World Operating Models

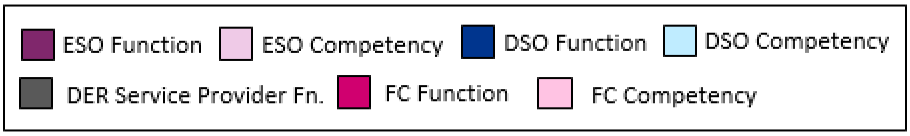
As part of the cost assessment methodology, we produced what we describe as operating models for each Future World. These were based on the information in the SGAMs and were designed to provide a visual summary of the key interactions in each Future World. They seek to capture the following:

- Where functions and competencies sit across different actors in each Future World (based on the DSO functions defined by the ENA).[85]
- An indication of the size of these functions within each actor (shown by the size of the boxes in the diagram)
- Where data exchange or co-ordination is required between actors (black arrows)
- Where interaction with network users is required (red dotted arrows)

These are not intended to replace the SGAMs but to summarise the outputs in a way which could be used to inform the Impact Assessment.

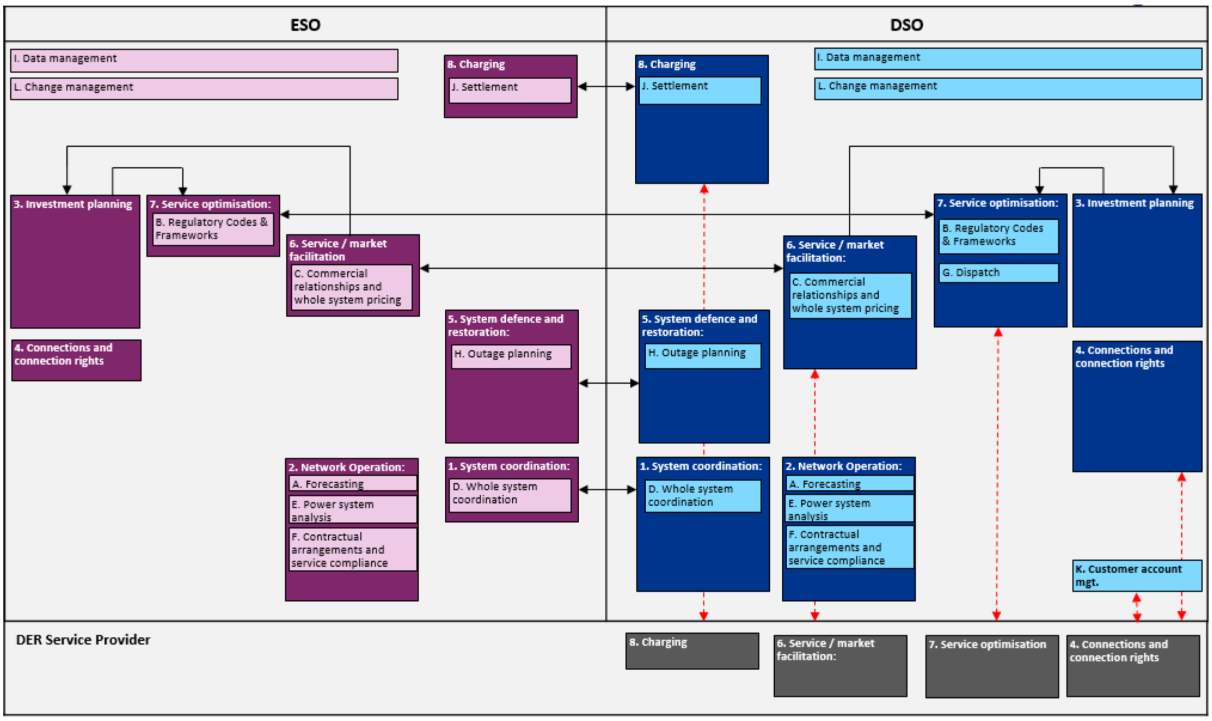
The key shown in Figure F1 should be used to interpret the diagrams:

Figure F1   Key for Future World Operating Models

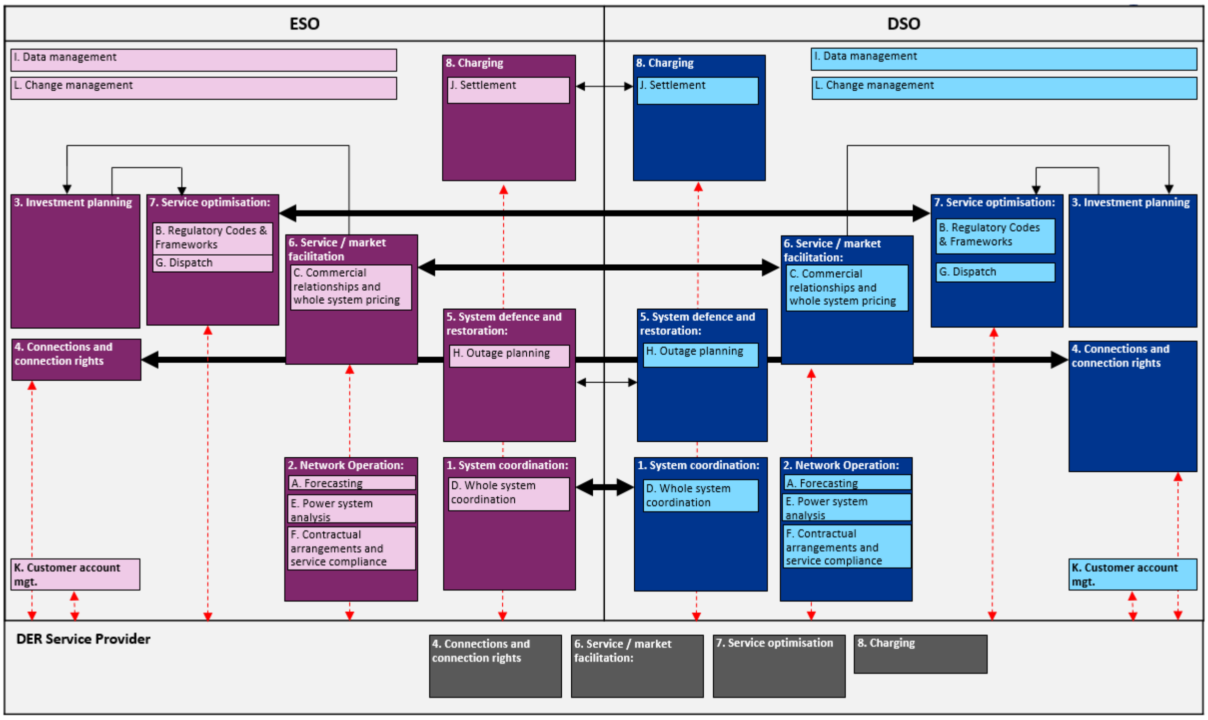


[85] http://www.energynetworks.org/assets/files/ON-WS3-P2%20DSO%20Functional%20Requirements.pdf

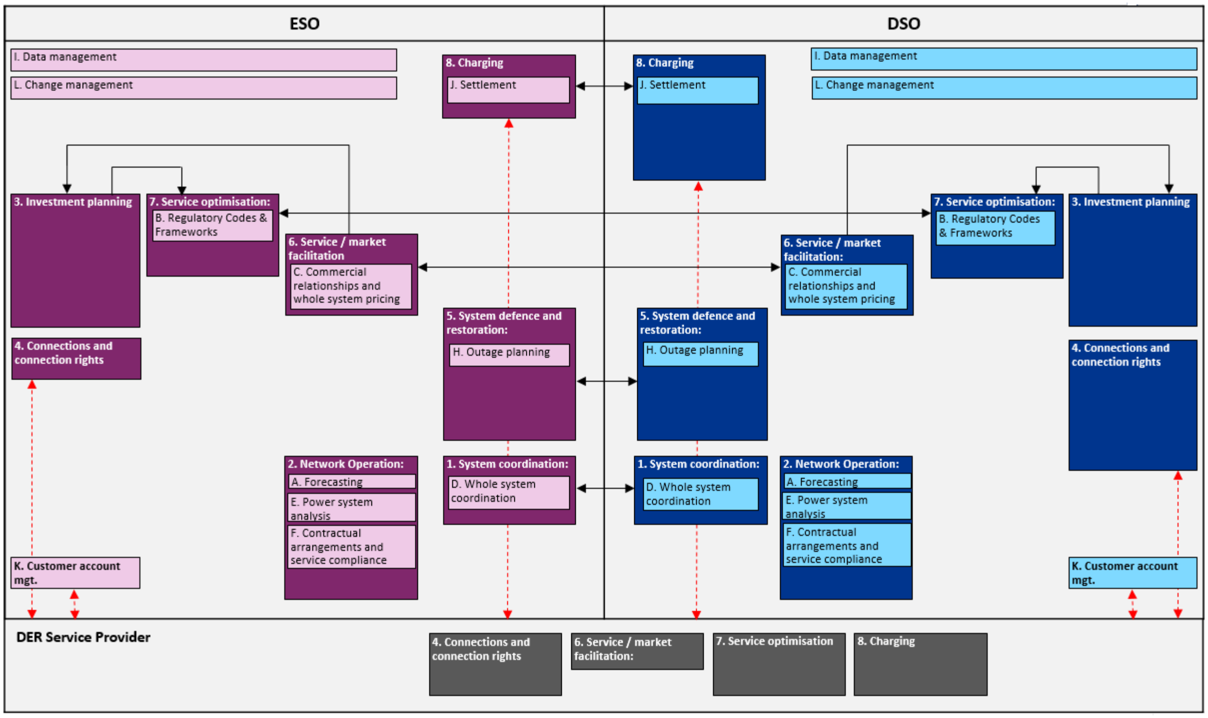
F.1 World A



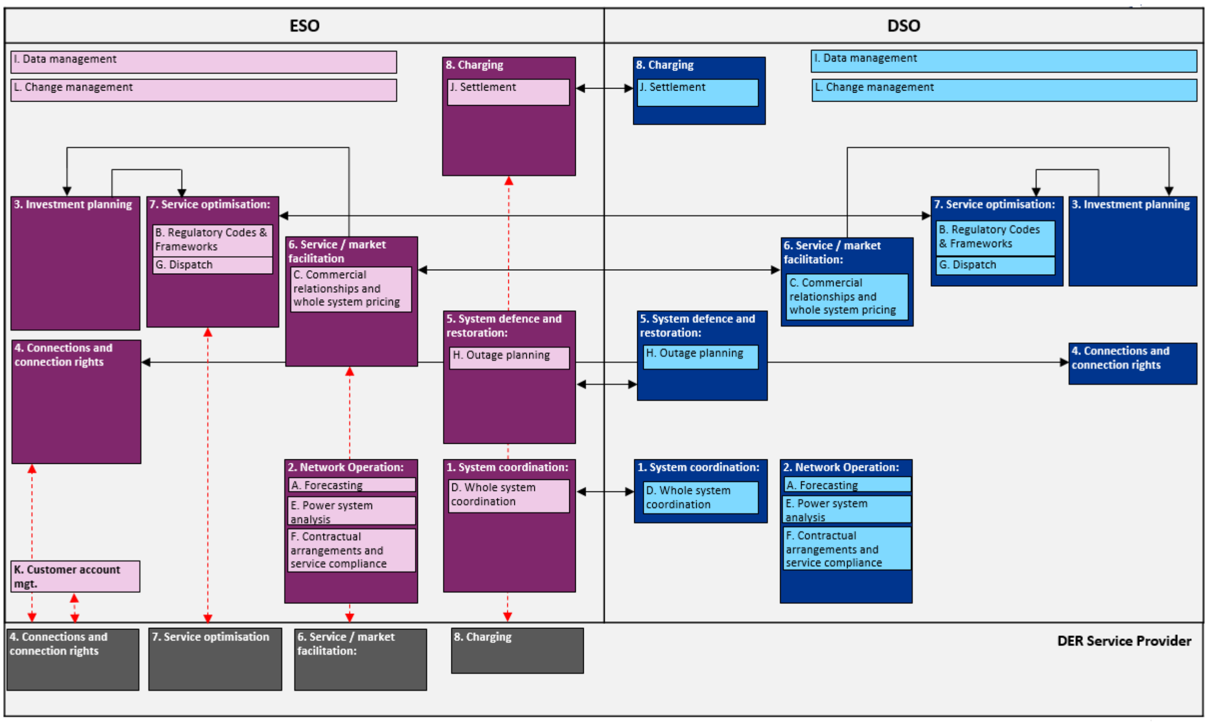
F.2 World B



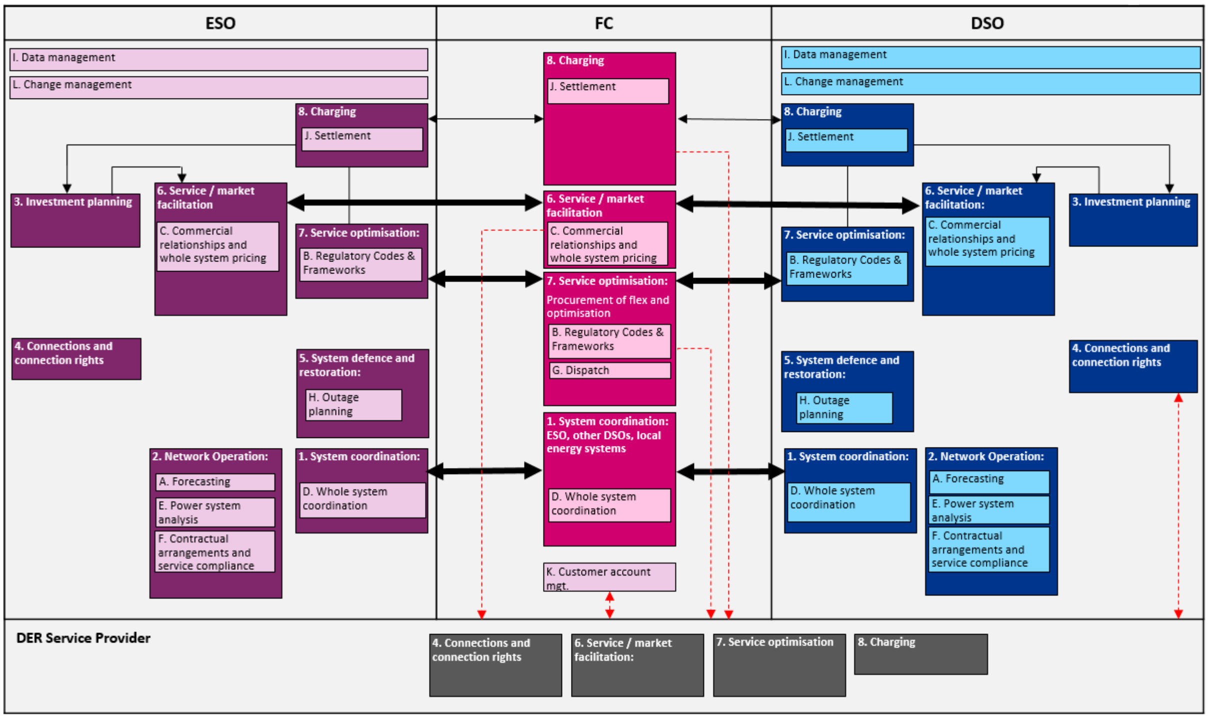
F.3 World C



F.4 World D



F.5 World E



ESO
FC
DSO
I. Data management
L. Change management
8. Charging
J. Settlement
3. Investment planning
6. Service / market facilitation
C. Commercial relationships and whole system pricing
7. Service optimisation:
B. Regulatory Codes & Frameworks
4. Connections and connection rights
5. System defence and restoration:
H. Outage planning
2. Network Operation:
A. Forecasting
E. Power system analysis
F. Contractual arrangements and service compliance
1. System coordination:
D. Whole system coordination
8. Charging
J. Settlement
6. Service / market facilitation
C. Commercial relationships and whole system pricing
7. Service optimisation:
Procurement of flex and optimisation
B. Regulatory Codes & Frameworks
G. Dispatch
1. System coordination: ESO, other DSOs, local energy systems
D. Whole system coordination
K. Customer account mgt.
I. Data management
L. Change management
8. Charging
J. Settlement
6. Service / market facilitation:
C. Commercial relationships and whole system pricing
3. Investment planning
7. Service optimisation:
B. Regulatory Codes & Frameworks
5. System defence and restoration:
H. Outage planning
4. Connections and connection rights
1. System coordination:
D. Whole system coordination
2. Network Operation:
A. Forecasting
E. Power system analysis
F. Contractual arrangements and service compliance
DER Service Provider
4. Connections and connection rights
6. Service / market facilitation:
7. Service optimisation
8. Charging