

Flexible Plug and Play

Principles of Access Report

Final report on smart commercial arrangements for generators connecting under the Flexible Plug and Play Project.

By Baringa Partners and UK Power Networks.

December 2012



Abbreviations

Term	Description	Clause ref
ANM	Active Network Management	Section 1.1.3
CSF	Constraint Sensitivity Factor	Section 5.2.2
DECC	Department of Energy and Climate Change	Section 1.1.1
DG	Distributed Generation	Section 1.1.1
DNO	Distribution Network Owner	Section 1.1.1
FID	Financial Investment Decision	Section 3.5
FIT	Feed-In-Tariff	Section 6.4.2
FPP	Flexible Plug and Play	Section 1.1.1
IRR	Internal Rate of Return	Section 6.3.2
LCNF	Low Carbon Networks Fund	Section 1.1.1
LIFO	Last In First Out	Section 1.1.1
NPV	Net Present Value	Section 1.3.2
RE	Renewable Energy	Section 1.1.1
RO	Renewable Obligation	Section 6.4.2

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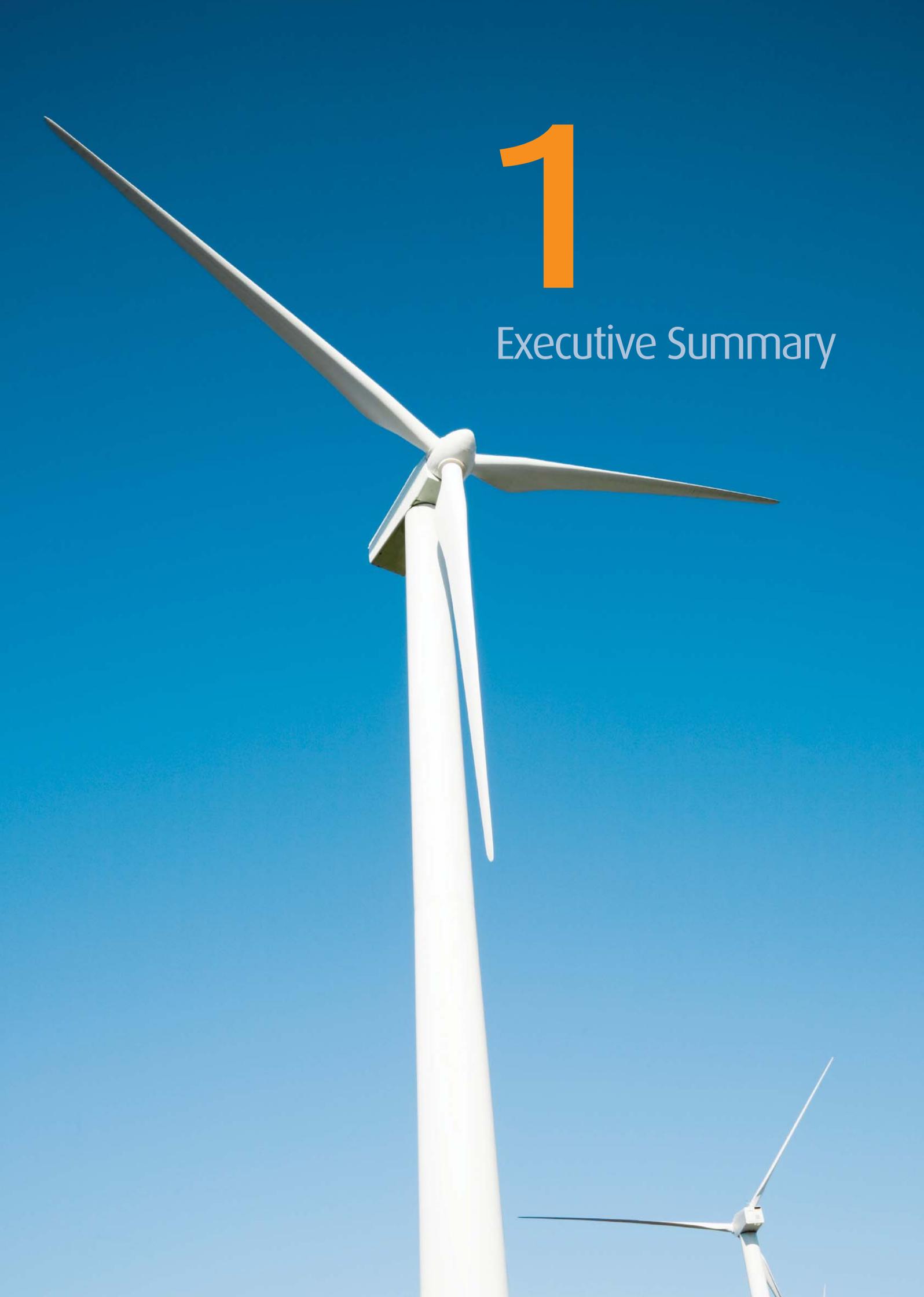
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1

Executive Summary

1.1

Introduction

1.1.1 Flexible Plug and Play

The Flexible Plug and Play (FPP) project is a Low Carbon Network Fund (LCNF) Tier 2 project that is trialling a number of innovative technical and commercial solutions for the connection of Distributed Generation (DG). The Department of Energy and Climate Change's (DECC) latest scenarios¹ project 13GW onshore wind connected to the network² by 2020. With much of this likely to require connections at the distribution network level, Distribution Network Operators (DNOs) are faced with the challenge of accommodating these volumes of new generation capacity in a manner that minimises network infrastructure costs to both the generators themselves and consumers while at the same time maintaining the reliability of their networks. The FPP project is part of a portfolio of projects being trialled by UK Power Networks looking at novel commercial and technical solutions to address this challenge.

1.1.2 The Trial Zone

The area chosen for the FPP project is an area of UK Power Networks' EPN distribution network of approximately 30km diameter (700 km²) between Peterborough and Cambridge (the "FPP Trial Zone"). This area is favourable to renewable generation, wind farms in particular. Over recent years UK Power Networks has experienced increased activity in renewable generation development in this area, and a rapid rise in connection applications, with 100MW of distributed generation already connected and around 200MW at the planning stage. The connection of these anticipated levels of wind generation is expected to require significant network reinforcement to mitigate network thermal and voltage constraints and reverse power flow issues.

1.1.3 Commercial Workstream

At the core of the technical solutions being trialled as part of the FPP project is the implementation of an Active Network Management (ANM) system which will allow more generation

to be connected under the existing infrastructure by using active control of distributed generators and smart technologies such as dynamic line rating, frequent use switches and novel reverse power protection schemes, amongst others. These solutions will allow higher power flows through the network and they will enable UK Power Networks the ability to monitor and manage network constraints in real time. As such, the FPP project will allow the connection of DG in constrained areas of the network in advance of reinforcement of the network to remove the constraint. However, in return, the output of these "FPP generators" will need to be curtailed in certain circumstances³. The Commercial Workstream within the FPP team is charged with developing appropriate commercial arrangements to govern the access rights of generators that connect under the FPP project. This effectively amounts to determining the basis on which curtailment will be allocated between generators in the event that the limit of a network constraint is reached. This report presents the findings of the FPP team and the proposed smart commercial arrangement for implementation on the FPP project.

¹ The UK Renewable Energy Map published July 2011 see the Department of Energy and Climate Change website at: www.decc.gov.uk/assets/decc/11/meeting-energy-demand/renewable-energy/2167-uk-renewable-energy-roadmap.pdf

² This is at both transmission and distribution level.

³ "Curtailment" in the context of this report is used in terms of a reduction of output signalled as a result of active network management. It is not concerned with reduced or interrupted output as a result of network faults.

1.2

Assessment Criteria

1.2.1 Five Principles

In developing an appropriate commercial package for generators connecting under FPP, it is important to do so against a clear set of criteria. Drawing on the lessons learnt from other industry case studies involving the use of active network management and the feedback from the FPP stakeholder engagement process⁴, the following set of principles were used to develop and assess the commercial proposals set out in this report:

- **Network efficiency** - maximise the amount of generation that can be economically connected in any constrained zone and drive the efficient build-out of the network over time;
- **Certainty** - provide each generator with certainty as to the long term level of curtailment;
- **Simplicity** - the solution must be easy to implement and understand; and
- **Fairness** - be equitable in its allocation of curtailment costs between generators;
- **Learning** - maximise the useful learning and insight generated for the distribution network industry as a whole in relation to the commercial allocation of curtailment risk under smart technological solutions.

1.2.2 Risk Transfer - Curtailment

As set out above, certainty as to long term impact of curtailment is of paramount importance to the development of a robust and financeable commercial proposal. One way of securing this certainty would be for UK Power Networks to provide a long term guarantee to generators that the level of curtailment will not exceed a certain pre-determined tolerable level (and paying compensation in the event that it does). Indeed, this was an approach advocated by developers who were interviewed as part of the FPP stakeholder engagement process⁵. It is, however, important to note at the outset that, while there may be some efficiency benefits of DNOs

underwriting curtailment risk, without significant changes to the allowed returns within the current regulatory framework, Distribution Network Operators are currently not able to earn sufficient rewards to enable the acceptance of this type of commercial risk⁶. As such, this report only considers commercial packages that leave all, or almost all, curtailment financial risk with the generators.

⁴ GL Garrad Hassan (2012), Flexible Plug and Play, Workstream 5 - Stakeholder Engagement Report, Section 3.2.

⁵ GL Garrad Hassan (2012), Flexible Plug and Play, Workstream 5 - Stakeholder Engagement Report, Section 3.2.

⁶ Please see Annex 2 for a further discussion of the potential benefits of UK Power Networks underwriting curtailment risk, and the regulatory barriers and prerequisites to being able to do so.

1.3

Rules of Curtailment

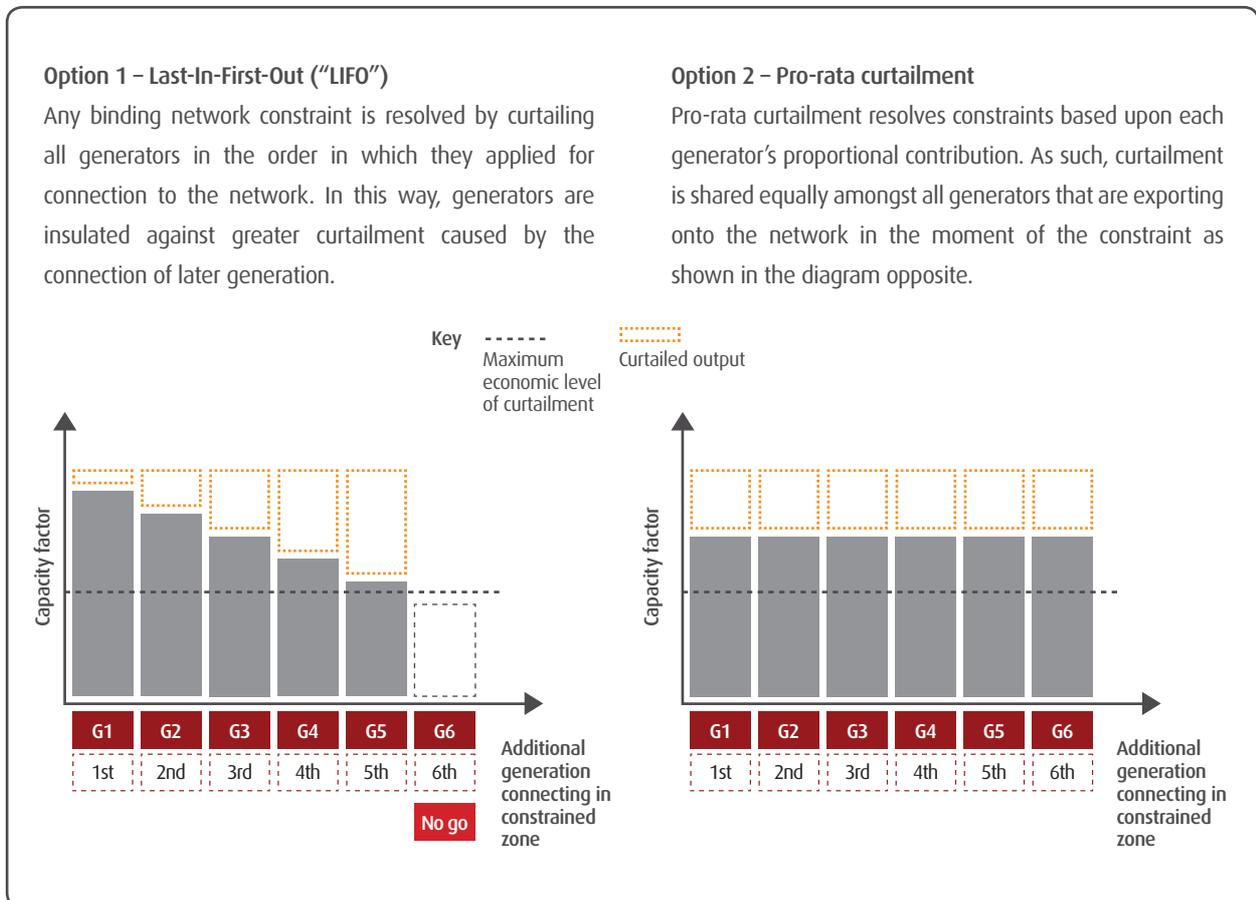
As explained in the section 1.2.2, the starting point for developing the FPP smart commercial arrangements was that the current regulatory framework for DNOs will continue to operate into RIIO-ED1 with the existing risk and reward sharing mechanisms for network investment. This assumption is primarily driven by the conflict in timing of the final project findings and the submission of the RIIO-ED1 business plan. Given this, in order to provide certainty to generators, a central component of the initial commercial proposal is to provide a clear and predictable set of rules by which generators will be curtailed in the event that a constraint occurs - i.e. the

principles of access. By modelling the technical characteristics of the distribution network using a robust set of assumptions and simulating curtailment under these specified principles of access, generators can then forecast the likely levels of curtailment through time with a reasonable degree of certainty.

1.3.1 Options

A number of alternatives have been proposed in the past for the rules by which generators could be curtailed where they contribute to network constraints⁷. However this report only considered two options which are set out in Box 1 below:

Box 1: Rules of Curtailment



⁷ Currie, R., O'Neill, B., Foote, C., Gooding, A., Ferris, R. and Douglas, J. (2011). Commercial arrangements to facilitate active network management. Paper presented at 21st international conference on electricity distribution (CIRED).

1.3.2 Appraisal of Options

This report describes a commercial proposition for implementation on the FPP project that is founded on the principle of pro-rata curtailment. While LIFO offers a simple, certain, tried and tested set of principles for allocating curtailment across competing generators, pro-rata curtailment could form the basis of a new commercial approach to drive (a) greater connection of renewable generators with the same infrastructure and (b) a more coordinated network build-out. These advantages are considered in more detail below.

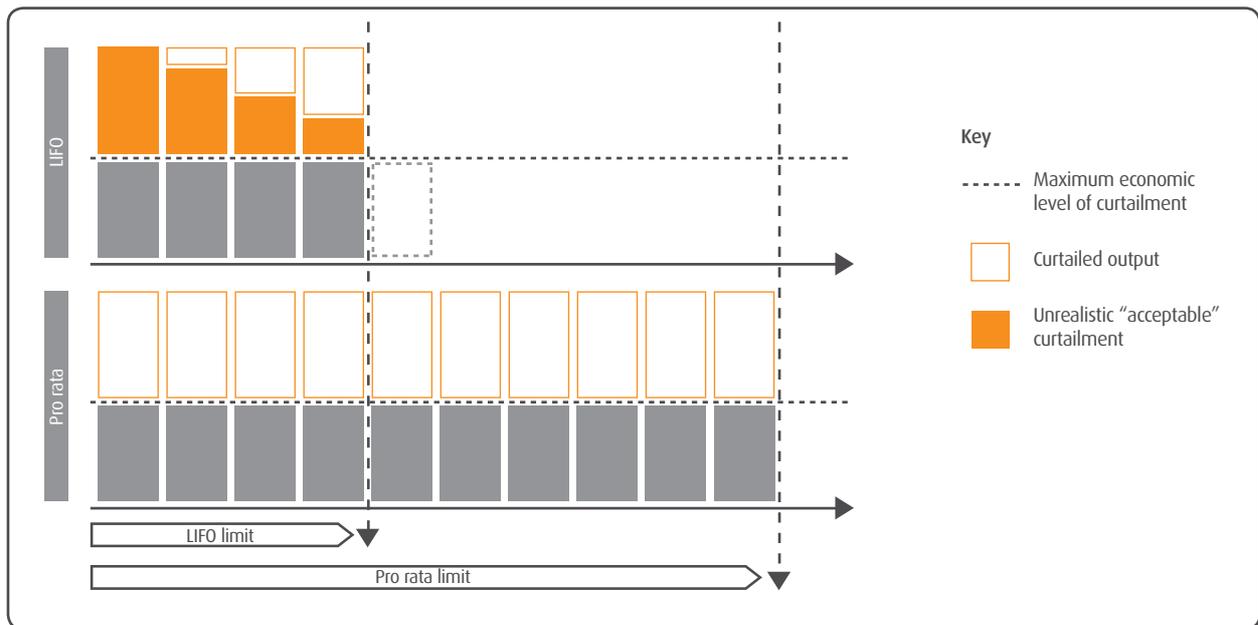
Network Utilisation

Using pro-rata curtailment should theoretically drive a greater amount of capacity connecting behind a given constraint and therefore greater network utilisation⁸. Each generation project connecting under FPP should theoretically be able to accept a level of “economic” curtailment before the project fails to

meet its internal investment hurdle rate (i.e. “acceptable” curtailment). This is on the basis that each generator should theoretically be receiving a saving on its upfront connection charge as the cost of connecting a generator firm (i.e. a section 16 firm connection charge)⁹ is invariably more expensive than a non-firm connection charge offer under FPP. LIFO is potentially inefficient in that it leaves a portion of this “acceptable” curtailment unutilised leading to a reduction in the overall amount of generation that can connect in any constrained zone. This dynamic is set out in Figure 1 below.

Indeed, this is borne out by the curtailment analysis for a particular constraint in the FPP Trial Zone. Assuming a maximum curtailment level of a 3% drop in annual capacity factor (i.e. a curtailed capacity factor of 27%)¹⁰, sharing curtailment across all wind generators pro-rata theoretically allows the connection

Figure 1: Curtailed generation potential



⁸ It is arguably less economically pure than LIFO since the marginal costs are not targeted to the marginal generator. However, given the overriding objective of promoting renewable generation and reducing carbon emissions from the power sector this is a lesser consideration.

⁹ S16 firm connection offer is a connection offer made under the existing connection process under which the generators output will no need to be curtailed under ANM.

¹⁰ This is for comparison purposes only. Determining a more reasonable assumption in this regard will need to be backed up by more detailed analysis of the internal economics of a typical generation project, as set out in section 6.3.

of around 83% more generation in a constrained zone than if generators were curtailed based on LIFO.

Allocation of capacity

The discussion above assumes that the initial capex savings available on connection costs from connecting under FPP vs. connecting under a section 16 (“s16”) firm connection offer are the same for all generators. In reality, however, the savings may differ depending on where each generator is located and the specific works considered for their connections. The problem with LIFO is that it is unable to distinguish between (a) marginal projects with a very expensive firm connection offer and (b) projects which are economically viable with or without FPP (i.e. their firm connection offer is not so expensive that the project is not viable). In this way, by connecting and curtailing on a first-come-first serve basis, LIFO potentially allocates the spare capacity released by FPP in a sub-optimal manner. For example, if we consider two generators:

- **Generator A** is the first to apply for a connection. It is located in a position that makes an s16 firm connection, at an upfront cost of £1 million, a viable option for its project. However, an FPP connection offer is also attractive with a £500,000 saving relative to its s16 firm connection offer in return for only low levels of projected curtailment (i.e. under 1%), since it is first in the LIFO curtailment order.
- **Generator B** is second to apply for a connection offer. It receives a firm connection offer of £3 million which it cannot accept as its project cannot support such an expensive upfront connection charge. It also receives an FPP connection offer of £500,000 and projected curtailment levels of 3% since it is second in the LIFO curtailment order.

Generator A is not a “marginal” project as it could have financed its project with the s16 firm connection offer. However, it accepted the FPP connection as it offered levels of curtailment that were low enough to outweigh the premium

required to connect firm. However, by accepting its FPP offer and using up the early “headroom”, Generator A effectively blocks Generator B as it does not have the option of an acceptable firm connection offer and curtailment levels of 3% are too high to be viable. As such, LIFO would allocate capacity to Generator A rather than Generator B, notwithstanding the fact that Generator A would have developed its project with or without a non-firm offer under FPP. Pro-rata curtailment avoids this problem, because all generators subject to a constraint are required to accept the same or similar levels of curtailment.

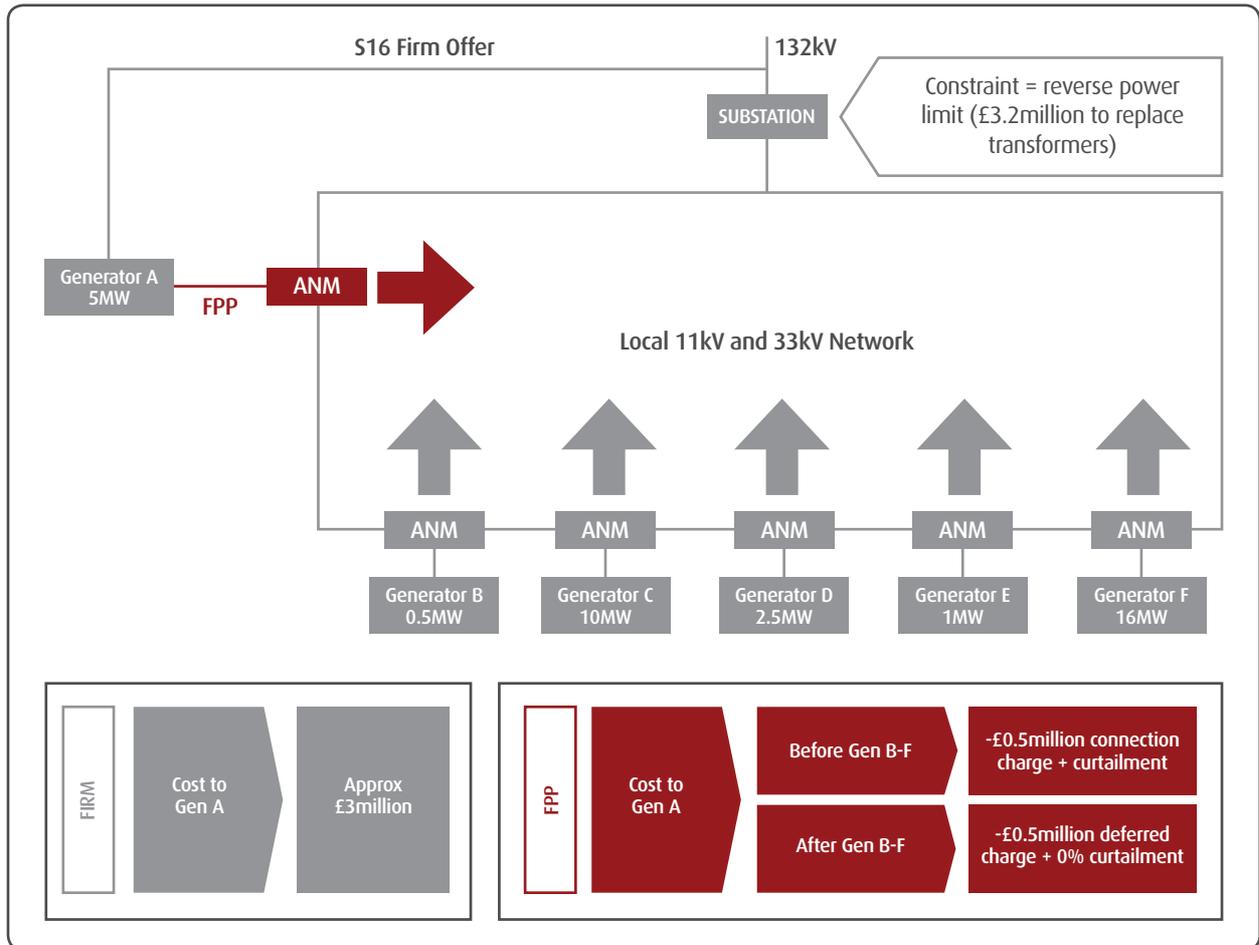
Collaboration on network reinforcement

One of the key advantages of ANM schemes is that they potentially allow a more coordinated connection approach to be taken to groups of generation projects which connect at different points in time, without the associated stranding risk associated with investment ahead of need. For many constraints on the distribution network, there is a reinforcement scheme that could remove the constraint to allow the connection of additional firm generation capacity. However, these reinforcement schemes are inherently “lumpy” and in many cases involve considerable over-sizing of capacity which cannot be funded by the first-come generator on its own. As such, when applying the charging methodology and the definition of the minimum scheme¹¹, there is invariably a cheaper incremental solution involving extended sole use assets to connect that single generator to another unconstrained part of the network.

By allowing connection under FPP, however, generators can instead connect in a constrained zone of the network without triggering the reinforcement immediately and instead accept a level of curtailment of their output. Then, if over time, enough generators have connected under FPP there could come a point where sufficient capacity has connected such that the shared cost of the modular reinforcement action is a viable proposition for generators. This dynamic is set out in Figure 2.

¹¹ See paragraph 5.1 of the Common Connection Charging Methodology for a precise definition of the minimum scheme.

Figure 2: Coordinated vs. incremental network reinforcement



The model highlighted above relies upon the generators themselves choosing to initiate reinforcement instead of accepting curtailment. The key issue with LIFO is that each generator would be experiencing different amounts of curtailment and therefore would appraise the value of reinforcing the network differently. As such, in a scenario where the most efficient option overall would be to pay for the local reinforcement (i.e. which arises where the Net Present Value (“NPV”) of the lost revenues from aggregate curtailment of all ANM generators is greater than the cost of the local

reinforcement), this action may not be taken due to the asymmetric allocation of the curtailment across the generators subject to the constraint. A commercial approach based on pro-rata curtailment, by contrast, would look to spread the cost of curtailment equally among all generators subject to the constraint. As such, when trading off the incremental cost of reinforcement against the reduction in curtailment experienced, generators would be in the same or at least relatively similar position, for assessing the trade-off.

1.3.3 Key Challenge - Building in Certainty

As set out in Section 1.2, with all curtailment risk left with the generator, the key consideration for each generator looking at whether to connect under FPP will be the level of confidence it can place in the curtailment forecasts at the point that it makes its investment decision. Any design feature of the commercial and technical arrangements that introduces greater uncertainty will make it more difficult for generators to “bank” their connection agreement.

While basing the commercial proposal on a pro-rata curtailment affords considerable benefits over and above LIFO, it does have one key draw-back in that it fails to provide generators with this long term certainty as to the expected levels of curtailment. This is because, while LIFO insulates first-comer generators from the effect of increased curtailment triggered by the connection of more generation capacity in the future, pro-rata curtailment does not. The more generation that connects in a constrained zone, the greater the levels of curtailment experienced by all generators in that constrained zone. With no way of knowing what level of generation will connect, generators are left with little certainty as to the worst case curtailment levels. As such, a commercial proposal based on pro-rata curtailment alone is not a financeable proposition for any generator without some form of assurance from UK Power Networks on the limit on the amount of additional generating capacity with which that generator will share curtailment risk.

1.4

Developing the Commercial Proposal

As explained, a commercial package founded on the principle of pro-rata curtailment must give each generator certainty and/or visibility, at the time that it accepts its FPP connection offer, as to the maximum capacity of additional generating capacity with which that generator will share curtailment. As such, each of the four options set out below has at its core the need to provide this certainty to generators while at the same time attempting to maintain the benefits of pro-rata curtailment described.

1.4.1 Vintaging

Description

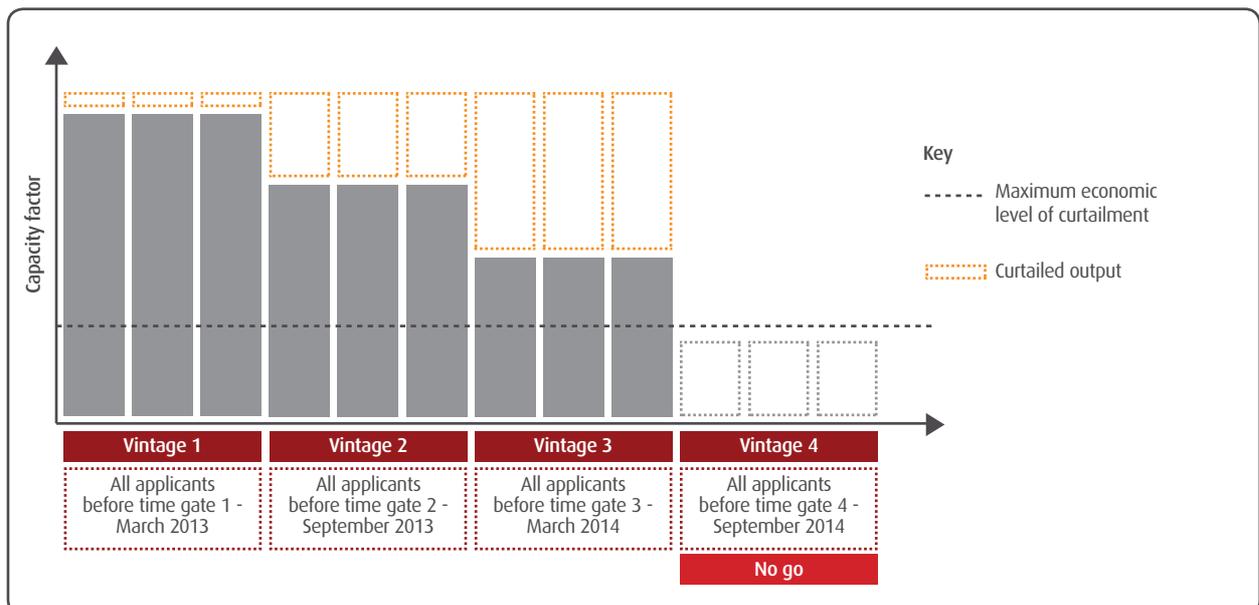
One option considered was to group generators into “vintages” by reference to the period of time, or “time gate”, in which they applied for connection. For example, as shown in Figure 3 below, generators that applied for connection before March 2013 would be allocated to Vintage 1, those between March and September 2013 to Vintage 2 and finally those between September 2013 and March 2014 to Vintage 3. In resolving any constraint, all generators in

Vintage 3 would be curtailed first, with curtailment applied pro-rata across all generators in that vintage. The generators allocated to Vintage 2 would only be curtailed in the event that the output of all the generators in Vintage 3 had been curtailed to zero (and so on). In this way, curtailment would be applied pro-rata within vintages; and LIFO between vintages.

Appraisal

Vintaging as an approach is critically limited by the fact that UK Power Networks is not in a position to manage the amount of generating capacity that applies for connection in a given time gate. For example, if too much generation looks to connect, curtailment levels could be too high, while if too few generators apply to connect (or if generators book a spot in a vintage but fail to build out their projects), a vintage could return relatively low levels of curtailment well below what the generators could have withstood given their saving on the connection cost. This would lead to inefficient under-utilisation of the network capacity.

Figure 3: Vintaging



1.4.2 Capacity Quota

Description

Capacity quotas look to overcome the principal issue with vintaging by defining upfront the maximum level of capacity that can viably connect in any given constrained zone. It does this by modelling how shared curtailment increases as the capacity of generation in a constrained zone increases. By fixing the limit on capacity at a level which returns tolerable levels of curtailment for all generators, a quota based approach looks to provide a volume certainty to generators. Figure 4 shows this in more detail.

Appraisal

While capacity quotas theoretically provide a universal approach by which capacity can be allocated, it has one key draw back in that setting the quota relies on the basic principle

that UK Power Networks DNOs are able to determine this “tolerable level of curtailment”. However, in reality, there is considerable variation in the sensitivity of different generators to curtailment which are driven by their technology type, capacity factor, capex assumptions and assumed savings on their FPP connection. Given the variance in appetite for curtailment amongst generator types and the sensitivity of the results to changes in the assumptions, picking the “right” level of maximum curtailment becomes a potentially problematic process. This would require UK Power Networks to make a value judgment that, given its position, it might not be feasible for it to make without extensive bilateral dialogue with its potential generator clients.

Figure 4: Determining the size of a capacity quota

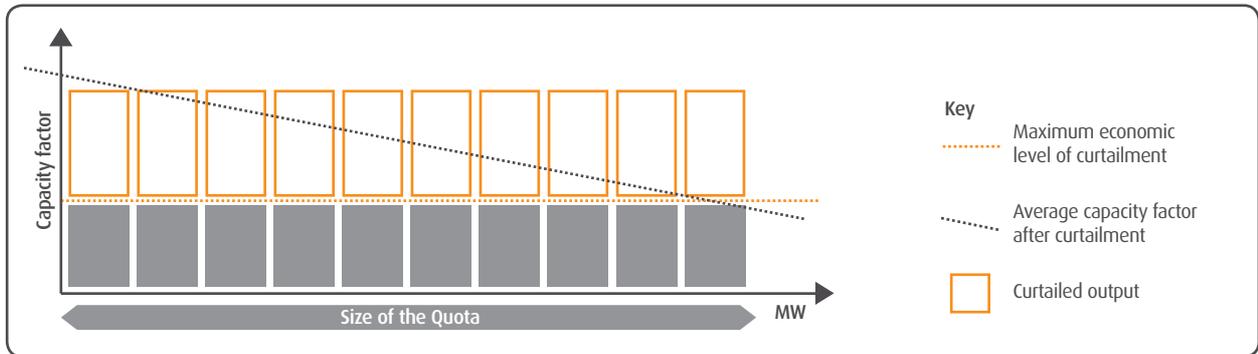
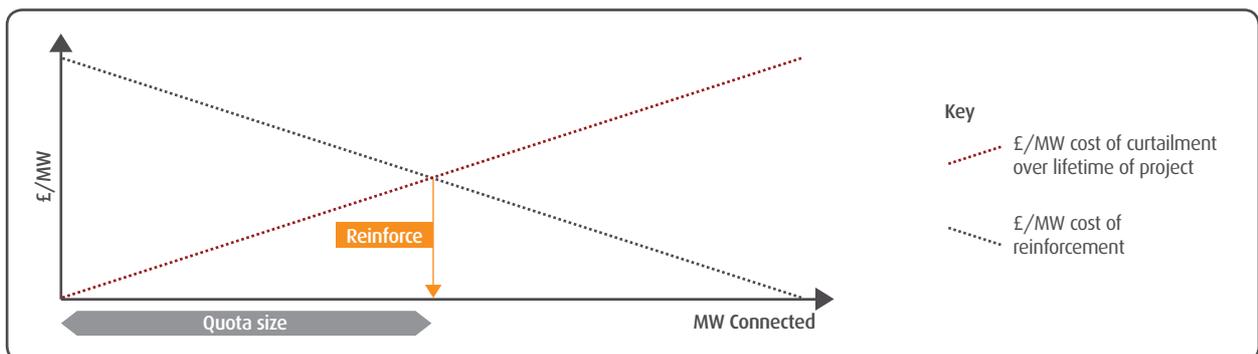


Figure 5: Quota set by reference to reinforcement costs



1.4.3 Reinforcement Quota

Description

This option is a variant on the capacity quota approach. However, instead of defining the quota by reference to a maximum curtailment level, it looks to define the quota by reference to the level of capacity connected in a constrained zone at which the cost to each generator in terms of lost revenue as a result of curtailment (i.e. "curtailment cost") equals or exceeds the cost of reinforcing the network to eliminate the curtailment altogether when shared across all non-firm FPP generators (i.e. the cost of "buying firm"). In this way, in deciding whether to connect under this proposal, a generator would have to get comfortable that its project can withstand the curtailment triggered by generation connecting up to the level of quota before reinforcement is triggered.

The question then arises as to how reinforcement is treated in the commercial arrangements once the quota is full. Broadly speaking, there are two options:

- **Mandatory Reinforcement** - This would include a hard-wired reinforcement cost into the contract. Once the quota had been filled, each generator would be obliged in the contract to fund the reinforcement at that pre-agreed price.
- **Voluntary Reinforcement** - Alternatively, reinforcement at the point the quota is full could be a voluntary arrangement with no hard-wired connection charge in the agreement. Instead, generators could be offered the option to reinforce at the point that the reinforcement trigger is exceeded. If they accept and decide to fund reinforcement, they would then have a firm connection. If they do not accept they would remain non-firm and subject to on-going potential curtailment.

For both alternatives, under this approach, ANM as well as FPP becomes less an enduring solution but rather a transitional process until sufficient generation has connected to the

network, so as to make a firm connection an economically attractive proposition for developers.

Appraisal

The key benefit of this approach is that instead of reinforcing first and either requiring the first generator (or the consumer, if socialised) to bear the stranded investment risk, generation is allowed to come forward in advance of the reinforcement decision while the quota is sized on the cost of a common ultimate objective – namely a fully firm connection. This use of the trade-off between curtailment costs and the cost of reinforcement resonates with the rationale that was used to underpin the "Connect and Manage" reforms implemented at transmission level in 2010. This approach also provides a robust methodology within which UK Power Networks is able to set the quota and reinforcement trigger, thereby avoiding it making too many assumptions about the internal economics of different generators.

One of the principal limitations, however, of this approach is that its viability depends on the characteristics of the existing network and the cost, nature and overall viability of the possible reinforcement solution. The extent to which this approach will be viable will depend on the extent to which:

- There is a reinforcement plan which is deliverable within viable timescales (e.g. does not require a new overhead line with the significant consenting challenges that such developments entail).
- The deployment of smart grid technology (i.e. Dynamic Line Rating, ANM, frequent use switches.) can unlock enough headroom in the assets such that a given volume of generation can connect without triggering prohibitively high curtailment levels.

- The subsequent reinforcement plan is not so expensive as to require the first comer non-firm generators that connect under FPP to fund significant over-sizing in the shared assets.

This dynamic is highlighted in Figure 6.

In Scenario B illustrated, either an increase in reinforcement cost (the blue line) or a reduction in available headroom released by FPP (the red line) can raise the worst case curtailment levels and associated deferred reinforcement cost to potentially unacceptable levels.

1.4.4 Capacity Auction

Description

The principal challenge of a capacity quota based approach is knowing the level of curtailment that generators can tolerate. While a reinforcement quota could circumvent this problem by setting the quota and reinforcement trigger by reference to the trade-off on reinforcement costs instead, it still suffers from the fact that it may not be applicable in every situation. As such, there is a need for a universal approach for allocating capacity by reference to some level of acceptable curtailment that can be applied in any constrained scenario.

A capacity auction could potentially do just this by combining elements of both vintaging and the capacity quota approach. For each constrained zone, UK Power Networks would

advertise the availability of network capacity under FPP. Over a period of time prior to the auction, UK Power Networks would recruit generators that might potentially be interested in connecting in that particular constrained zone. Once the “time gate” had closed, UK Power Networks would ask each generator to bid the annual level of curtailment that it would be prepared to accept over the lifetime of its project. The level of demand for connection at different levels of curtailment could then be matched against the maximum capacity quota that returned that level of annual curtailment.

Appraisal

Auctioning has the key advantage in that, UK Power Networks would simply be matching available capacity to the bid curtailment tolerances. In this way, auctioning does not require UK Power Networks to make any determinations in respect of the level of curtailment generators should be able to withstand (as with capacity quotas). However, this approach relies upon there being sufficient volumes of capacity looking to connect at a particular constrained zone at the same time. Without competition for capacity, generators may not bid the “true” level of their acceptable curtailment resulting in a loss of efficiency. Moreover, evaluating bids from generators in different stages of the development life cycle (and therefore differing probabilities of actually delivering the project) presents an additional technical challenge for UK Power Networks in administering this process.

Figure 6: Wider applicability of the reinforcement quota

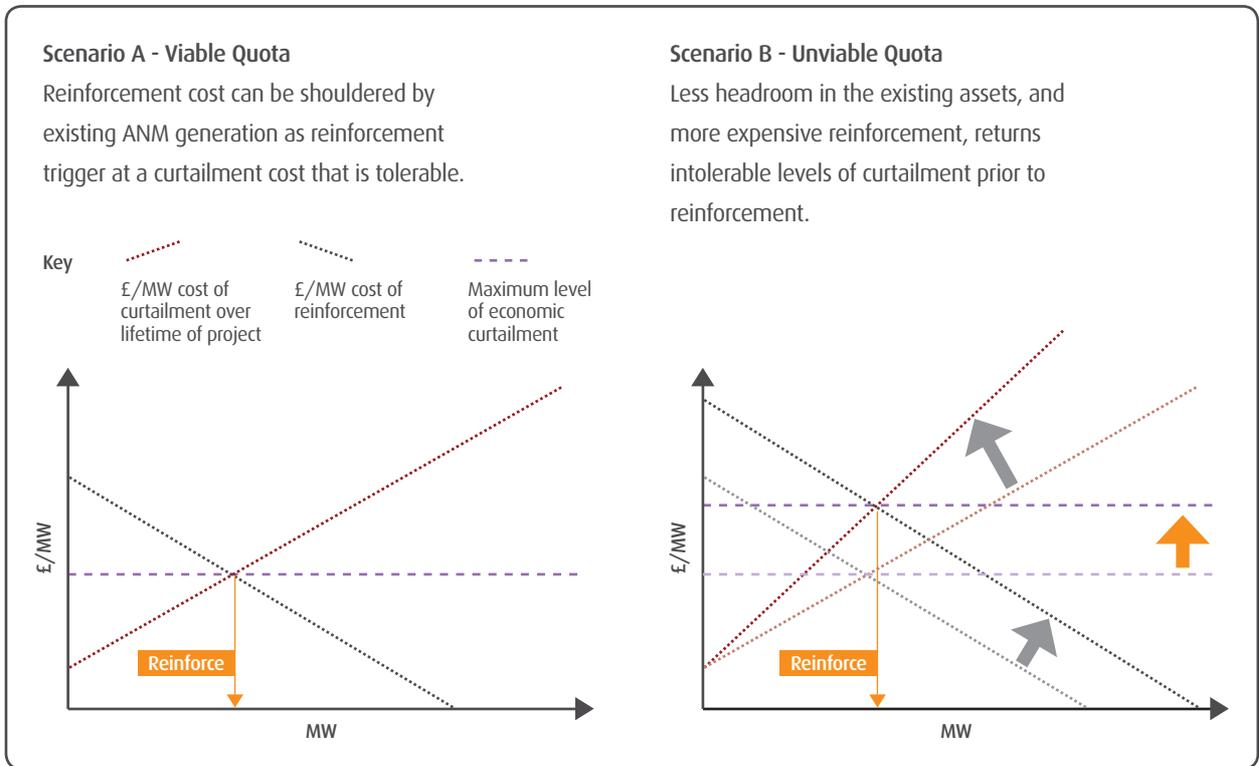
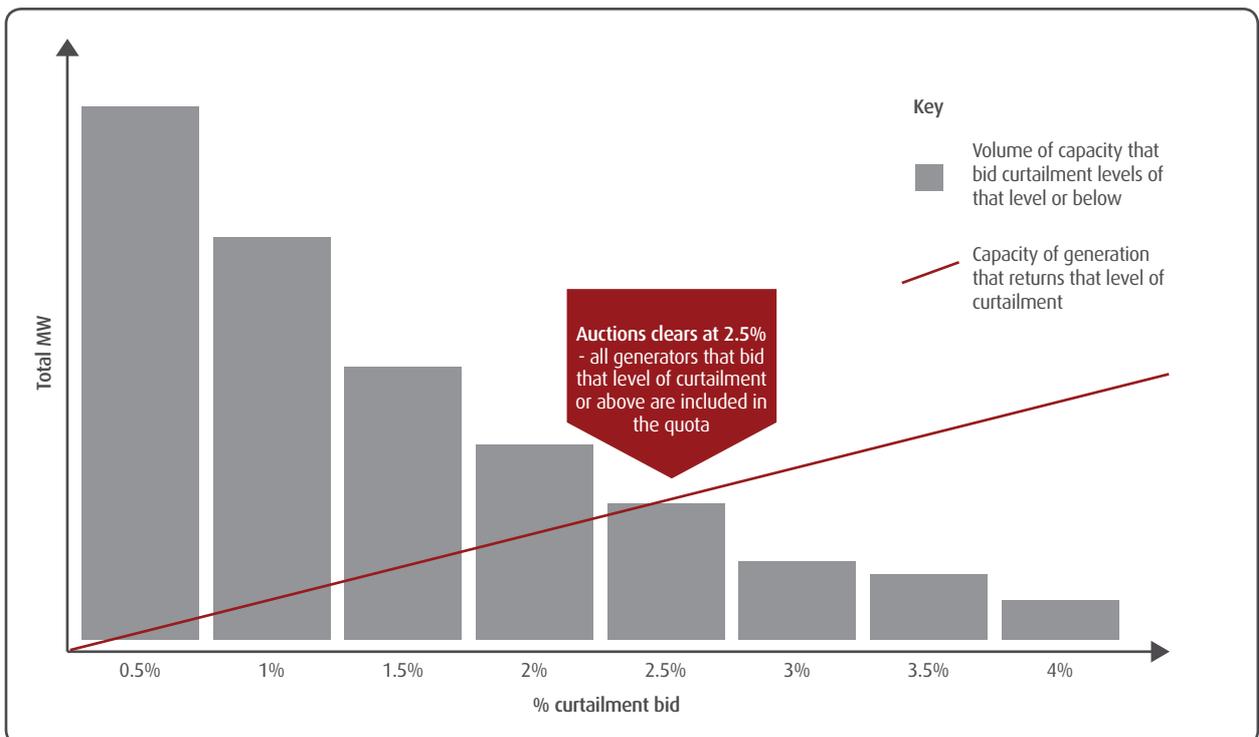


Figure 7: Clearing the auction of capacity



1.5

Conclusions

1.5.1 Multi-tiered Approach

In light of the conclusions set out, it is proposed that the smart commercial arrangements governing the connection of generators under FPP should use a multi-tiered hierarchical approach involving:

- the reinforcement quota as the primary proposal where there is a viable reinforcement scheme; and
- the capacity auction as a secondary option where either (a) there is no viable coordinated reinforcement scheme in respect of any given constraint or (b) the size of the quota determined by reference to the trade-off against reinforcement costs requires generators to withstand unreasonable levels of curtailment.

The objective of the FPP project is to provide cheaper and faster connections to generators. This multi-tiered approach acknowledges the dual role that ANM can play in terms of achieving this goal. It can provide a potentially temporary mechanism by which generators can exchange savings on incremental firm connection offers for curtailment, with the option of reinforcing on a coordinated basis once a critical mass of generation has materialised at a later date. However, in addition, it can also provide an enduring solution by which additional headroom in the network assets can be unlocked for generators that choose a permanent non-firm connection option with long term curtailment risk.

1.5.2 Exploring Strategic Investment

The reinforcement quota envisages that the first comer generators should shoulder the full cost of curtailment and any lumpy reinforcement cost, such that no stranding risk is left with UK Power Networks in relation to any particular reinforcement scheme. On the basis that the savings generated by FPP accrue principally to the generators themselves, this is consistent with the existing connection charging methodology. However, having said that, one of objectives of FPP is to

explore how smart solutions can facilitate a more strategic approach to network development. What the reinforcement quota allows is a more sophisticated appraisal of the need for strategic investment.

For example, a reinforcement quota might return an intolerable worst case curtailment level and deferred connection charge where the size of the required investment is very large and the headroom in the existing assets released by smart solutions relatively small. However, instead of discounting this as an option and moving to Option 4 immediately, UK Power Networks could instead include an interim step by using this analysis to investigate what level of investment in the relevant reinforcement scheme would be required to reduce the curtailment levels and deferred reinforcement costs to tolerable levels. As such, in much the same way as one might prime a pump, where there is an area of good renewable resource and a strong pipeline of projects, a strategic deployment of a small amount of a capital could bring forward significant volumes of renewable generation.

1.5.3 Mandatory vs. Voluntary Reinforcement

As discussed above, reinforcement can either be hardwired into the contract from day one with a mandatory requirement to fund when the quota is full. Or alternatively, the decision to reinforce can be a voluntary one, which the generators decide whether or not to fund at the point at which the quota is full. Including mandatory reinforcement in the FPP Commercial agreement has the advantage of providing certainty to generators that at the point the quota is full, the constraint will be relieved at a price that has been agreed up front. As this will be a shared cost of a coordinated connection solution, the total cost to that generator of a firm connection will therefore be less than the cost of connecting that generator alone. Moreover, by hardwiring the reinforcement cost into the contract from day one, the issue of “free-riding” is avoided

where one generator refuses to fund its share but then benefits from reduced curtailment in the event that other generators decide to fund the reinforcement.

However, the key drawback of hardwiring reinforcement into the contract is that it could create significant financing challenges for generators who would, in effect, need to put in place a contingent standby facility for the payment of deferred connection liability. This could significantly increase financing costs and leave the generator with the uncertainty of not knowing whether this contingent charge will in fact be levied. As such, one of the key next steps for the finalisation of the commercial arrangements will be to understand from project developers which of these approaches would be preferable.

2

Introduction



2.1

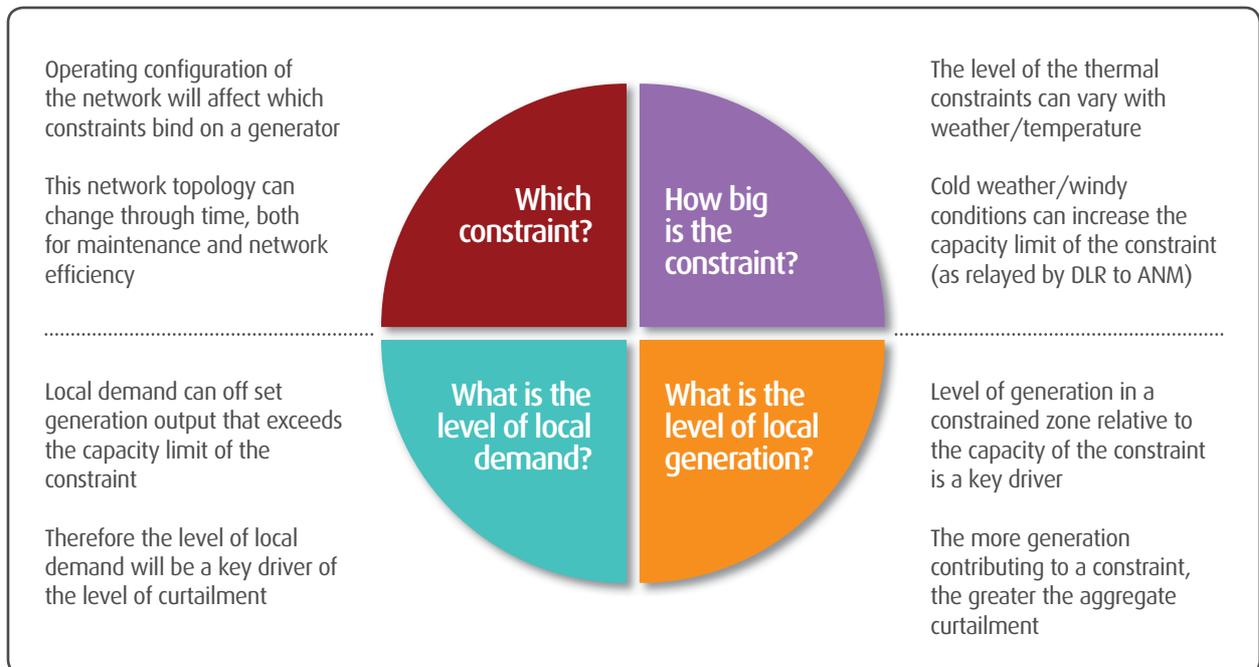
Drivers of Curtailment

The primary aim of the FPP project is to provide **cheaper** and **faster** connections to generators connecting to constrained areas of the distribution network. In return, these generators will have to accept a level of curtailment of their output. This is controlled via an ANM scheme that will allow UK Power Networks to manage the output of generators in real time in response to constraints on the network. The aggregate level of curtailment of generation output in any given constrained zone is a function of the extent to which the local generation exports exceed the sum total of (a) the amount of local demand and (b) the size and nature of the constraint itself.

In view of the fact that, in the majority of scenarios, a number of generators will be contributing to any constraint, the cornerstone of any enduring smart commercial package is to develop an order of curtailment, or “principles of access”, that sets the rules of how to allocate aggregate curtailment between these competing generators in a constrained zone.

This dynamic is set out in more detail in Figure 8 below:

Figure 8: Drivers of curtailment on an ANM System



2.2

Report Structure

This report looks to provide an objective appraisal of a number of potential options for allocating curtailment that have been developed by the FPP team and, based on this assessment, make a recommendation as to the optimal solution for implementation on the FPP project. The report is structured as follows:

- Section 3 sets out the criteria against which the respective commercial options have been developed and subsequently assessed;
- Section 4 introduces a particular constraint network scenario that will be used as a case study to enable the conclusions of this paper to be grounded in the realities of the network conditions of the trial zone;
- Sections 5 and 6 assess the relative merits of a number of commercial packages that could be used to connect generators under FPP against the criteria of assessment;
- Section 7 draws the conclusions together into a proposed commercial proposal for implementation on FPP; and
- Finally, having settled on the broad principle on which access will be allocated, Section 8 highlights the key terms and conditions of the FPP connection agreement that will be offered to generators recruited into the FPP process.

3

Criteria of Assessment



3.1

Introduction

In deciding on an appropriate commercial package for generators connecting under FPP, it is important to assess each option against a clear set of criteria. Sections 3.2 to 3.6 set out the five key principles against which the different commercial packages are appraised in this paper. These principles have been informed by a number of influences:

- First, we have tried to draw on the lessons learnt from a number of other industry case studies that have been explored in detail by Cambridge University¹². The most relevant to the FPP project are the “Connect and Manage” approach implemented at transmission level in GB, the development of non-firm network access agreements for generators connecting to the transmission network in Ireland and the ANM scheme implemented by Scottish and Southern Electricity (“SSE”) on Orkney, Scotland.
- Second, we have incorporated the feedback received through the FPP stakeholder engagement process on the principal concerns of generators in relation to the allocation of curtailment¹³.

It is worth noting at this stage that while all the criteria are important, particular significance has been placed on the need to maximise network efficiency (Section 3.2) while providing certainty to generators as to the long term impact of curtailment on their project (Section 3.3).

¹² Dr. Karim L. Anaya, Dr. Michael G. Pollitt (2012), Experience of the use of smarter connection arrangements for distributed wind generation facilities - Sections 4.1 and 4.2.

¹³ GL Garrad Hassan (2012), Flexible Plug and Play, Workstream 5 - Stakeholder Engagement Report, Section 3.2.

3.2

Network Efficiency

The commercial package offered to developers under the FPP project should, to the extent possible, look to be as efficient as possible. Efficiency, in this context, is defined in two ways:

- **Network Utilisation:** One of the primary objectives of the FPP project is to look to maximise the utilisation of the existing network. In this way, to the extent possible, curtailment should be distributed amongst generators in such a manner that overall the maximum number of MWh of generation are transported using the existing infrastructure. Broadly speaking, this roughly equates to maximising the volume of installed generation capacity that can viably connect, subject to curtailment.
- **Reinforcement Decisions:** Another less quantifiable indicator of efficiency is the extent to which different commercial arrangements allow more efficient decision making with respect to the build out of the distribution network to accommodate the additional generation volumes anticipated. A key criterion of appraisal will be the extent to which the commercial arrangements developed under the FPP project can, where appropriate, drive a more coordinated (and overall less expensive) network development solution in “generator dominated” areas like the FPP trial zone by reducing investment-stranding risk (for UK Power Networks and/or the generators themselves) for any over-sizing of network assets.

The common charging methodology only provides for firm connections, and does not consider controlling generator’s output. Therefore, it does not consider alleviation of curtailment by investing in reinforcement of the network¹⁴. Broadly speaking, generators are required to fund all costs triggered by the connection of their assets at the voltage level at which it connects and the voltage level above.¹⁵ As such, it is assumed that any additional works required to reduce or alleviate curtailment for generators at any point following

connection under a FPP connection offer, would need to be recovered from the generators that “triggered” those costs. In this case, it would be the generators that stand to benefit from reduced curtailment – provided the reinforcement actions did not relate to sections of the network two voltage levels above the generator’s point of connection.

¹⁴ Statement of methodology and charges for connection to the electricity distribution systems of Eastern Power Networks plc, London Power Networks plc and South Eastern Power Networks plc (19 July 2012), Section 5 - Common Connection Charging Methodology.

¹⁵ Connection charging methodology requires DNOs to opt for the connection scheme that results in the lowest aggregate cost (i.e. the “minimum scheme”). Once it has decided on the lowest cost solution, cost apportionment may apply for assets that are classed as “reinforcement assets” – i.e. upgrades to the shared use distribution system. However, on the basis that the minimum scheme invariably drives a more incremental solution (i.e. with primary sole use assets), the majority of connection cost are shouldered by the generators at a distribution level.

3.3

Certainty

Of paramount importance to a DG developer and its financiers will be the certainty (at the point of investment decision) as to the long term financial impact on its project of curtailment under FPP. Certainty in this regard can be provided in one of two ways.

- **Curtailment forecasting** – Under this approach, UK Power Networks would simply set out the rules on which generators will be curtailed to resolve any particular constraint (the “principles of access”). By then modelling the technical characteristics of the network and simulating curtailment under these specified principles of access, UK Power Networks would provide generators with a forecast of likely levels of curtailment over time. Developers would then need to get comfortable as to the long term impact of curtailment on their generation project by carrying out a detailed technical appraisal of the assumptions under-pinning the curtailment forecast. Crucially, under this approach, UK Power Networks would not be giving any undertaking as to the accuracy of those assumptions or the absolute level of curtailment over time. In many ways, this is no different from what is already done by generators connecting under a firm section 16 (“s16”) connection offer¹⁶. Generators connecting under these firm connection agreements succeed in banking their projects, not off the back of the obligation on the DNO to pay compensation in full for its lost revenues in the event of interruption, but rather on the basis of a robust technical appraisal of the resilience of their connection and the surrounding network.
- **Risk transfer to UK Power Networks** – An alternative approach advocated by developers who were interviewed as part of the FPP stakeholder engagement process, would be for UK Power Networks itself to provide the long term certainty by guaranteeing to generators that the level of curtailment will not exceed a certain level (and paying compensation in the event that it does). This would therefore involve a transfer of risk away from the generators to UK Power Networks.

It is important to note at the outset that this paper only considers commercial packages that leave all, or almost all, curtailment risk with the generator. The FPP team has developed a number of additional options that involve risk transfer to UK Power Networks. While there might be benefits from the network efficiency perspective of UK Power Networks underwriting curtailment risk for generators, UK Power Networks is currently not in a position to accept this type of commercial risk on the basis that the existing regulatory framework disincentivises it to do so. However, for further discussion of the potential benefits of UK Power Networks underwriting curtailment risk, and the regulatory barriers and prerequisites to being able to do so, please see Annex 3.

¹⁶ By a section 16 firm connection offer, we mean any connection offer which does not envisage curtailment under an ANM scheme.

3.4

Simplicity

It is important that the commercial package offered to developers of generation projects looking to connect under the FPP project is simple and easy to implement and understand.

This is for two reasons:

- **Timing:** UK Power Networks has committed to make a FPP connection offer to generators that have opted to participate in the FPP project at the latest on 1 March 2013. Generators will then have at least a month to decide whether to accept this offer. As such, any commercial package developed must, to the extent possible, be simple and easy to implement to ensure that the FPP project is able to connect generators soon enough to enable the technical and commercial solutions being trialled as part of FPP to be properly tested prior to the expiry of the project in December 2014.
- **Nature of the Customer:** While developers of distribution connected generation projects can be large experienced market participants, a significant proportion of participants in DG market are developing projects without the scale and transaction value to support detailed legal and technical risk analysis. As such, the value of introducing additional complexity in the commercial arrangements underpinning FPP should be carefully considered against the capacity of its target customers to effectively appraise it. This contrasts to developers of transmission connected generation projects, which tend to be larger, more sophisticated and well advised portfolio players who are in a position to appraise the nature of risks introduced by complex commercial and regulatory proposals (i.e. in relation to allocation of curtailment risk).

3.5

Fairness

With a limited amount of capacity being released by FPP, the allocation of that capacity between generators connected or looking to connect in the FPP Trial Zone should be as equitable as possible. This can be broken down into two key concepts:

- **Grandfathering:** The property rights of existing generators who have connected under firm connection agreements must be respected when allocating capacity under FPP. These generators would have already paid for a firm connection and invested on that basis. To introduce additional risk now (without commensurate compensation payments) would be manifestly unfair and would abrogate a key principle in the energy sector – that of grandfathering of property rights from the moment of Financial Investment Decision (“FID”)/commissioning.
- **Allocation between new generators:** With all existing generators “grandfathered”, the manner in which curtailment risk is allocated across new generators connecting under FPP will need to be perceived to be “fair” and “equitable” by reference to a set of industry accepted norms and methodologies. It is noted that fairness in this context is necessarily a subjective matter, with winners and losers under any given option or scenario.

3.6

Learning

One of the primary objectives of the LCNF is to generate learning within the DNO community as to how to drive more efficient use of their networks while meeting the demands of their customers (both present and future). Indeed, Ofgem has made it clear that funding should not be provided for “unnecessary duplication on projects”¹⁷. The commercial package implemented under the FPP project should drive commercial innovation and avoid unnecessarily replicating work from other similar projects implemented elsewhere. To the extent possible, the FPP project should instead be looking to build upon the learning generated on earlier projects to develop an improved approach to similar or related problems. It is noted, however, that learning is not an end in its self. The FPP commercial team is mindful of the fact that the FPP project is dealing with real customers whose legitimate expectations as to the likely benefits and risk of the FPP project should be respected.

¹⁷ Electricity Distribution Price Control Review; Final Proposals – Incentives and Obligations, 7 December 2007, paragraph 1.24 – “For a project to be eligible for LCN funding, it must involve the introduction of a technical or commercial application by a DNO that....generates knowledge that can be shared amongst all GB licensed electricity DNOs”.

4

Case Study



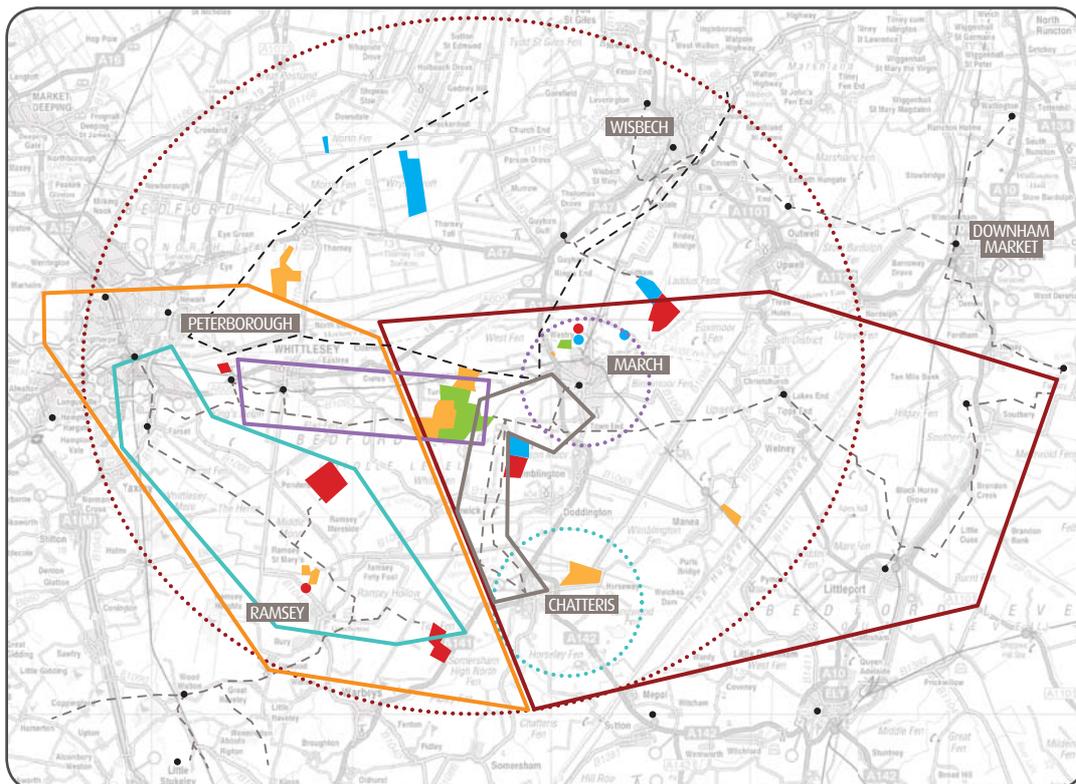
4.1

FPP Trial Zone

The area chosen for the FPP project is an area of UK Power Networks' EPN distribution network of approximately 30km diameter (700 km²) between Peterborough and Cambridge (the "FPP Trial Zone"). This area is well suited to renewable generation, wind generation in particular. Over recent years UK Power Networks has experienced increased activity in renewable generation development activity in this area, and a rapid rise in connection applications, with 121MW of

wind generation already connected and around 193MW at the planning stage as at November 2012. The connection of these anticipated levels of wind generation is expected to require significant network reinforcement to mitigate network thermal and voltage constraints and reverse power flow issues. Figure 9 below shows the FPP Trial Zone and some of the constraints that will be triggered by the anticipated volumes of generation.

Figure 9: Constraint zones in the FPP Trial Zone, in Cambridgeshire. Map submitted in 2011 as part of FPP bid.



Key

— Zone 1	■ Connected Wind Farms
— Zone 2	■ Consented Wind Farms
— Zone 3	■ Applications received
— Zone 4	■ Applications in scope
— Zone 5	
⋯ Zone 6	
⋯ Zone 7	

4.2

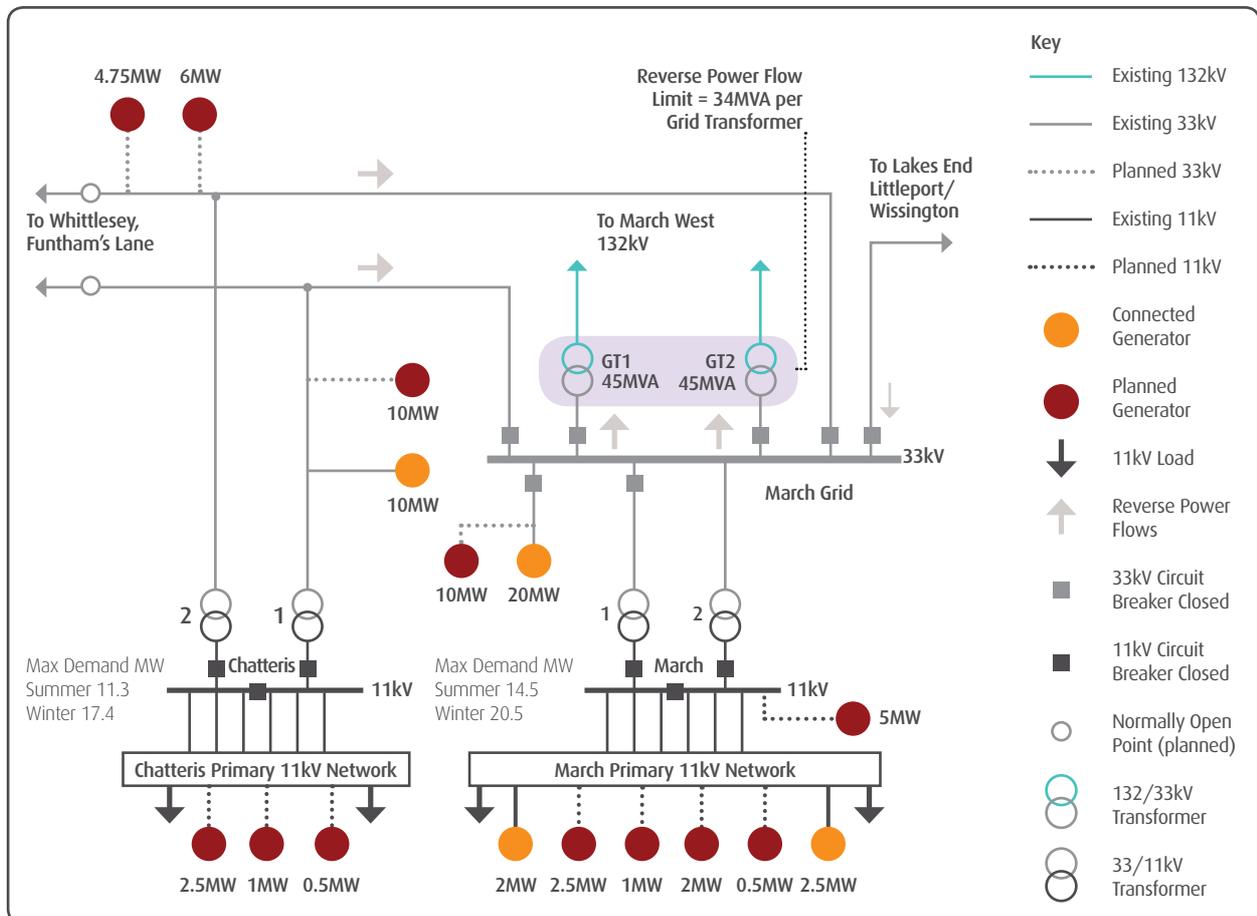
The March Grid Constraint

In order to bring a real life relevance to the appraisal process set out in this paper, it is important that each commercial package is assessed in relation to an actual constraint in the trial zone. The constraint is the reverse power flow through the March Grid transformers (the “March Grid Constraint”) shown as Zone 6 in Figure 9. Figure 10 sets out the single line diagram of the section of the network that is subject to this constraint.

The reverse power limit on the March Grid transformers has been reached with the existing volumes of firm generation. However, owing to the intermittent nature of that firm generation and the fact that there is up to 42/64MW

(summer/winter peak respectively) of demand behind the March Grid Constraint, by using ANM to manage generation output in response to demand, additional generation can be connected under FPP without breaching the reverse power flow limit on the transformers. To remove the March Grid Constraint, the reverse power flow limit would need to be increased by replacing the legacy protection system on one end, and later replacing the existing transformers with bigger capacity transformers. This could be done at an estimated cost of £3.2 million and would increase the reverse power limit by approximately 45MVA.

Figure 10: Simplified single line diagram of March Grid



4.3

Generation

There are a number of generators that are looking to connect that have been identified as potentially benefitting from an FPP connection that will be affected by the March Grid Constraint. These are set out in Table 3 below. Annex 1 provides a more detailed discussion of how each of these generators has been engaged and the extent to which they are committed as at the date of this report to the FPP project. These generators are used in the following analysis to demonstrate how the different commercial packages allocate curtailment. It is noted, however, that these generators are at differing stages of development.

Table 3: Identified generators who would be affected by the March Grid Constraint

Project	Capacity	Technology
Generator A	5MW	Wind
Generator B	2.5MW	Wind
Generator C	0.5MW	Wind
Generator D	1MW	Wind
Generator E	10MW	Wind
Generator F	16.4MW	Wind

4.4

Quantification of Curtailment

This report considers how curtailment is allocated across competing generators in response to network constraints. All curtailment forecasts have been generated by Smarter Grid Solutions using their network modelling tools based on input data and assumptions provided by UK Power Networks. Please see Annex 5 for a detailed breakdown of the methodology and assumptions employed. What is important to explain, however, is how levels of curtailment are quantified and compared in this report. In Sections 5 and 6, curtailment is discussed in terms of “percentage curtailment”. This is not meant to imply a percentage reduction on each generators uncurtailed output, but rather a percentage point reduction on their uncurtailed capacity factor. For example, 2% curtailment would mean a reduction in the annual capacity factor of the plant from 30% to 28%.



5

Rules of Curtailment

5.1

Background

As explained, the starting point for developing the smart commercial arrangements was that UK Power Networks will not be able to underwrite the level of curtailment that generators would actually experience through time. As such, the central component of the commercial proposals is the rules by which generators will be curtailed in the event that a constraint occurs – i.e. principles of access. A number of alternatives have been proposed in the past as the rules on which generators could be curtailed. Currie et al (2011)¹⁸ set these out as follows:

- **Last-In-First-Out (“LIFO”)** – the marginal curtailment caused by each new generator is targeted back onto that generator alone;
- **Pro-rata/shared** – curtailment is shared equally among all generators in proportion to their capacity and contribution to the constraint;
- **Market based** – generators bid their short run marginal cost and then are curtailed in the order of the least expensive first to minimise the aggregate cost of curtailment to resolve any given constraint;
- **Lowest carbon last** – generators are curtailed in order of carbon intensity with the generation units with the lowest emission levels curtailed last; and
- **Technically best/most convenient/largest first** – generators are curtailed on the basis of operational efficiency and/or reduced ANM sophistication.

This report considers two of these options – LIFO and pro-rata or shared curtailment. While a market based approach would arguably represent the economically most efficient option, and has been implemented with some success at transmission level¹⁹, this was not considered an option for the purposes of the FPP project owing to the implementation challenges of putting in place a real time bidding mechanism for such a small trial area.

Moreover, there were question marks over the level of competition within the FPP Trial zone, which risks exploitation of temporal market power. Lowest carbon benefit was also discounted on the basis that it was not considered the role of a DNO to make decisions of who to connect and curtail based on their carbon emissions, but rather the role of the government in setting the carbon price and subsidy levels of low carbon technologies. Moreover, all of the generators that UK Power Networks have engaged to date on the FPP project are low carbon generators; therefore, curtailing them on this basis would not provide an effective basis for differentiation. Finally, curtailing on the basis of optional efficiency and/or convenience lacked the predictability necessary for robust curtailment forecasting.

¹⁸ Currie, R., O’Neill, B., Foote, C., Gooding, A., Ferris, R. and Douglas, J. (2011) Commercial arrangements to facilitate active network management. Paper presented at 21st international conference on electricity distribution (CIRED).

¹⁹ Connect and Manage uses the Balancing Mechanism (“BM”) to offer compensation to curtailed generators in response to network constraints.

5.2

Options Considered

5.2.1 Last-In-First-Out (“LIFO”)

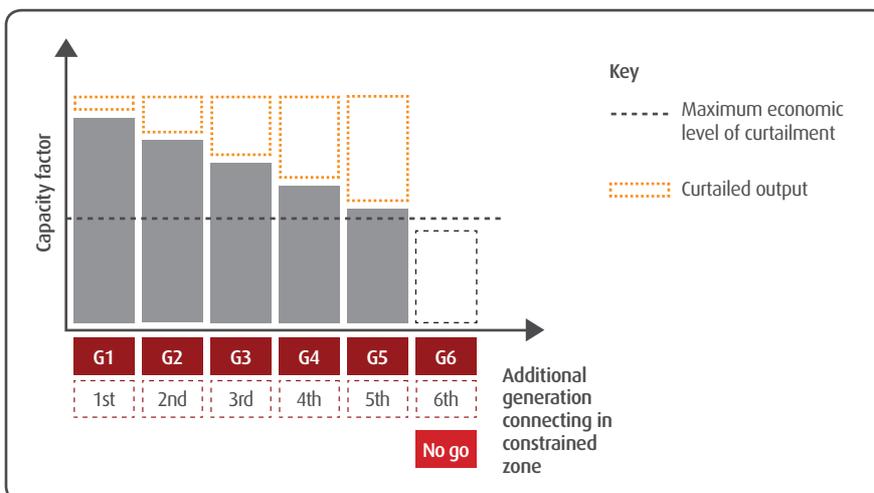
The only order of curtailment for actively managed distribution connected generators that has been demonstrated thus far in GB is LIFO²⁰. This order of curtailment allocates capacity on a first-come-first-served basis with generators connected and then curtailed in the order of which they applied for connection to the network (i.e. the LIFO “stack”). Figure 11 below sets out how LIFO works.

Under LIFO, the incremental curtailment triggered by each new generator that connects is targeted back onto that generator and that generator alone. For example, in the graph shown below, the connection of G5 will not impact the curtailment levels of the other 4 generators. Generators will continue to connect until such point as the forecast curtailment reaches a level at which either (a) it is more economic for that generator to connect under a firm connection or (b) it walks away as its project is no longer economic (i.e. its annual capacity factor after curtailment falls below the grey dotted line in Figure 11 below, which is the maximum level of economic curtailment) – i.e. G6.

5.2.2 Pro-Rata Curtailment

Pro-rata curtailment resolves constraints based upon each generator’s proportional contribution. As such, curtailment is shared equally amongst all generators that are exporting onto the network in the moment of the constraint. For example, if there are three wind generators with nameplate capacities of 4MW, 3MW and 1MW respectively feeding into a constrained location with a maximum capacity of 6MW, on a windy day when all of these generators are operating at their maximum, total generation capacity exceeds the available network capacity by 2MW. In the event that pro-rata curtailment is applied, the generators’ output would be curtailed by 0.25MW per 1MW of generation capacity (i.e. the 2MW of excess generation capacity divided by the total generation capacity of 8MW). As such, the first generator will have to be constrained by 1MW (4 x 0.25MW), the second generator by 0.75MW (3 x 0.25MW) and the last generator by 0.25MW (1 x 0.25MW) leaving curtailed capacities of 3MW, 2.25MW and 0.75MW respectively (which, in total, equals 6MW).

Figure 11: Last-In-First-Out



²⁰ SSE's Orkney Smart Grid Project, further information available at the following website - <http://www.ssep.co.uk/OrkneySmartGrid/KnowledgeSharingInfo/>

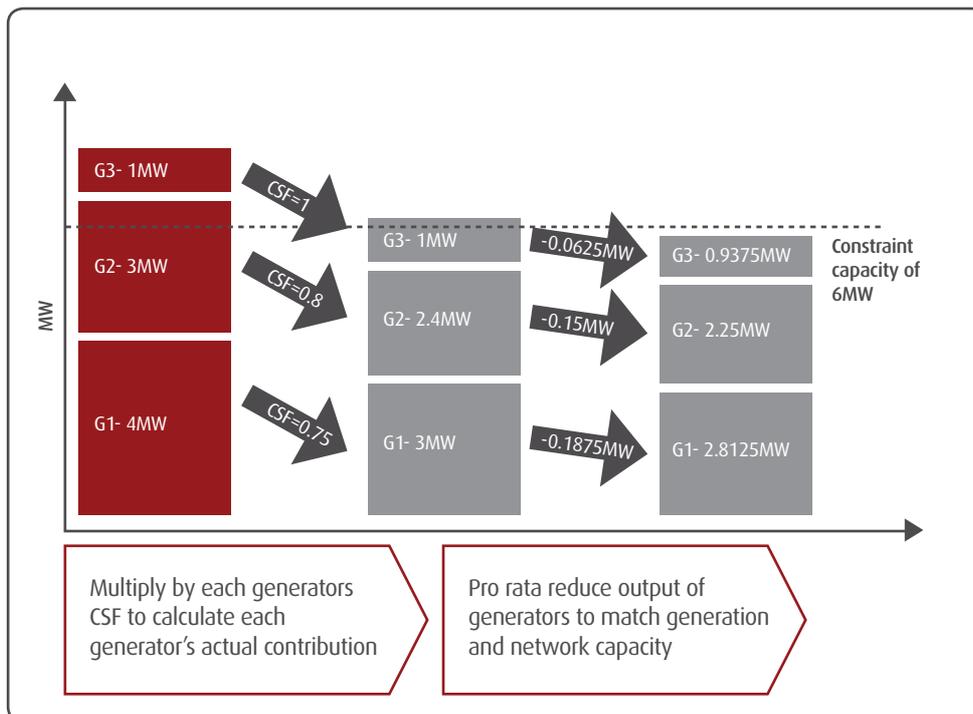
In reality, it is a little more complicated than this in a meshed network, since the sensitivity of a constraint to the output of different generators may differ depending on each generator’s location. This sensitivity is known as the “constraint sensitivity factor” or “CSF”. For example, where a 10MW generator has a CSF of 0.5, its effective contribution to any constraint is actually only 5MW (i.e. 10MW multiplied by its constraint sensitivity factor of 0.5). As such, if the generators considered above had CSFs of 0.75, 0.80 and 1 respectively, before applying pro-rata curtailment it is important to first calculate their actual contribution to the constraint. In this case it would be in total 6.4MW which broken down by generators is as follows:

- For the first generator - it would be 3MW (i.e. 4MW x CSF of 0.75);
- For the second generator - it would be 2.4MW (i.e. 3MW x CSF of 0.8); and

- For the third generator - it would be 1MW (i.e. 1MW x CSF of 1).

Hence, generation capacity only exceeds network capacity by 0.4MW (i.e. the total contribution to the constraint of 6.4MW less 6MW being the network capacity limit). The proportional reduction in capacity factors would therefore be the excess capacity divided by the total capacity contributing to that constraint (i.e. 0.4MW/6.4MW). This equals a reduction in capacity of 0.0625MW per 1MW contribution to the constraint. Reductions in output for each of the generators in the moment of the constraint will therefore be 0.1875MW for the first generator (i.e. 3MW x 0.0625), 0.15MW for the second generator (i.e. 2.4MW x 0.0625) and 0.0625MW for the third generator (i.e. 1MW x 0.0625). It is noted that the ANM scheme will automatically allocate curtailment in this manner. This set out in diagrammatic form in Figure 12 below:

Figure 12: Application of pro-rata curtailment with differing CSF



5.3

Appraisal of the Options

Pro-rata curtailment offers some considerable advantages over LIFO. While LIFO offers a simple, certain, tried and tested set of principles for allocating curtailment across competing generators, pro-rata curtailment could form the basis of a new commercial approach to drive (a) greater connection of renewable generators with the same infrastructure and (b) a more coordinated network build out. Pro-rata curtailment does, however, have one key weakness in that by exposing early generators to increased curtailment caused by later connectees, it would provide little certainty to generators that connect under FPP as to the long term level of curtailment. The relative advantages of these two bases of curtailment are considered in Sections 5.3.1 and 5.3.2, while Section 5.3.3 draws some conclusions and sets out some of the key design challenges facing an approach founded on pro-rata curtailment.²¹

5.3.1 Advantages of Pro-rata

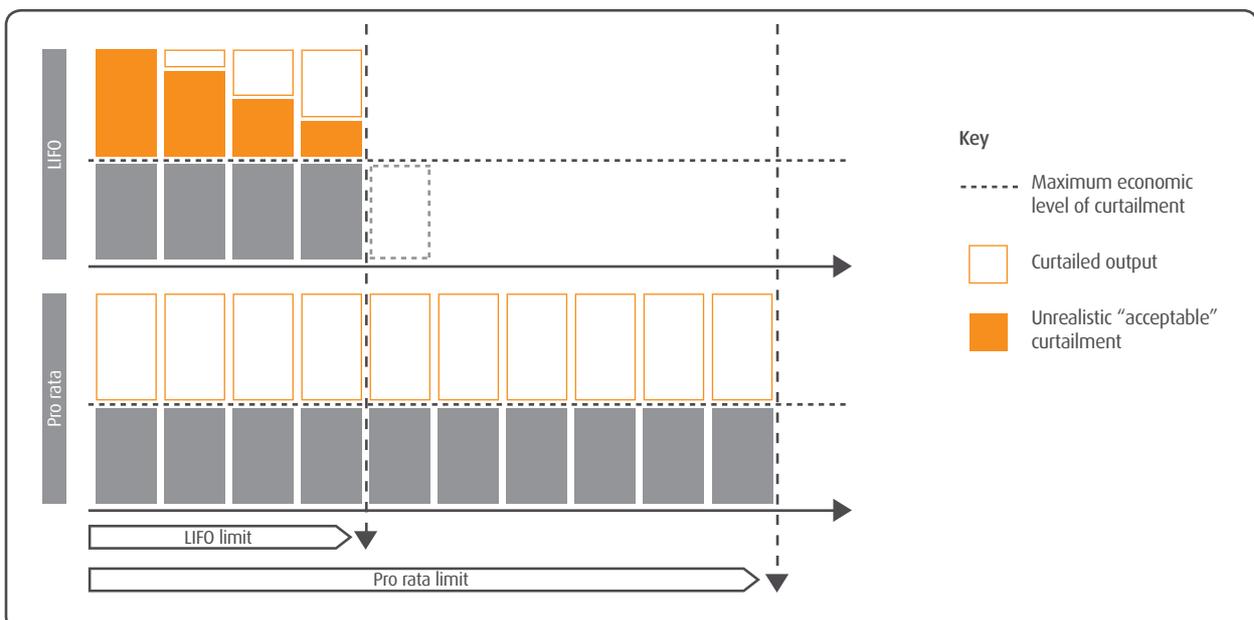
Network Utilisation

Using pro-rata curtailment should theoretically drive a greater amount of capacity connecting in a constrained location and therefore greater network utilisation (i.e. number of MWh

transported). Each generation project connecting under FPP will be receiving a cheaper connection offer than under the s16 firm connection approach. As such, FPP is based on the premise that each generator should theoretically be able to accept a level of “acceptable” curtailment before the cost of curtailment over the lifetime of the project outweighs the saving on its firm connection offer. The issue with LIFO is that by allocating curtailment on a marginal basis, earlier generators experience low levels of curtailment relative to later generators. As such, a portion of this acceptable “first loss” is not accessed by LIFO which results in a lower capacity of generation that can viable connect in any constrained zone. This dynamic is set out in Figure 13 below.

This principle is born out in the curtailment modelling of generation output in relation to the March Grid Constraint. Figure 14 overleaf plots curtailment levels (a) for the last generator to connect under LIFO (the red line) and (b) for each generator assuming that curtailment is shared across all generators (dotted line). As can be seen, assuming a minimum capacity factor of 27% (as shown by the purple line),

Figure 13: Lost curtailment potential



²¹ It is arguably less economically pure than LIFO since the marginal costs are not targeted to the marginal generator. However, given the overriding objective of promoting renewable generation and reducing carbon emissions from the power sector this is a lesser consideration.

sharing curtailment across all generators within a quota allows the connection of around 83% more generation in this constrained zone than if generators were curtailed based on LIFO.²²

Shared Risk

In the same way that pro-rata curtailment looks to share curtailment across all generators, it also shares the downside risk. While LIFO targets the curtailment risk onto the last generator, sharing that margin for error across a number of

generators can have the effect of de-risking the effect of curtailment forecast error for all generators. This is supported by the curtailment modelling for generators subject to the March Grid Constraint. Figure 15 shows the variation in curtailment for the last block of 5MW that connect. As can be seen, that variability increases for the last block under LIFO vs. pro-rata as under LIFO it will experience the risk associated with the variability of the block itself and the variation of the blocks already connected to the network.

Figure 14: Curtailed capacity factors under LIFO vs. Pro-Rata

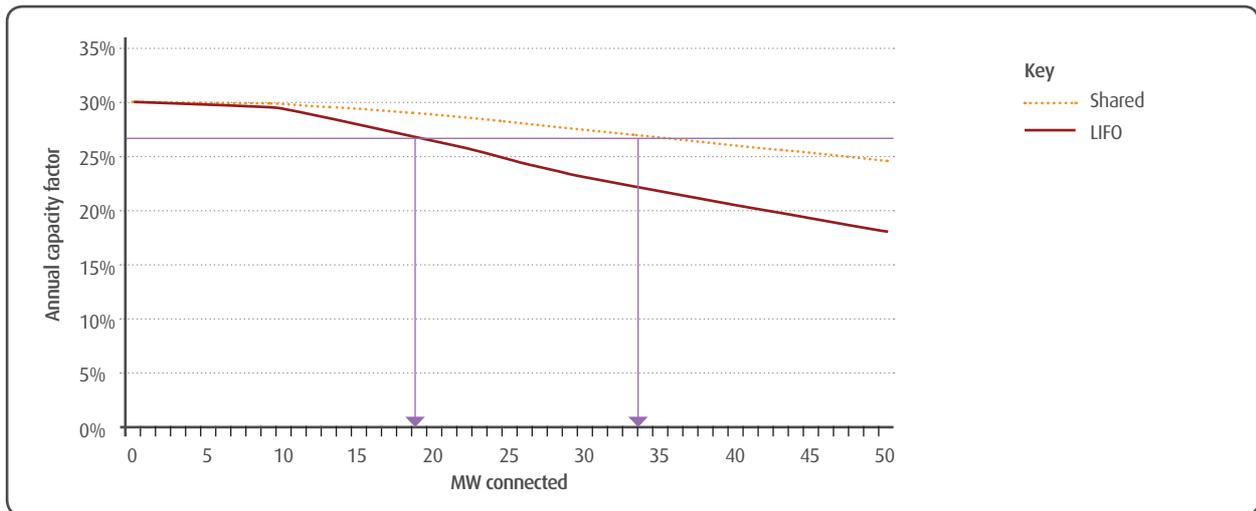
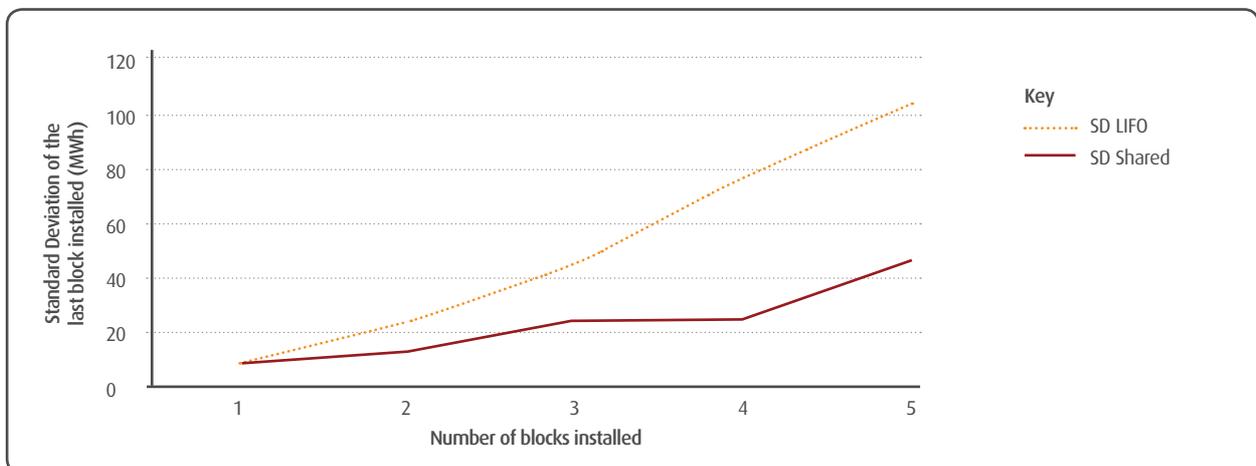


Figure 15: Standard Deviation of the energy curtailed for the last generator (5MW) connecting to the network, Pro-rata vs. LIFO



²² It is noted that Figure 14 is based upon an analysis which assumes that all generators are wind farms with an uncurtailed annual capacity factor of 30%, which is typical for the Cambridgeshire region.

Capacity allocation

Up to this point, it has been assumed that the initial capex savings available on connection costs from connecting under FPP vs. connecting under an s16 firm connection are the same for all generators. In reality, however, the savings may differ depending on where each generator is located and the specific works considered for their connections. In this way, not only does LIFO potentially result in lower volumes of viable generation capacity, by connecting and curtailing on a first-come-first serve basis there is the potential to allocate the spare capacity released by FPP in a sub-optimal manner. As the level of curtailment is dependent on the order in the stack, LIFO is not able to differentiate between truly marginal projects and those that could potentially finance their project with an s16 firm connection agreement.

For example, if we consider two generators:

- **Generator A** is the first to apply for a connection. It is located in a position that makes an s16 firm connection, at an upfront cost of £1 million, a viable option for its project. However, an FPP connection offer is also attractive with a £500,000 million saving relative to its s16 firm connection offer in return for only low levels of projected curtailment (i.e. under 1%), since it is first in the LIFO stack.
- **Generator B** is second to apply for a connection offer. It receives a firm connection offer of £3 million which it cannot accept as its project cannot support such an expensive connection charge. It also receives an FPP connection offer of £500,000 and projected curtailment levels of 3% since it is second in the LIFO stack.

Generator A is not a “marginal” project as it could have financed its project with the s16 firm connection offer. However, it accepted the FPP connection as it offered levels of curtailment that were low enough to outweigh the premium required to connect firm. However, by accepting its FPP offer and using up the early “headroom”, Generator A effectively

blocks Generator B as it does not have the luxury of an acceptable firm connection offer and curtailment levels of 3% are too high to be viable. As such, LIFO would allocate capacity to Generator A rather than Generator B, notwithstanding the fact that Generator A would have developed its project with or without FPP. Pro-rata curtailment avoids this problem, because all generators subject to a constraint are required to accept the same or similar levels of curtailment.

Driving a coordinated network build-out

One of the key advantages of ANM schemes is that it potentially allows a more coordinated connection approach to be taken to groups of generation projects which connect at different points in time, without the associated stranding risk associated with investment ahead of need. If we take the March Grid Constraint as an example, as explained in Section 4, connection to the 11kV and 33kV networks would trigger the replacement of the March Grid transformers at a cost of approximately £3.2 million, which for one generator alone would be too expensive. Moreover, the transformer upgrade would add up to 45MVA of additional reverse power flow capacity which for any generator below this capacity would therefore involve considerable over-sizing. As such, the cheaper option for any one generator would be to offer them a connection either to another part of the network or to the EHV network above the reverse power flow constraint on the March Grid transformers. These are still expensive. However, relative to shouldering the full cost of the transformer upgrade, they do represent the “minimum scheme” as specified in the charging methodology²³.

By allowing connection under FPP, however, generators can instead connect to 11kV and 33kV networks for a relatively low upfront cost and accept a level of curtailment as their output is managed against the March Grid Constraint. Then, if enough capacity connects under FPP there could come a point where sufficient capacity has connected such that

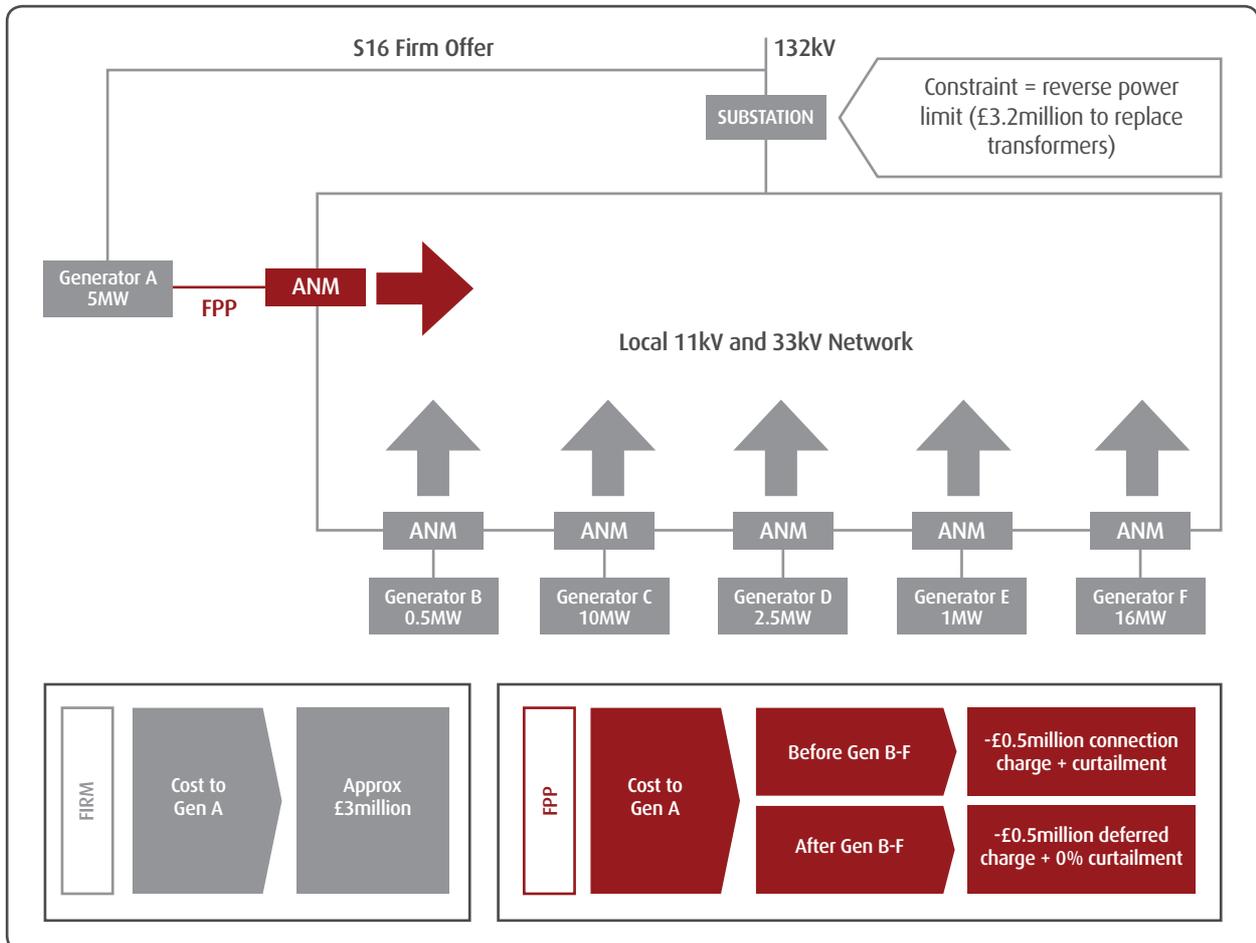
²³ See paragraph 5.1 of the Common Connection Charging Methodology for a precise definition of the minimum scheme.

the shared cost of the transformer upgrade is a viable proposition for generators. This dynamic is demonstrated in Figure 16 below.

This however relies upon the generators themselves choosing to reinforce instead of accepting curtailment. The key issue with LIFO is that each generator would be experiencing different amounts of curtailment and therefore would appraise the value of reinforcing the network differently. As such, in a scenario where the most efficient option overall would be to pay for the reinforcement (i.e. Net

Present Value (“NPV”) of the lost revenues from aggregate curtailment of all ANM generators is greater than the cost of the local reinforcement), this action may not be taken due to the asymmetric allocation of the curtailment across the generators in any constrained location. A commercial approach based on pro-rata curtailment, by contrast, would look to spread the cost of curtailment equally among all generators subject to the same constraint. As such, when trading off the incremental cost of reinforcement against the reduction in curtailment experienced, generators would be in the same position, or at least relatively similar position,

Figure 16: Coordinated vs. incremental network reinforcement



making it easier to build a consensus to take the decision to pay for that reinforcement action.

Fairness

It is important that any spare capacity released by the FPP project is allocated in a fair and equitable manner. It might be arguable that LIFO satisfies that criteria as the principle of allocating capacity to the first comer is tried and tested, and has been widely applied in the industry²⁴. In this way, when benchmarked against the “industry norm” of first-come-first-served, LIFO can be viewed a fair and widely accepted approach. However, it is equally arguable that a generator who connects under FPP and receives a discounted connection offer should not take a windfall benefit by virtue of an accident of timing. Moreover, concentrating all curtailment and risk onto later generators might be viewed as discriminatory. Indeed, UK Power Networks would be acting squarely within its regulatory mandate to develop “an efficient and coordinated network” by looking to develop a set of commercial arrangements that drives maximum network utilisation and allocates capacity on a fair and transparent basis. As demonstrated in the section on network efficiency, there is clear evidence that pro-rata curtailment could potentially drive considerable efficiencies than allocating capacity based on LIFO.

Learning

As noted above, LIFO was used on an ANM scheme implemented on Orkney by SSE (Scottish and Southern Energy) as part of a Registered Power Zone (“RPZ”) project launched in 2005²⁵. This project has connected 20MW of additional generation without triggering expensive traditional reinforcement solutions²⁶. As part of the stakeholder engagement process²⁷, the FPP team interviewed the Orkney smart grid team and have gained valuable insight into the key learning points that have emerged from trialling ANM generally, and LIFO in particular,

on that project.²⁸ Indeed, these lessons have profoundly affected the commercial design team’s emerging thinking on the appropriate commercial package for FPP.

However, one of the disadvantages of choosing to implement a commercial package based off LIFO on FPP would be that it would create little additional learning over and above what has already been gained through the Orkney project. As such, pursuing an alternative commercial solution based on pro-rata curtailment would allow the FPP project to explore different commercial solutions to those already tried and tested on other innovation projects. Indeed, one of the key challenges of the FPP commercial workstream is to try and harness the advantages of a pro-rata approach while at the same time providing generators with a simple, credible and certain set of principles on which it and other FPP generators will be connected and curtailed.

5.3.2 Advantages of LIFO

Certainty

As explained in Section 3.3, with all curtailment risk left with the generator, the key consideration for each developer looking at whether to connect under FPP will be the level of confidence it can place in curtailment forecasts at the point that it makes its investment decision. Any design feature of the commercial and technical arrangements that introduces greater uncertainty will make it more difficult for generators to “bank” their connection agreement, and thereby threatens the success of the FPP project as a whole.

LIFO is the default choice for DNOs when it comes to allocating curtailment in actively managed scenarios because it is the only order of curtailment that fully protects generators who have already connected against the impact of increased aggregate curtailment triggered by the connection of new generation

²⁴ Both on a s16 firm basis and with other ANM schemes (i.e. LIFO was used on an ANM scheme implemented on Orkney by SSE as part of a Registered Power Zone (“RPZ”) project.)

²⁵ The Registered Power Zone (“RPZ”) scheme was the pre-cursor to the LCNF that covered innovation projects under DPCR 4.

²⁶ Indeed, the total capex of the scheme was £500,000 compared with a £30 million capex requirement to reinforce the subsea inter-link with mainland Scotland.

²⁷ GL Garrad Hassan (2012), Flexible Plug and Play, Workstream 5 - Stakeholder Engagement Report

²⁸ Dr. Karim L. Anaya, Dr. Michael G. Pollitt (2012), Experience of the use of smarter connection arrangements for distributed wind generation facilities – Sections 4.1 and 4.2.

at a later date. It does this by targeting this incremental curtailment back onto that newly connected generator alone (as further described in Section 5.2.1). In this way, for each new generator that is deciding whether to connect under LIFO, its curtailment forecasts will not be dependent on the credibility of assumptions about future generation projects that connect after it because by definition, they should have no impact. Broadly speaking, therefore, it only needs to concern itself with the credibility of the assumptions in relation to the other key drivers of constraint already highlighted in Figure 8 of Section 2 – namely:

- the output of ANM controlled generators that have already connected (or are due to connect in the future and are higher in the LIFO stack);
- growth of micro generators too small to be included in the ANM scheme;
- likely demand profile;
- temperature and weather patterns; and
- network topology, network conditions and network reliability.

Using an approach based on pro-rata curtailment, in contrast to LIFO, does expose existing ANM controlled generators to greater levels of curtailment triggered by the connection of later generation projects. Indeed, the more generation that connects in a constrained zone, the greater curtailment. With no way of knowing what level of generation that will connect, generators are left with no certainty as to the worst case impact

that curtailment as a result of existing network constraints will have on their project. While each generator may be able to take comfort from the fact that later generators that connect will also have to be comfortable with the level of curtailment that they drive across the group, if later generators are less sensitive to curtailment (e.g. due to being a different technology or subject to a different subsidy regime), they could potentially impose these higher (intolerable) levels on earlier generators. As such, without further assurances as to the level of generation output and/or the long term level of curtailment, pro-rata curtailment without some form of limit on the amount of generation that can connect subject to the same constraint is not a bankable proposition for the connection of generation projects under FPP.

Simplicity

LIFO has the undoubted advantage of being both simple to implement and understand. It is self-regulating with UK Power Networks only responsible for setting out the rules, providing forecasts and allowing the generators themselves to make the decision as to whether to connect. It thereby presents the most “hands off” approach for UK Power Networks. Curtailment forecasting under LIFO also involves fewer assumptions and fewer interdependencies between generators. As it is not making any assumptions in relation to future connections, each generator can be considered in isolation when looking at its impact on the network at a given time.

5.4

Conclusions

LIFO has the undoubted advantage of offering a simple, credible and most importantly, relatively certain set of rules for connecting and curtailing generators in an actively managed scenario. Pro-rata, on the other hand, offers the chance to develop a fresh commercial approach that could potentially drive greater capacity of generation connecting to the same infrastructure as well as a more coordinated local network build out to accommodate new volumes of DG. As such, the commercial packages in this paper are built around pro-rata approaches to curtailment allocation.

However, as described in Section 5.3, the challenge facing a commercial proposal founded on pro-rata curtailment principle is to build in sufficient long term certainty as to the worst case curtailment levels while at the same time avoiding unnecessary additional complexity. Section 6 explores a number of different approaches that look to do just that.

6

Commercial Packages - Pro-Rata

6,909.00
8,045.00
1,315.00
615.00
6,000.00

6,909.00	8,045.00	1,315.00	615.00	6,000.00
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6.1

The Challenge

As explained in Section 5.4, a commercial package founded on the principle of pro-rata curtailment has to overcome one key challenge – the lack of certainty over the likely long term impact of the connection of future generation. The only way that this can be solved, short of UK Power Networks underwriting curtailment risk (which has not been considered – see Section 3.3 and Annex 3), is for UK Power Networks to give each generator certainty and/or visibility, at the time that it accepts its FPP connection offer, as to the maximum capacity of additional generation with which that generator will share curtailment. In this way, each of the four options set out have at their core the need to provide this certainty to generators while at the same time attempting to maintain the efficiency benefits described in Section 5.3.1.

6.2

Option 1 - Vintaging

6.2.1 Description

Under this option, generators would be grouped into “time vintages” by reference to the period of time, or “time gate”, in which they applied for connection. For example, as shown in Figure 17 below, generators that applied for connection before March 2013 would be allocated to Vintage 1, those between March and September 2013 to Vintage 2 and finally those between September 2013 and March 2014 to Vintage 3. In resolving any constraint, all generators in Vintage 3 would be curtailed first, with curtailment applied pro-rata across all generators in that vintage. The generators allocated to Vintage 2 would only be curtailed in the event that the output of all the generators in Vintage 3 had been curtailed to zero (and so on). In this way, curtailment would be applied pro-rata within vintages; and LIFO between vintages. Figure 17 sets this out in more detail.

6.2.2 Application

If we applied Vintaging in respect of the generators that have applied to connect behind the March Grid Constraint described in section 4, and assume that the time gate for the first vintage was the 1 March 2013, then we are left with a potential

vintage of 34.6MW. As such, assuming that these developers connect in the order set out in Table 3 of Section 4.3, curtailment of generators within that vintage would progress as show in Figure 18.

Any further generation that intends to connect and feed into the March Grid Constraint, would be curtailed in before these six generators and as such, assuming that they all connect as envisaged, the worst case curtailment that each generator could expect to experience in this first vintage of 35.4MW is around 3.2% (approximately 287MWh/year/MW of generation capacity connected). Of course, if for any reason any one of these projects fails to connect as envisaged (e.g. because of planning refusal, inability to secure financing, procurement issues etc.), then the vintage will in effect shrink thereby reducing overall shared curtailment level for the group as a whole.

6.2.3 Appraisal

Vintaging is broadly based upon the LIFO principle and therefore shares many of its advantages in terms of certainty

Figure 17: Vintaging

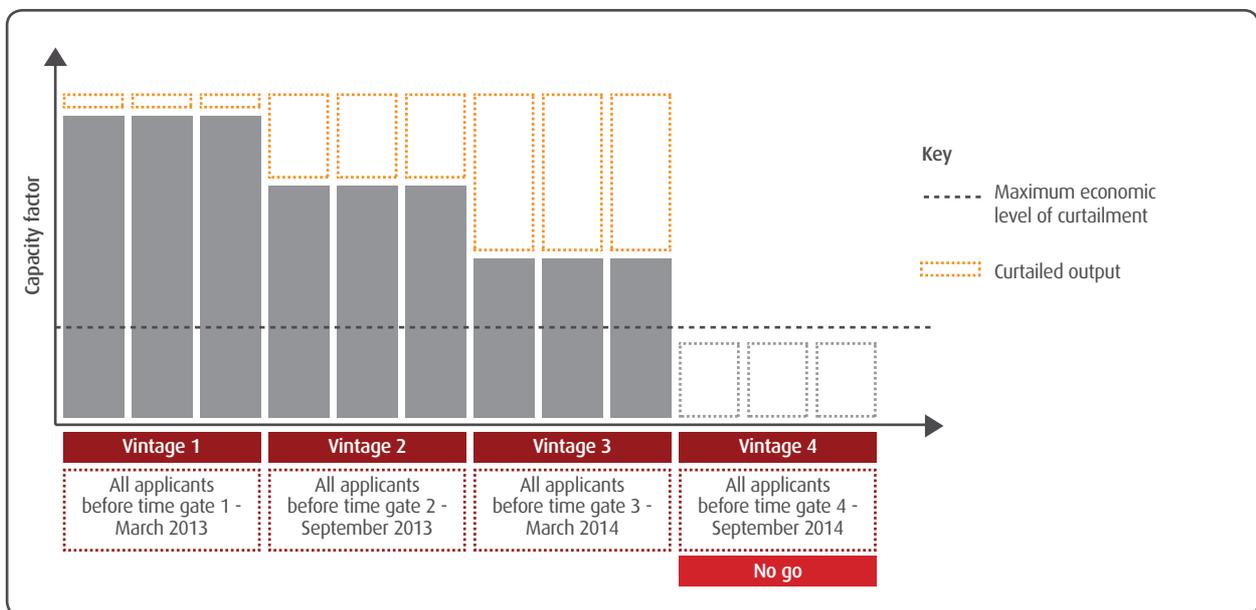
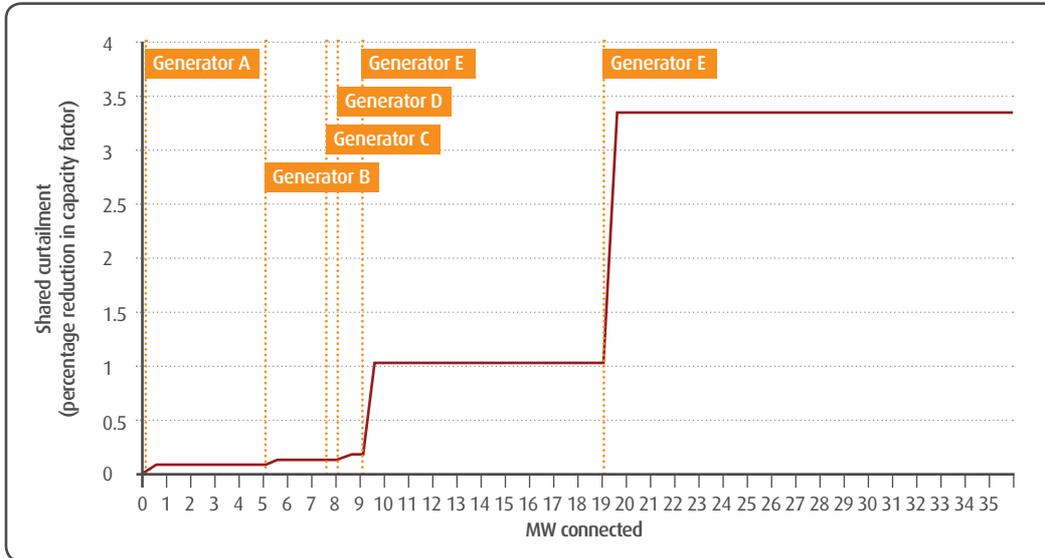


Figure 18: Estimated curtailment (in percentage points) for the first vintage at the March Grid Constraint



and simplicity. As with LIFO, generators connecting in any vintage will know the characteristics and total capacity of the generators in each current vintage and any vintage that is higher in priority. Furthermore, by collecting generators based on time gates, vintaging potentially offers a simple and easily implementable way of using pro-rata curtailment. There are, however, a number of drawbacks that are highlighted below.

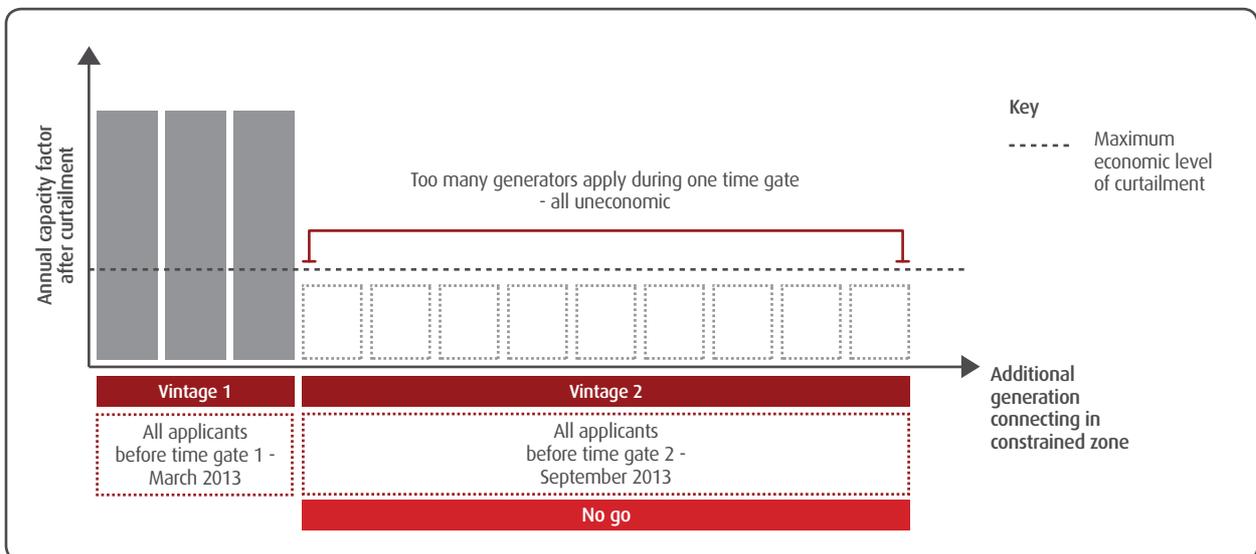
Dealing with oversubscription

Vintaging could potentially put UK Power Networks in a difficult position due to the problem of “overshooting”. This might occur in the event that too many applicants apply in

one time gate such that aggregate curtailment for that vintage as a whole falls below a level which is financially feasible for any or all the projects. Figure 19 represents the problem of having too many generators connecting within a given vintage.

This problem could be solved in one of two ways. One option would be to not connect any of the generators in that vintage (which would result in a loss of efficiency in utilising the network). Alternatively, UK Power Networks could cull generators off the back of the vintage (i.e. the latest applicants) until the vintage was of a capacity that returned curtailment forecasts that were tolerable to generators. This could however

Figure 19: “Overshooting” with vintaging



create significant problems for UK Power Networks as it would have a cohort of generators expecting to be able to connect. Deciding on the maximum capacity against the expectations of a group of generators would be extremely difficult, as each generator would have a different view on what is an acceptable level of curtailment. This would be challenging to implement in a consistent and fair manner and could therefore increase the risk of challenge by a disgruntled generator.

Underperformance with under-subscription

Pro-rata curtailment does not reduce the aggregate amount of curtailment required to resolve a constraint relative to LIFO, it just allocates it in a different manner such that theoretically a greater capacity of generation could viably connect in a particular constrained zone (see Figure 14). As such, where a vintage closes, curtailment for the first generator to connect in the next vintage returns to the level one would expect under LIFO. This can be seen from Figure 20 below. The light blue line shows pro-rata curtailment with an unlimited vintage size, while the dark blue line shows the marginal curtailment under LIFO. As can be seen, for each different sized vintage,

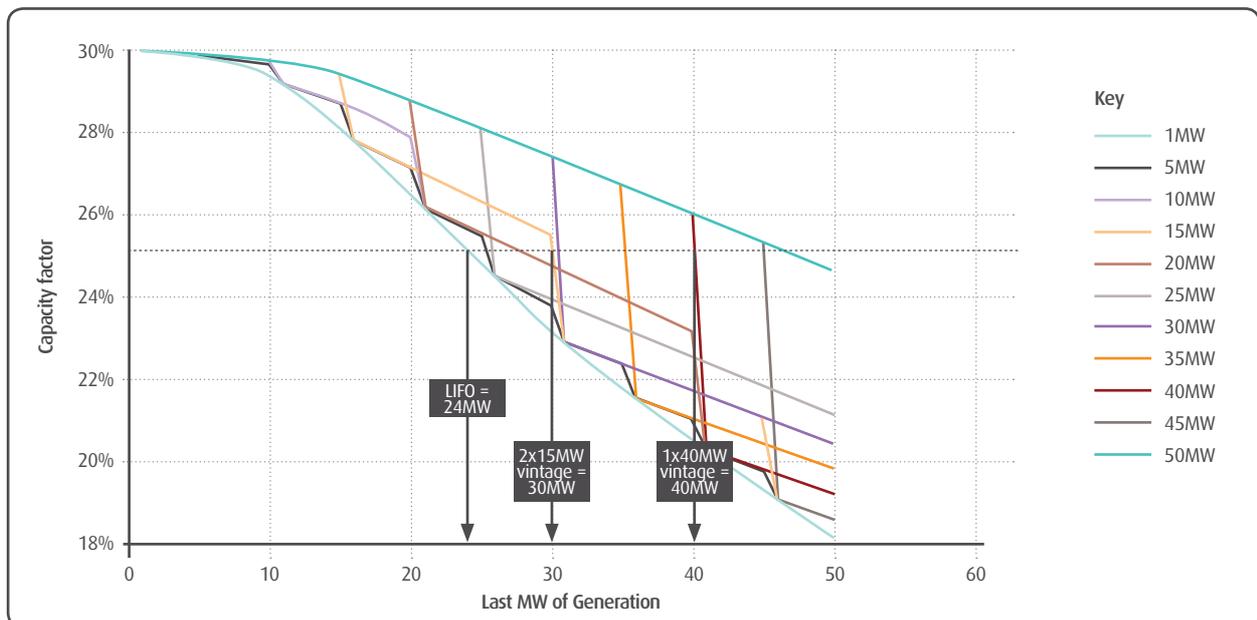
average curtailed capacity factor stays above the marginal LIFO curve until the vintage closes and a new one starts at which point the curtailment capacity factor for the next generator to connect return to what they would have been under LIFO.

As such, the only circumstance when vintaging outperforms LIFO in terms of the capacity that will connect is when the next generator to connect on the closure of the vintage experiences curtailment levels result in a curtailed capacity factor less than the theoretical minimum viable annual output. As the size of each vintage is simply a function of which applications are received in a given time period, the extent to which it actually out performs LIFO is a function of chance. Moreover, with greater numbers of vintages, the variation in curtailment cost across all generators increases making the building of a reinforcement consensus more difficult.

“Attrition” reduces efficiency

The final issue with vintaging is “attrition”. If one generator in a vintage fails to deliver its project, then in effect the MW connected within each vintage will shrink by an amount

Figure 20: Curtailment forecast under LIFO vs. Vintaging²⁹



²⁹ Note that Figure 20 assumes that all generators are wind farms with uncurtailed capacity factors of 30%.

equal to that generator's capacity. While this will benefit other generators in the vintage, it will reduce the efficiency overall as that "slot" in the vintage cannot be kept open to be filled with another generator as later generators will be allocated to a later vintage and curtailed first.

6.2.4 Overview

Table 4 below summarises the performance of this option against the criteria set out in Section 3. Note that a score of 5 indicates that the option fully satisfies that criterion, while a score of 1 indicates that the option fails to satisfy that criterion.

Table 4: Overview and scoring of Vintaging against the criteria of assessment

Criteria	Score	Explanation
Efficiency	2	The extent of the potential to utilise existing capacity in a particular constrained zone efficiently prior to any reinforcement offered by pro-rata curtailment is a function of the volume of generation that applies in each time gate. This will be out of the control of each individual generator and UK Power Networks. Moreover, with generator attrition, the size of a vintage could be reduced over time without the ability to re-allocate this capacity. Finally, with multiple vintages, there will be increasing asymmetry in the distribution of curtailment costs making efficient reinforcement decisions by generators unlikely.
Certainty	2 - 4	Once a vintage is closed, vintaging is on a par with LIFO in terms of certainty on the grounds that forecasts will be generated against a known group of generators (i.e. technology type, likely capacity factor, CSF). However, if "time gates" were a significant period apart then this could reduce short certainty for early generators as they would be left in limbo with no visibility on the viability of their network connection until the time gate has closed.
Simplicity	3	UK Power Networks would not be required to make any judgement call on tolerable levels of curtailment. UK Power Networks simply sets the rules and provides forecasts. Having said that, solving "overshooting" could increase complexity.
Fairness	2	While it involves pro-rata curtailment, it still does not move significantly away from the principle of first-come-first-served. Further, managing generator expectations where vintage is over-subscribed could create additional risk of challenge.
Learning	3	Vintaging has been proposed in Ireland for transmission connections, but would be a new approach in the distribution context. Nevertheless, while vintaging involves pro-rata curtailment, it still does not move significantly away from the principle of first-come-first-served upon which LIFO is based.

6.3

Option 2 - Capacity Quota

6.3.1 Description

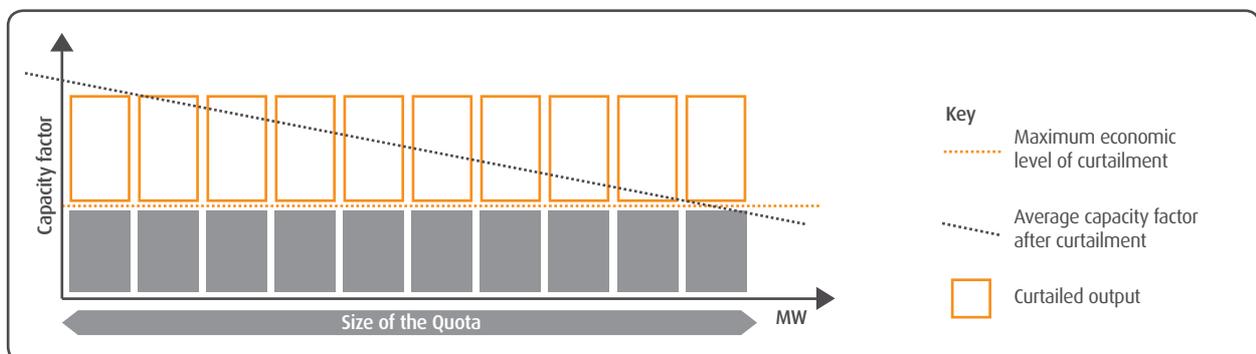
The material limitation of vintaging is that UK Power Networks is not in a position to manage the amount of generation that applies for connection in a given time gate. For example, if too much generation looks to connect, curtailment levels could be too high, while if too few generators apply to connect (or if generators book a spot in a vintage but fail to build out their projects), a vintage could return relatively low levels of curtailment well below what the generators could have withstood given their saving on the connection cost. Thus connections of future generators may be delayed until reinforcement. As such, an alternative approach would be to define up-front the fixed capacity of generation that could connect and be curtailed pro-rata – termed in this paper a “**capacity quota**”. Any generator that wants to connect once this capacity quota has been filled would then be curtailed in before those generators that have been allocated to the capacity quota.

The question, therefore, is how to set the level of the quota. One way would be set at a level such that, once the quota is full, curtailment levels will not breach “acceptable levels”.

UK Power Networks would therefore need to carry out the following analysis:

- First, UK Power Networks would need to decide the maximum level of curtailment any generator could potentially withstand or would be prepared to accept (i.e. the maximum level of economic curtailment). This would involve UK Power Networks making some reasonable assumptions about the internal economics of the generation projects likely to connect in a given constrained zone, including construction and operating costs, electricity revenue and subsidy level and connection costs.
- Second, UK Power Networks would need to model pro-rata curtailment with increasing amounts of generation connecting in that particular constrained zone.
- Finally, UK Power Networks would set the size of the quota at the capacity of generation connected in a constrained zone that results in shared curtailment levels equal to or slightly less than the maximum level of economic curtailment determined in the first step. This process is set out in Figure 21 below.

Figure 21: Determining the size of a capacity quota



Once the capacity quota has been set for a particular constrained zone, any generator applying to connect in that constrained zone would then be provided with two curtailment forecasts:

- The first would be a curtailment forecast based on the capacity of generation already connected in that constrained zone.
- The second would be a worst case curtailment forecast which assumes that the limit of generation capacity for a particular quota actually connects in that constrained zone.

Prior to accepting its FPP connection offer and in advance of financial investment decision on construction of the generation project, each developer would have to conduct its own technical due diligence on the assumptions and methodologies underpinning these forecasts to get itself comfortable that (a) they represent a realistic projection of future curtailment levels and (b) that its project is still viable under the maximum curtailment forecast (i.e. in a scenario where all generation capacity of a quota connects as envisaged) or its return would not be better if it opted to pay for the more expensive firm connection offer.

6.3.2 Application

As explained in Section 6.3.1, setting a quota would essentially involve two key steps. These are as follows:

- First, UK Power Networks needs to determine what level of curtailment it considers should be reasonable to impose on generation projects that are to connect in the quota – the maximum level of tolerable curtailment;
- Once the curtailment limit has been determined, UK Power Networks can then set the quota by reference to the anticipated levels of curtailment at increasing levels of generation output – the capacity cap.

It is important to note, however, that it would be the capacity cap, not the maximum curtailment level, that would characterise UK Power Networks' obligations to generators under the FPP connection agreement. By way of illustrating how this would be applied in practice, each of these two steps are set out below using the March Grid Constraint as a case study.

Step 1 - Determining the "Curtailment Cap"

Conceptually, the maximum curtailment that any generator will tolerate under an FPP connection agreement will be the lesser of:

- the maximum curtailment before the relevant project fails to meet a minimum level of financial viability (e.g. a target internal rate of return ("IRR")); and
- the maximum curtailment before the project fails to meet the rate of return that the project would expect to have returned had it paid for an s16 firm connection.

As the capacity quota is based upon the premise that it can be set in isolation from the actual generators that are looking to connect in that particular moment in time, it is important that UK Power Networks looks at the sensitivity of different "generic" generator types to the curtailment. This will be a function of a number of factors, namely, technology type (i.e. driving capex and opex costs as well as likely capacity factors), subsidy regime that a generator falls within (driving revenue loss as a result of curtailment) and the extent of the cost savings from the non-firm connection. In view of this potential variation, and to ensure that the capacity quota approach can be a truly generic methodology that does not unfairly favour one technology type over another, the modelling approach used looks to model a wide spectrum of generator types. These are set out in Table 5 overleaf.

Figure 22 below sets out the results of the analysis of the maximum level of curtailment for different generator types. This graph shows how the level of curtailment for different generator types varies depending on the extent of the savings on the FPP connection. As such, connection charge savings are simply equated with lost revenue over the life time of the project. It is worth noting that this takes into account only the saving in connection cost, and does not consider the overall level of financial return. Nevertheless, interestingly the actual gradients of these relationships do not vary significantly between technologies.

On this chart we have illustrated a range of potential savings in connection costs under FPP. These are taken from real projects and suggest a range from £77/kW to as high as £3000/kW. This

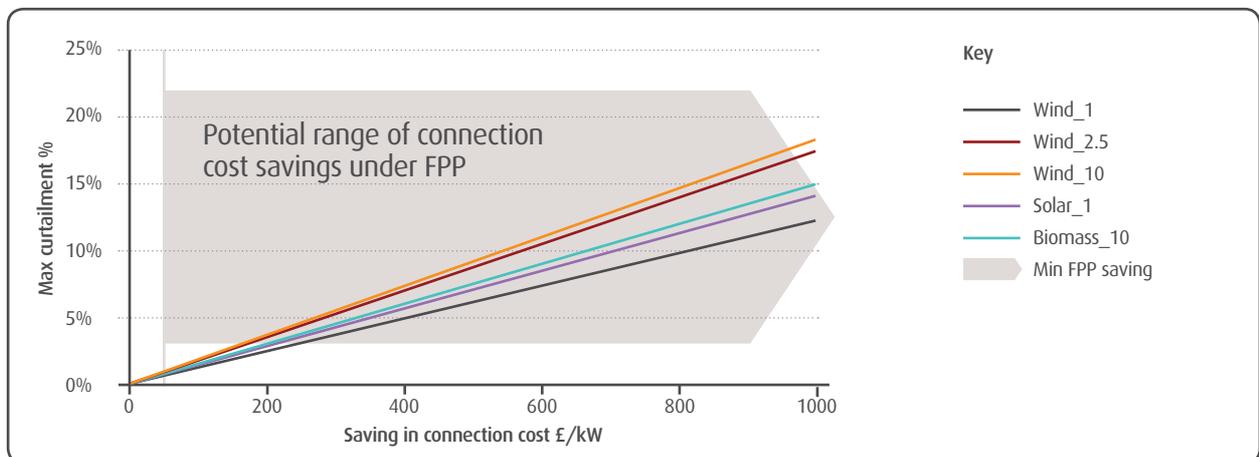
wide range in connection cost savings translates into a wide range of potential maximum curtailment levels. Specifying a single maximum curtailment level would require a choice on the assumption of FPP connection cost saving. For example if we took the minimum saving of £77/kW, the maximum curtailment would be between 0.9% and 1.1% (depending on technology type). At the other end of scale, there are very large connection cost savings where the firm connection offer is very high. This suggests a high level of curtailment is acceptable in return for large saving in connection costs. However this does not recognise that the overall return on the project is unlikely to meet the required hurdle rate.

We have therefore considered the maximum curtailment achievable for each generator type for a post-tax real hurdle

Table 5: Key generator assumptions

Type	Capacity (MW)	Capacity factor	Subsidy regime
Wind_1	1	30%	Small Scale FIT
Wind_2.5	2.5	30%	Renewables Obligation
Wind_10	10	30%	Renewables Obligation
Solar_1	1	15%	Small Scale FIT
Biomass_10	10	100%	Renewables Obligation

Figure 22: The relationship between maximum curtailment and FPP savings



rate of 10%. Figure 23 below sets out the results of the analysis. It is assumed that the FPP connection costs for all generators will be £114/kW, which is the median value of the indicative FPP connection cost data for generators that could potentially connect at March Grid. As can be seen, the maximum curtailment varies significantly between generator types. The range is large, from about 13% for a generic 10MW biomass project to less than 2% for a 1MW solar project.

It should be noted, however, that the analysis above is based on central assumptions. The maximum curtailment

assumption is very sensitive to input assumptions driving the project return. These include:

- Capital cost
- Capacity factor
- Required rate of return/capital structure

By way of an example, Figure 24 shows the impact of capital cost sensitivities on the maximum curtailment. Further details of the derivation of High, Median and Low capital costs can be found in Annex 4. In the high capital cost sensitivity scenario,

Figure 23: Maximum acceptable curtailment under a 10% post tax real return for different generator types

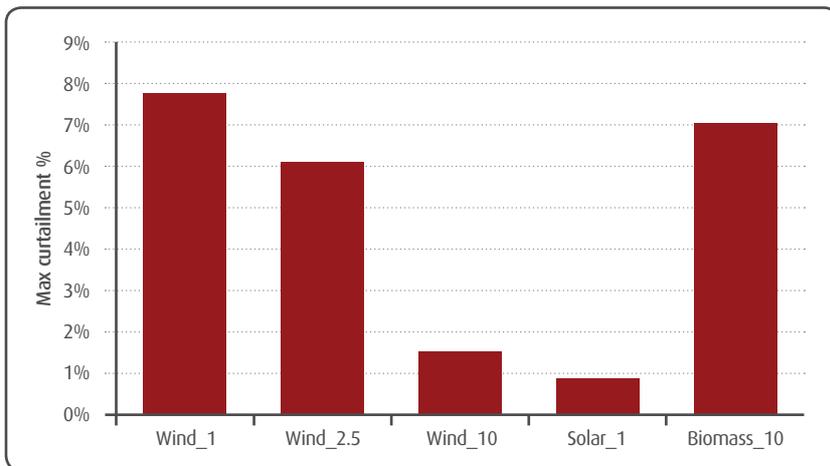
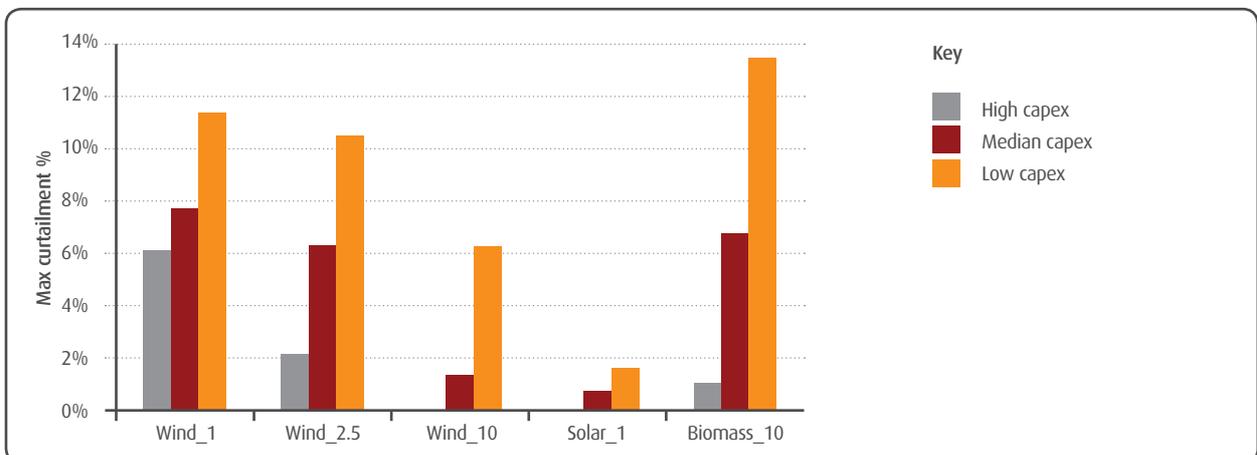


Figure 24: Maximum curtailment sensitivity to capital cost



some project types (like the 1MW solar plant) do not meet their project return of 10% and therefore cannot bear any level of curtailment.

Further details of the methodologies, assumptions and sensitivities for the generator financial modelling are provided in Annex 4. It is clear that there is considerable variation in the level of curtailment that generators could theoretically withstand. As such, UK Power Networks would need to decide whether in setting the quota it intended to include all generator types or whether it would be possible to justify excluding those generator types which are particularly sensitive to curtailment. UK Power Networks would also need to take views on the likely range of project returns, capital costs and capacity factors for real projects.

Step 2 - Setting the "Capacity Cap"

Assuming that a "maximum curtailment cap" could be determined, UK Power Networks would then need to decide on the maximum capacity that will return that level of curtailment. Again, not knowing the nature of the generators that might connect in the quota creates issues. This is because a given capacity of generation could return very different levels of curtailment depending on the nature of the generation that connects in that quota. The most material of these characteristics, which will not be known upfront, is the generation mix itself. The nature of the generation mix could impact curtailment levels in the following interrelated ways:

- **Correlation of output** - If all the generation that connects in a quota is wind, generation output is likely to be highly correlated and therefore curtailment will be higher than if the quota was filled with an even mix of, for example, wind and solar (whose output would be less correlated).
- **Capacity factor** - The higher the capacity factor, the greater the energy output of each MW that connects in any constrained zone and therefore the greater the probability

that a constraint will be triggered. While capacity factor could be driven by location (i.e. a particularly windy site), it could also be driven by technology, with wind farms averaging just under 30%, solar performing at around 12-15%, while biomass or any other thermal generator normally looking for an availability approaching a capacity factor of 100%.

It is useful to demonstrate the nature of this uncertainty with an example. If Generator A, a wind generator, is looking to connect and feed into the March Grid Constraint, UK Power Networks could choose to set the quota assuming that all the generation that will fill this quota will be wind generation. This would not be an unreasonable assumption given the pipeline of projects at present are all wind and the nature of the area has good wind resource. Figure 25 shows the anticipated curtailment levels for each MW of wind generation as the total capacity increases in the constrained zone. If UK Power Networks was looking to set a quota that would return a worst case curtailment of 3%, it would set the quota at 33MW.

However, while wind generation is the most likely generation type in the area, there is not an insignificant chance that a biomass generator might look to connect under FPP given the potential savings. This could cause issues for Generator A who has connected assuming that the worst case curtailment was 3%. As can be seen from Figure 26, by including, for example, 50% biomass in the generation mix, this would increase curtailment levels for generator A at a quota of 33MW above the assumed worst case of 3%³⁰.

³⁰ Although the level of curtailment for a wind generator would be similar at times of maximum output since it can be expected that the biomass generator would also be operating at maximum output, it is the periods that wind plant are operating slightly below maximum capacity that would be affected since the biomass plant would still be operating at maximum output thus leaving less spare network capacity for wind generators.

Figure 25: Setting a quota for the March Grid Constraint assuming 100% wind

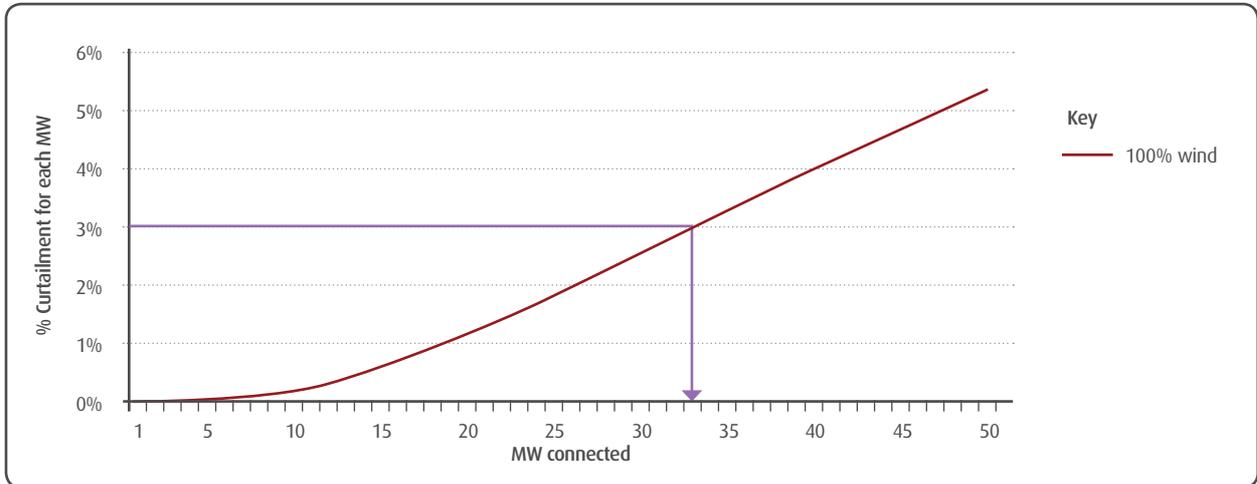
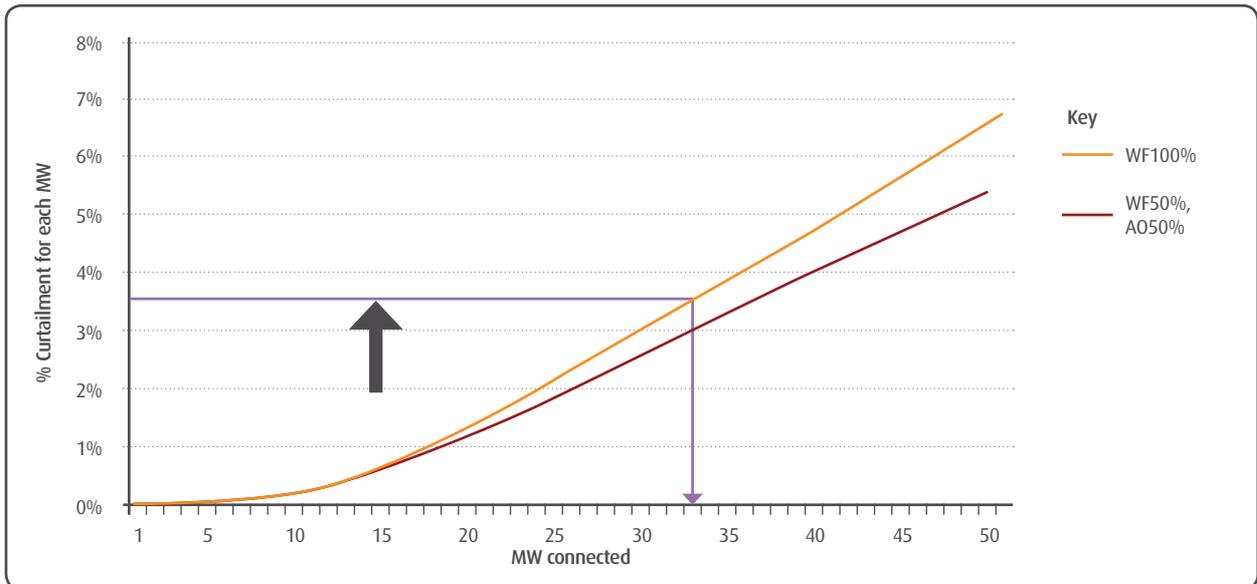


Figure 26: Curtailment for wind assuming a generation mix of 50% wind 50% biomass



While the likelihood of any biomass generator connecting in the constrained zone is relatively low, especially given the fact that biomass should be more flexible in terms of where it locates and would therefore expect to look for a connection in a less constrained area of the distribution network, wind generators looking to “bank” their connection agreements cannot be blind to the possibility. As such, any methodology for setting quotas needs to deal with this additional uncertainty around the nature of future generation, so as to provide sufficient visibility as to the worst case curtailments levels once the quota is filled. We explore options to address the issue next.

Cornerstone Quota

Under this approach, UK Power Networks would determine a quota size based upon a set of conservative assumptions around the characteristics of the future generation that might fill the quota. This is because generators will be unlikely to bank their projects off a “worst case” curtailment forecast that does not, in fact, cover the worst case scenario. In this way, it would be assumed that the rest of the quota will be filled in its entirety by some sort of “always-on” generator, like biomass. This is because the higher the proportion of always-on generation in the capacity mix, the higher the aggregate

levels of curtailment, given that its energy output is the greatest (i.e. an assumed capacity factor of nearly 100%). Figure 27 below shows the curtailment levels for the March Grid Constraint assuming that 100% of the capacity in the quota was always-on generators (like biomass).

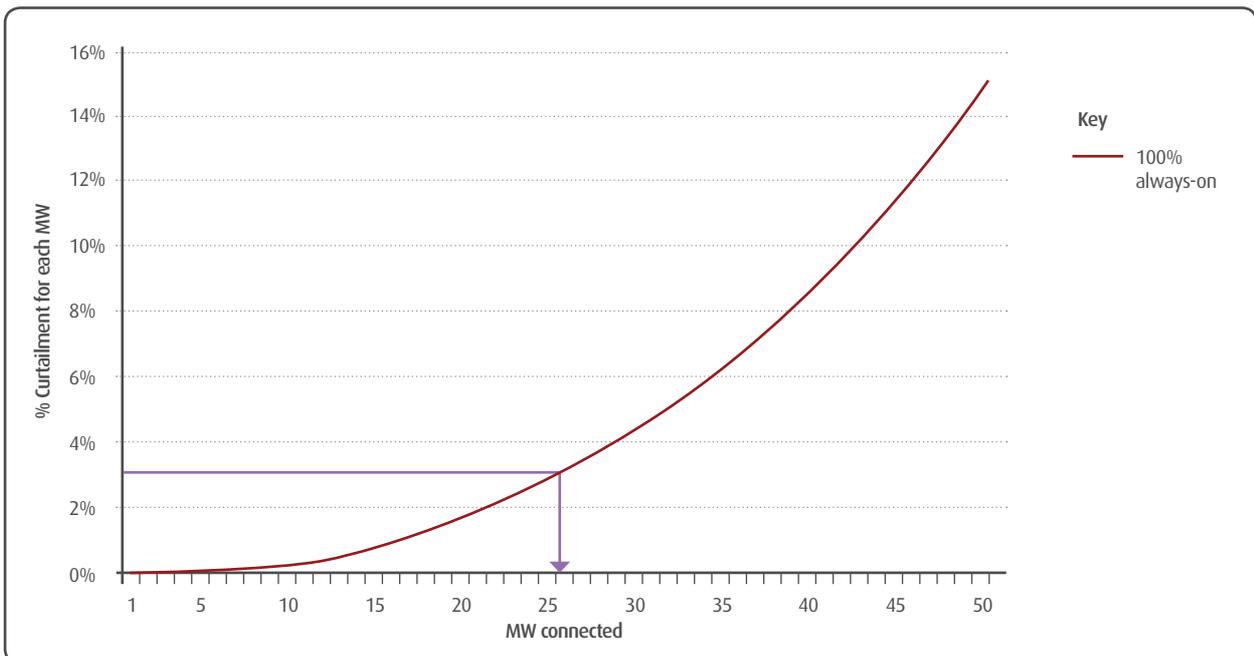
By assuming a maximum curtailment level of 3%, UK Power Networks would set the quota at 24MW based on the always-on assumption (compared to the 33MW described above under the all wind assumption). As the quota is very unlikely to be filled with 100% always-on generators, curtailment levels are therefore unlikely to be as high as assumed under the methodology above. As such, if in reality the quota of 24MW is filled by all wind generators or a balanced mix of uncorrelated wind and solar plant, there could be a scenario in which not a significant amount of additional capacity would have connected over and above what would have connected in any event had LIFO been implemented from the start. It is however worth noting that a quota can never be less efficient than LIFO on the basis that, once

the original quota has been filled, all additional generation can be connected and curtailed on the basis of LIFO, in any event.

A “Reflexive” Quota

The alternative approach to using a cornerstone quota is to try and hardwire into the contract a “reflexivity” in the limit on the quota depending on the characteristics of the generation that actually connects through time. The challenge with this approach is determining an appropriately robust relationship between the generation mix and the total quota limit. One possibility would be to determine a quota for each combination of wind, solar and always-on generation which returned curtailment levels - for each generation type in the quota - that did not exceed a pre-determined maximum. This would involve modelling curtailment under each generation mix, and then setting a quota that returned the desired curtailment levels. Figure 28 sets this process out in more detail. The look up table shows % of wind horizontally, % of solar vertically and the % of always-on in the table itself.

Figure 27: Cornerstone quota based upon an assumption of 100% always-on



The table in figure 29 would be included in a generators contract and would bind UK Power Networks in terms of its connection of further generation. Take the example that UK Power Networks had connected 20MW of wind generation subject to the March Grid Constraint and it received a request for connection from a 5MW solar park. In deciding whether this solar park could be connected and curtailed pro-rata with the other wind farms, UK Power Networks would carry out the following steps:

- First, it would work out the generation mix following the connection of the new generator. This would be 20% solar and 80% wind.
- Next it would read off the look-up table in Figure 29 as to what the capacity quota is for that particular generation mix. In this case, for a generation mix of 80% wind and 20% solar, the maximum quota limit is 52MW.
- Finally, UK Power Networks would ensure that the total capacity of generation in the quota following connection of the new solar park does not exceed the quota limit. In this case, there would be no problem as total capacity in the constrained network, once that solar park connected, would be 25MW (i.e. 20MW of wind and 5MW of solar) which falls well below the limit of 52MW.

This process would be repeated for every connection application. Where the connection of any generator would result in a breach of the allowed quota size for that resultant generation mix, the prospective generator would be still be offered a connection under FPP, but would not however be included in the quota but instead curtailed ahead of those generators that had been allocated to the quota.

6.3.3 Appraisal

Capacity quotas have the undoubted advantage of offering a potentially universal approach, with the available capacity that could be offered non-firm connections behind each constraint being calculated in advance. This could significantly

improve the connection process if applied more widely as available capacity under an actively managed network could be displayed together with the worst case curtailment levels where the desired quota was filled. It does, however, present some significant challenges which have been touched upon in Section 6.2.3 and are further summarised below.

The challenge of determining “maximum curtailment”

Setting a quota, whether it be a cornerstone quota or a reflexive quota, relies on the basic principle that the size of the quota should be limited to ensure that all generators in that quota should not, in the worst case in which the quota is actually filled, experience curtailment in excess of a particular level. As already highlighted in the analysis set out in Section 6.3.2, the key challenges with setting a quota by reference to a maximum curtailment level are as follows:

- The sensitivity of generators to curtailment will vary depending on their technology type, subsidy mechanism and project specific circumstances. Imposing the same level of curtailment on all generators subject to the same constraint raises the problem of whether this is set at a level that includes all generator types or excludes some.
- Secondly, maximum curtailment levels are highly sensitive to changes in assumptions around capacity factor, capex costs and revenue loss. This makes it very difficult to say with any confidence that any particular generator type should be able to withstand a particular level of curtailment, and would be vulnerable from challenge by generators who would have much better visibility on their internal project economics.
- Finally, this issue is heightened by the problem that the level of curtailment that different generators will accept will in some cases be dependent on the extent of the savings offered by FPP over and above their firm alternative. Deciding on a “minimum” level of savings before participation in FPP has the risk of being a little arbitrary.

Given the variance in appetite for curtailment amongst generator types and the sensitivity of the results to changes in the assumptions, picking the “right” level of maximum curtailment becomes a potentially problematic process. This would require UK Power Networks to make a value judgement that, given its position, it might not be in the best position to make without extensive bilateral dialogue with its potential generator clients.

Trade-off between complexity, efficiency and certainty

As can be seen from Section 6.3.2, even if a maximum curtailment level can be determined, setting the quota limit itself also has its challenges. The first approach of setting a cornerstone quota is relatively simple. However, by assuming a worst case generation mix that is unlikely to materialise, there is a potential loss of efficiency (i.e. the amount of generation that can connect over and above LIFO), which would be one of the principle drivers for choosing pro-rata curtailment in the first place. If the amount of viable generation capacity is to be maximised, a reflexive quota approach could be adopted. However, this has the significant disadvantage of being a complex mechanism which might be difficult to understand and appraise for a smaller generator. As such, there is a trade-off between: reduced complexity but reduced efficiency of the cornerstone approach and the increased efficiency but increased complexity of a reflexive quota approach.

6.3.4 Overview

Table 6 below summarises the performance of capacity quotas against the criteria set out in Section 3. Note that a score of 5 indicates that the option fully satisfies that criterion, while a score of 1 indicates that the option fails to satisfy that criterion.

Table 6: Overview and scoring of capacity quotas against the criteria of assessment

Criteria	Score	Explanation
Efficiency	4-5	A reflexive quota approach presents the possibility of maximising the efficiency by driving the greatest volume of generation capacity that could viably connect in any constrained area. However, if the simpler cornerstone approach is taken, these efficiency gains are less certain.
Certainty	2 - 4	A quota based approach introduces a number of additional uncertainties that generators do not have to contend with under LIFO or vintaging – and that is uncertainty as to the characteristics of the future pipeline of generation that might fill the quota. As explained above, this uncertainty can be significantly reduced with the additional complexity of a reflexive quota, or it can be mitigated by taking very conservative upfront assumptions when setting a cornerstone quota (with a corresponding loss of efficiency).
Simplicity	2	Setting a maximum level of curtailment presents a significant challenge for UK Power Networks. It is arguable that UK Power Networks as DNO is not best placed to predict the internal economics of the generators looking to connect and therefore determining the maximum level of curtailment becomes a difficult process.
Fairness	2	The question as to whether using quotas is fair comes down to the level of maximum curtailment that is used to set them. Some generator types might argue that they are being discriminated against were quotas set by reference to a level of curtailment that they could not withstand.
Learning	5	This is an ambitious approach and has the significant advantage of being widely applicable to all constraint locations.

6.4

Option 3 - Reinforcement Quota

6.4.1 Description

This option is a variant on the capacity quota approach. However, instead of defining the quota by reference to a maximum curtailment level, it looks to define the quota by reference to the level of capacity connected in any constrained zone at which the cost to each generator in terms of lost revenue as a result of curtailment (i.e. "curtailment cost") equals or exceeds the cost of reinforcing the network to eliminate the curtailment altogether when shared across all non-firm FPP generators (i.e. the cost of "buying firm").

The question then arises as to how reinforcement is treated in the commercial arrangements. Broadly speaking, there are two options:

- **Mandatory Reinforcement** - build into each FPP generator's connection agreement a "deferred" connection charge that reflects the costs in £/kW of carrying out the local reinforcement at the point the quota is full (the "reinforcement trigger"). This would give generators certainty that once the quota is filled, the reinforcement will proceed and protects the generators from the "tyranny of the minority" where one generator decides that it does not want to carry out the works

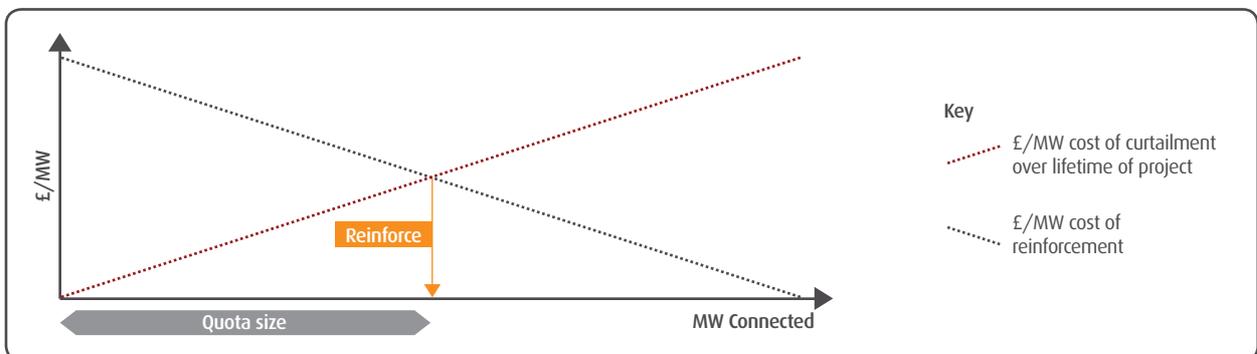
necessary to reinforce the constraint (e.g. for cash flow reasons or because its revenue loss caused by curtailment is different from the other generators in the quota).

- **Voluntary Reinforcement** - reinforcement at the point the quota is full would be a voluntary arrangement with no hard-wired connection charge in the connection agreement. Instead, generators could be offered the option to reinforce at the point that the reinforcement trigger is exceeded. If they accept they go firm, if they do not accept they would remain non-firm.

Both alternatives, based on a reinforcement quota approach, active network management becomes less an enduring connection option, but rather a temporary solution until sufficient generation has connected to the network, so as to make a firm connection an economically attractive proposition for generators. By allowing generators to get an earlier "non-firm" connection, they avoid the expensive connection charge, in advance of the wider reinforcement being carried out (if needed).

To decide whether to connect under this proposal, a generator has to get comfortable with two key commercial terms:

Figure 30: Quota set by reference to reinforcement costs



- First, that its project can withstand the curtailment triggered by generation connecting up to the level of quota before reinforcement is triggered, i.e. the worst case scenario; and
- Once the reinforcement has been triggered, the cost of “buying firm” would be financially viable and attractive proposition.

Where, in funding reinforcement, the generators fund any additional over-sizing above what is needed to accommodate that group of generators alone, there could be a “claw-back” to these early generators as and when this capacity is used by later generators that connect and utilise this capacity. This accords with the charging methodology in relation to over-sizing of assets required to accommodate a new generator.³¹

6.4.2 Application

The March Grid Constraint, described in Section 4, is a good example of where ANM and FPP can facilitate a more coordinated network build out of the network. As explained in Section 4, the reason why no further firm connections can be offered at the 33kV/11kV level primarily relates to the fact the reverse power limit on the transformers has been reached with existing generation connected. While at a cost of £3.2³² million, this reverse power flow constraint could be increased from by 45MVA, none of the firm connection offers issued to generators looking to connect in the vicinity of March Grid involve taking this action because, when considered in relation to each generator alone, it is cheaper and simpler to connect the generator with sole use assets at EHV above the reverse power constraint or at another unconstrained point on the network. However, while this approach minimises stranding risk (and accords with the charging mechanism and the definition of the minimum scheme), it results in an incremental rather than coordinated network build out, which when considered in its entirety, is relatively expensive. However, by connecting under FPP, generators can connect to the 33kV/11kV network in the constrained zone of March

Grid and accept curtailment instead. Once sufficient generation has come forward, then the replacement of the transformers can be funded jointly at much lower aggregate cost than the total cost of the incremental s16 firm approach. The question is therefore, at what point would it be preferable for the generators connecting under FPP in the constrained zone of March Grid to fund the replacement of the transformers than accept curtailment (i.e. the “reinforcement trigger”)?

Methodology

It is proposed that the quota and trigger for reinforcement for the March Grid Constraint be determined as follows:

³¹ See paragraphs 5.35 of the Common Connection Charging Methodology (July 2012) in relation to the payments of rebates where a customer has funded excess capacity that is utilised by later customers.

³² Note this is an indicative high-level planning estimate used for illustration purposes in this report.

Figure 31: Methodology for determining reinforcement trigger

Step 1	
Determine Generation Mix	<ul style="list-style-type: none"> • Determine the most likely generation mix that is likely to connect behind the constraint. • UK Power Networks would determine this by reference to generation growth patterns in the area, the existing pipeline of generation projects and the available renewable resources.
Step 2	
Calculate the Reinforcement Trigger	<ul style="list-style-type: none"> • By making assumptions around likely revenue loss for generators behind that constraint, calculate how curtailment cost increases as capacity increases. • Calculate capacity of generation at which the cost of curtailment exceeds the share cost of local reinforcement.
Step 3	
Run Sensitivities	<ul style="list-style-type: none"> • Characterise a number of scenarios of different mixes of generation types that might fill the quota up to the Reinforcement Trigger. • Model curtailment levels for different generation types for each of the different generation mix scenarios to understand the range of possible curtailment levels.

Results

Step 1 - Determine the Generation Mix

As explained in Section 4, the flat area in Cambridgeshire in which the trial zone is located is ideally suited for onshore wind generation. Indeed this would explain why 100% of generators already connected in that area are wind farms (i.e. 9 installations with an aggregate capacity of 121MW) and all generation projects in the pipeline are wind generators (see Table 3 in Section 4). In this way, for the purposes of determining what the most likely generation mix, it would not be unreasonable for UK Power Networks to assume that this will be all wind generation.

Step 2 - Calculate Reinforcement Trigger

Assuming 100% wind generation, the next step is to calculate the point at which curtailment cost in terms of lost revenue to each wind generator exceeds the shared cost of reinforcement. However, as already highlighted in Section 6.3, the level of revenue loss will depend on the subsidy regime under which each wind generator is governed. As such, it is important to assess how the trade-off between lost revenue and shared reinforcement cost varies across wind generators funded under the two principal support schemes – the Renewable Obligation (“RO”) and the small scale Feed-In-Tariff (“FIT”). Table 7 below sets out the different generator types modelled and the revenue loss assumptions used.

Table 7: Revenue loss assumptions³³

Tech	FIT ³⁴ (€/MWh)	RO (€/MWh)	LECs (€/MWh)	Electricity (€/MWh)	Embedded benefits (€/MWh)	Total Loss (€/MWh)
Wind (FIT)	95	-	5.24	65.6	5.5	171
Wind (RO)	-	40.30	5.24	65.6	5.5	117

³³ See Annex 3 for further details on economic assumptions used in relation to generator costs and revenue.

³⁴ This assumes that (a) the FIT generator is 1MW; (b) that the generator will opt out of the export tariff and instead sell its electricity to a supplier in the short term PPA market and (c) that the generator does not consume any electricity on site and exports all that it generates (which may not be the case as the FIT is structured to incentivise and onsite consumption).

By modelling how average curtailment (in MWh/year/MW) increases as the volumes of wind generation increase in the constrained zone of March Grid, it is possible to calculate:

- the revenue loss for one MW of each wind generator type (i.e. the Net Present Value (“NPV”) of the revenue loss assuming a 10% discount factor and a 20 year asset life); and
- the shared curtailment costs for one MW of wind generation by dividing the total cost of reinforcement (i.e. £3.2 million) by the amount capacity subject to the constraint. The results of this analysis are shown in Figure 32 below³⁶.

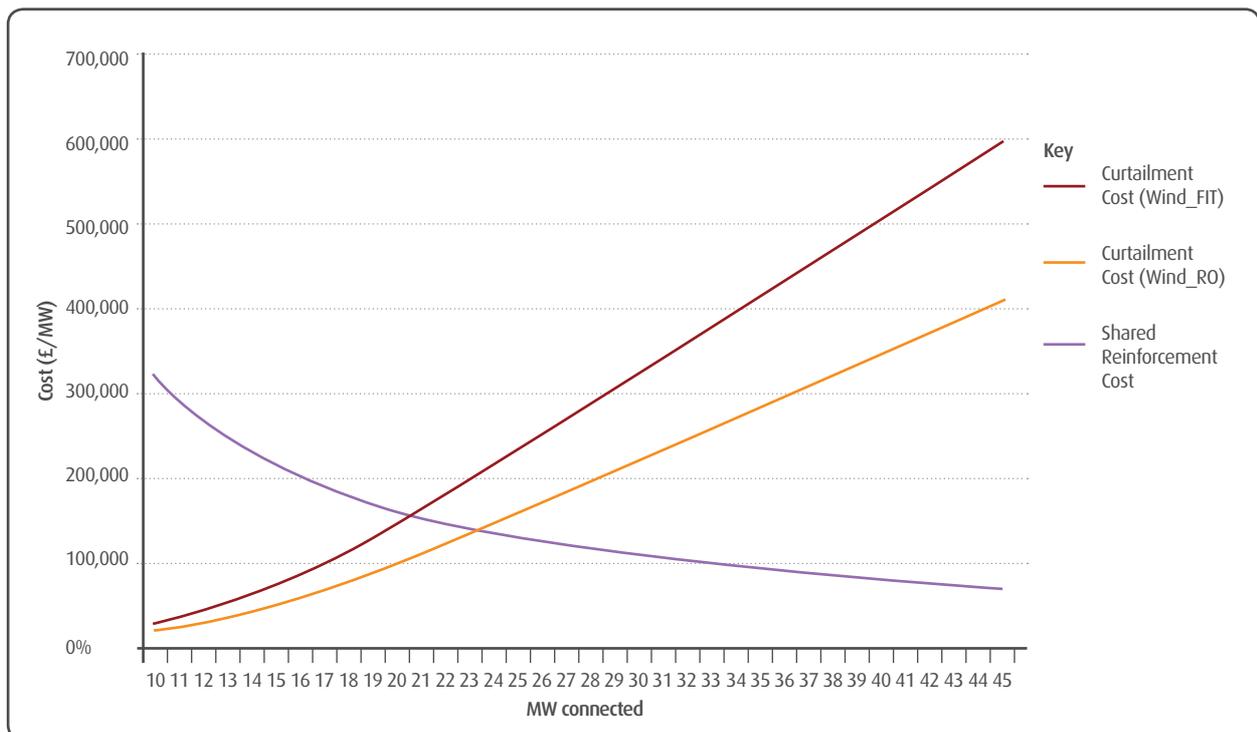
Since the revenue loss assumptions for the different wind generators differ, the point at which the NPV of the lost revenue exceeds the shared cost of reinforcement differs for RO vs. FIT funded wind generators. It ranges from just under 21MW for a FIT generator to around 23MW for an RO generator.

Taking a mid-point value, the trigger point for reinforcement could therefore reasonably be set at 22MW of capacity at a reinforcement cost approximately £145,000 per MW.

Step 3 - Run Sensitivities

While the likely generation mix is 100% wind, there is a possibility that some of the capacity that connects up until the reinforcement trigger of 22MW might actually consist of other generation technology types. As such, in order to assess the viability of the 22MW threshold, it is important to assess what the range of curtailment levels might be for different types of generator across a range of generation mixes. In this analysis we have used wind, solar and an always on generator, which in this case is assumed to be biomass (but could easily be any other thermal generator type with a capacity factor approaching 100%). Table 8 shows what the level of curtailment these technologies might experience under

Figure 32: Curtailment/reinforcement trade-off for wind generators



³⁶ Note that this analysis assumes that all generation connects at the same time (and therefore lost revenues are discounted over the full 20 year asset life). However, in reality, generation will connect on a staggered basis and as such, the asset life of 20 years would be inappropriate for earlier generators). However, for the sake of simplicity, this nuance was not catered for in the methodology.

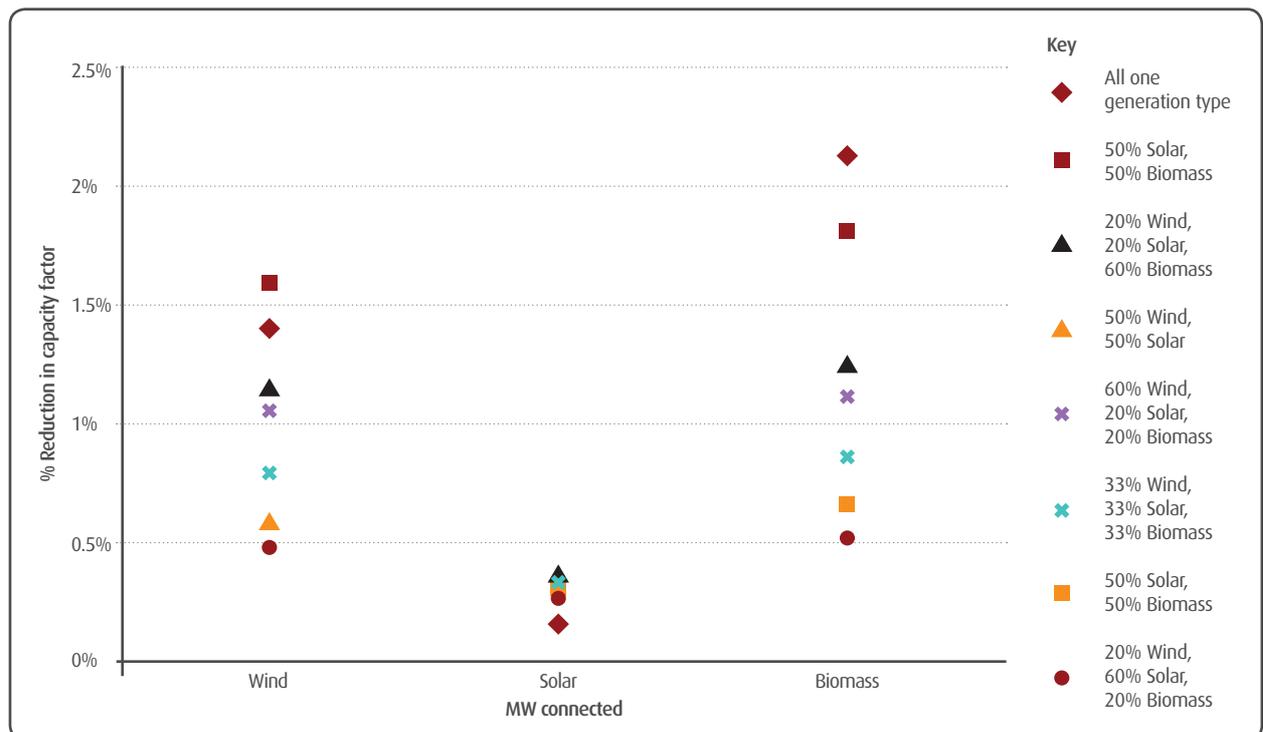
different generation mix scenarios. This spread of potential variability in terms of percentage reduction in capacity factor

that each technology might experience within a 22MW quota is displayed in Figure 33 below.

Table 8: Variation in average curtailment by technologies and generation mix scenario for a 22MW quota

Scenario	Mix	Wind ³⁷	Solar ³⁸	Biomass ³⁹
Wind only	100% Wind	1.41%	-	-
Solar PV only	100% Solar	-	0.22%	-
Biomass only	100% Biomass	-	-	2.10%
Balance of Wind and Solar PV	50% wind, 50% Solar	0.55%	0.27%	-
Balance of Solar and Biomass	50% Solar, 50% Biomass	-	0.31%	0.66%
Balance of Wind and Biomass	50% Solar, 50% Biomass	1.60%	-	1.74%
Predominance of Wind	60% Wind, 20% Solar, 20% Biomass	1.04%	0.33%	1.11%
Predominance of Solar PV	20% Wind, 60% Solar, 20% Biomass	0.48%	0.27%	0.51%
Predominance of Biomass	20% wind, 20% Solar, 60% Biomass	1.17%	0.37%	1.26%
Balanced portfolio	33% wind, 33% Solar, 33% Biomass	0.83%	0.33%	0.89%

Figure 33: Spread in curtailment levels by scenario



³⁷ Curtailment assumes uncurtailed capacity factors of 30%, and that the output of all generators is correlated.

³⁸ Curtailment assumes uncurtailed capacity factors of 30%, and that the output of all generators is correlated.

³⁹ Curtailment assumes uncurtailed capacity factors of 100%.

As such, it can be seen that under these scenarios, the worst case curtailment for each technology is as follows:

Simulation

Having set the quota at 22MW, we can now simulate how this might evolve for the March Grid Constraint. To simulate how the reinforcement quota would apply to the March Grid case study, table 10 below sets out an order of connection and cumulative capacity build-up of those projects that have

already been identified as potentially benefiting from an FPP connection. Note that this is for illustrative purposes only and it is not the sequence that these generators have actually made applications for connection.

Taking these figures into account, we can now simulate how contractual arrangements might unfold where UKPN opts for either a Mandatory Reinforcement or Voluntary Reinforcement approach.

Table 9: Worst case curtailment estimates for a quota of 22MW

Technology	Scenario	Worst case curtailment
Wind	50% Wind, 50% Biomass	1.60%
Solar PV	20% Wind, 20% Solar, 60% Biomass	0.37%
Biomass	100% Biomass	2.10%

Table 10: Simulation of build-up of capacity at March Grid

Project	Order	Capacity (MW)	Cumulative Capacity (MW)	Tech	Reinforcement	Average Curtailment
Generator A	1st	5MW	5	Wind	Connect & Curtail	0.07%
Generator B	2nd	2.5MW	7.5	Wind	Connect & Curtail	0.12%
Generator C	3rd	0.5MW	8	Wind	Connect & Curtail	0.13%
Generator D	4th	1MW	9	Wind	Connect & Curtail	0.17%
Generator E	5th	10MW	19	Wind	Connect & Curtail	1.02%
Generator F	6th	16.4MW	35.4	Wind	Connect & Invest	0%

Mandatory Reinforcement

As discussed in Section 6.4.1, this option would hardwire a deferred connection charge upfront into the generators connection agreements. One option for implementing it would be as follows:

- As shown, Generators A, B, C, D and E would connect under FPP rather than pay their much more expensive s16 firm connection offers. This would bring the total capacity of FPP generators contracted to connect subject to the March Grid Constraint to 19MW, returning an average curtailment estimate of 1.02%⁴⁰. Since at this point the trigger point of 22MW is not breached, UK Power Networks does not make the decision to reinforce the March Grid Constraint.
- In the event, however, that Generator F applies for connection, this would take total capacity above the 22MW quota. As such, instead of offering an FPP connection offer, UK Power Networks would offer Generator F a firm connection and call in the deferred reinforcement charge from the first five generators that initially connected under FPP.
- The total cost of the upgrade to each generator would actually cost less than originally envisaged as the aggregate capacity (including Generator F) over which reinforcement cost would be spread would be 35.4MW (not the 22MW on which the quota was sized).
- This would bring the actual deferred connection cost for this generator group down from the £145,000/MW hard coded into their connection offer to £91,000/MW. In this way, the end result would be a cheaper firm connection for all generators on a coordinated rather than incremental basis. Further, this optimal lowest cost solution would have been achieved without pushing stranding risk onto the consumer or the generators themselves, with investment ahead of need.

Voluntary Reinforcement

As discussed in Section 6.4.1, this option would not hardwire

any deferred connection charge upfront into the generators connection agreements. Instead, a softer approach would be taken that leaves the decision as to whether to reinforce with the generators at the point that the reinforcement trigger is exceeded. One option for doing this would be as follows:

- As above with Mandatory Reinforcement, Generators A, B, C, D and E would connect under FPP rather than pay their much more expensive s16 firm connection offers bringing the total capacity subject to the March Grid Constraint to 19MW;
- In the event that Generator F requested connection, UK Power Networks would canvas Generators A, B, C, D and E as to whether any or all of them would be interested in reinforcing at a cost equal to their share of the reinforcement cost when shared across all six generators (i.e. £91,000/MW as above).
- In calculating the “minimum scheme” for the purposes of connecting Generator F, UK Power Networks would take into account any commitment from Generators A, B, C, D and E to fund the reinforcement at a cost of £91,000/MW.
- If there is insufficient support for reinforcement amongst Generators A, B, C, D and E such that it is cheaper (in total) to connect Generator F elsewhere on the network, then the reinforcement will not be triggered and Generator F would either:
 - connect firm under its s16 Firm connection offer connecting elsewhere on the network (i.e. the “minimum scheme”); or
 - connect non-firm behind the March Grid Constraint, however subject to the condition that in resolving any constraint it will be curtailed before Generators A, B, C, D and E (thereby ensuring that Generator F does not trigger higher curtailment levels for the earlier generators);

⁴⁰ This is less than the worst case forecast since (a) the quota is not exactly filled and 2) it is all wind rather than 50% wind, 50% AO.

- If a sufficient proportion of non-firm generators already connected under FPP opt to reinforce such that the reinforcing the March Grid Constraint becomes the cheapest connection option for Generator F (i.e. the “minimum scheme”), then UK Power Networks would offer to connect Generator F firm at a cost of £91,000/MW (plus the cost of any sole use assets).
- Any shortfall in the cost of the reinforcement not recovered from the generators would be funded by UK Power networks in accordance with the rules of cost apportionment in the common connection charging methodology⁴¹. This funding would then be clawed back from non-firm generators should additional generators connect at a later date.⁴²
- Those that do not fund their share of reinforcement would be left with interruptible contracts. In this way, while they might therefore get a short term benefit of lower curtailment at the point that the reinforcement is carried out, longer term they could still potentially be exposed to curtailment risk if further generation is connected in that constrained zone. As the cap on capacity (i.e. quota) would have expired with the reinforcement, this theoretically open ended curtailment should, in turn, provide a strong incentive to fund their share of the reinforcement cost.

6.4.3 Appraisal

The key advantage of the Reinforcement Quota approach is that it provides a robust methodology within which UK Power Networks is able to set the quota and reinforcement trigger, which avoids UK Power Networks making too many assumptions about the internal economics of different generators. In addition, this approach could potentially drive a coordinated (and overall cheaper) connection solution for generators without minimal stranding risk on investment ahead of need. Indeed, initial estimates indicate that this approach has the potential to save generators connecting to March Grid just under £9 million in total when you compare:

- the aggregate cost of connecting these generators under their incremental s16 firm connection offer - against
- the total cost of connecting under FPP and then paying the deferred connection charge once the reinforcement trigger has been exceeded.

It is interesting to note that this use of the trade-off between curtailment costs against the cost of reinforcement resonates with the rationale that was used to underpin the Connect and Manage reforms implemented at transmission level in 2010. The difference in this case, however, is that the cost of curtailment is being borne by the FPP generators themselves (in return for a cheaper connection overall) and not socialised across all generators and consumers.

There are, however, are a couple of issues that should be noted with this approach. These are set out below.

Context specific

One of the principle limitations of this approach is that its viability depends on the characteristics of the existing network and the cost and nature of the possible reinforcement solution. The extent to which this will be viable will depend on the extent to which:

- There is a reinforcement plan which is deliverable within viable time scales (e.g. does not require a new over-head line with the significant consenting challenges that such developments entail).
- The deployment of smart grid technology (e.g. Dynamic Line Rating or ANM) can unlock enough headroom in the assets that a sufficient volume of generation can connect without triggering prohibitively high curtailment levels.
- The subsequent reinforcement plan is not so expensive so as to require the first comer non-firm generators that connect under FPP to fund significant over-sizing in the assets.

⁴¹ See Sections 5.23 to 5.28 of the Common Connection Charging Methodology. We note that cost apportionment in this context would be slightly different in that the cost to generator F would be the cost in £/MW offered to the first generators rather than just the total cost of reinforcement divided by the new network capacity.

⁴² It is noted that this methodology would potentially involve over-sizing of assets being funded by both the funding generators and UK Power Networks. As such, in the event that this additional capacity is filled with further connectees, the claw back mechanism would need to cater for the fact that both the funding generators and UK Power Networks would need to benefit as both could potentially have funded over-sizing.

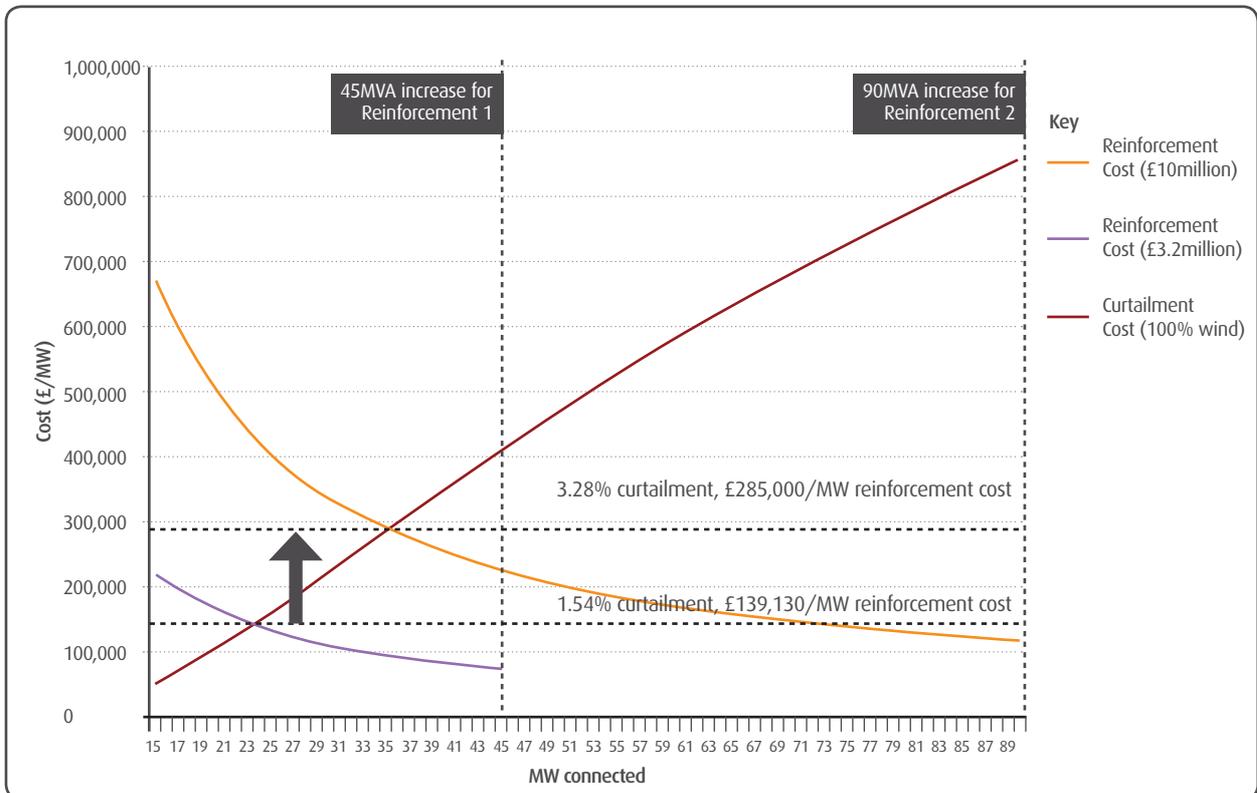
For example, if instead of a £3.2 million reinforcement cost to add 45MW of additional capacity on the March Grid, the reinforcement action involved the addition of 90MW of additional capacity at a cost of £10 million, the point at which the shared cost of reinforcement equals the cost of curtailment would shift which has been simulated in Figure 34 below. If it is assumed that the generation mix is 100% RO Wind, the quota required to reach the trade-off point shifts from 23MW to around 35MW. This has a knock on effect on curtailment by increasing the resultant curtailment from 1.54% reduction in capacity factor to a 3.28% reduction in capacity factor. Moreover, the cost of reinforcement has risen from around £139,000/MW to roughly £285,000/MW.⁴³ As such, the over-sizing that generators would have to fund is significantly increased.

In this second hypothetical scenario, accepting as much as 3.28% reduction in capacity factor and paying almost £300,000/MW on reinforcement may be a far less attractive proposition to generators. As such, in the same way as for an incorrectly sized capacity quota, no generation would connect as the curtailment cost and subsequent reinforcement cost would be prohibitively expensive to be shouldered by those generators alone.

Given diversity of generation types and uncertainty around generation mix, the Reinforcement Trigger may not be correctly set

The reinforcement quota is fundamentally underpinned by the same conceptual framework as the Capacity Quota – the setting of a generic cap on generation that will share curtailment.

Figure 34: Impact of change in reinforcement cost on quota size and maximum curtailment



⁴³ Note that these maximum curtailment figures and Reinforcement Triggers are different in this example since we have only used RO-Wind rather than comparing RO wind and FIT wind as in the analysis above.

As such, it suffers from some of the same issues identified in Section 6.3.2 and 6.3.3 in relation to the Capacity Quota – namely the uncertainty with regard to what assumptions are used with respect of the likely capacity mix that fills the quota. This has the important implication that, while the methodology above looks to set the quota and reinforcement trigger at the point it would be more advantageous to reinforce than to continue to accept curtailment, this point will in reality differ depending on:

- who is experiencing the curtailment because (a) different technologies experience different levels of curtailment (depending on their generation profile and capacity factor) and (b) different technologies experience different levels of revenue loss;
- who the other generators are because the curtailment levels will be dependent on the actual generation mix as shown in Table 8.

However, it is precisely for this reason that it may be beneficial that the generators are locked into the payment of the deferred reinforcement cost once the quota is filled.

Dealing with reinforcement

In Section 6.4.1, we propose two potential options with regard to the treatment of reinforcement costs. Reinforcement can either be mandated upfront in the contract or it can be voluntary. There are advantages and disadvantages of both which are set out in Table 11. The analysis looks at the relative merits of the two approaches from the perspective of three key stakeholders:

- UK Power Networks as network operator;
- all those generators that connect prior to the initial quota being filled (“Class 1 Generators”);
- all those generators that connect after to the initial quota being filled (“Class 2 Generators”).

Table 11: Relative merits of the two options

Option 1 – Mandatory Reinforcement

	Advantages	Disadvantages
UK Power Networks	<p>From an overall network benefit perspective, probably optimal as it will drive the coordinated connection strategy without any stranding risk for UKPN (or consumers).</p> <p>Mechanistically, relatively simple to understand.</p>	<p>Requires UKPN to assume (a) credit risk on generators and (b) price risk on the cost of the reinforcement.</p> <p>There is currently no direct incentive on UK Power Networks to assume this risk (other than certain indirect benefits under output measures).</p>
Class 1 Generators	<p>Will provide certainty that if curtailment is actually greater than expected when quota is almost full, they will be able reinforce at a specific cost.</p> <p>Provides certainty that no single generator can hold the group to ransom with payment pre-agreed.</p>	<p>Generators will be required to pay a deferred connection charge which could create financing challenges.</p> <p>Generators would in effect potentially need to put in place a contingent standby facility - which would increase financing costs</p>
Class 2 Generators	<p>Will be offered a coordinated solution (thereby cheaper) if reinforcement is funded by all generators (new and old).</p>	<p>None</p>

Option 2 – Voluntary Reinforcement

	Advantages	Disadvantages
UK Power Networks	<p>Does not require UKPN to accept (a) credit risk on generators or (b) price risk on reinforcement cost.</p> <p>Easier to administer in terms of dealings with generators as do not need to coordinate reinforcement and call on deferred charges at a later date.</p>	<p>Could drive sub-optimal network connection, as if early generators refuse to fund, a later generator connecting after the quota is filled is unlikely to be able to fund reinforcement on its own (unless very large).</p> <p>There are incentives on generators to free ride.</p>
Class 1 Generators	<p>Optionality regarding whether to pay for reinforcement thereby reducing the financing challenge with funding reinforcement.</p> <p>Parties can assess the actual level of curtailment at the time rather than trying to predict it in the future.</p>	<p>Not hardwiring the reinforcement cost into the contract will leave reinforcement cost uncertainty with the generator.</p> <p>Incentive to game the system could mean it will be difficult to build consensus to reinforce.</p> <p>This will leave generators potentially with a long term, rather than just short term, curtailment risk which may change their view on connecting non-firm in the first place.</p>
Class 2 Generators	<p>None</p>	<p>Connection charges will likely be higher than under a Mandatory Reinforcement because, without commitment from earlier generators to part fund the coordinated solution, the cheapest option (i.e. "minimum scheme") for that generator will be a relatively expensive incremental connection - a long sole use extension asset to an unconstrained network location.</p>

6.4.4 Overview

Table 12 below summarises the performance of a reinforcement quota against the criteria set out in Section 3. Note that a score of 5 indicates that the option fully satisfies that criterion, while a score of 1 indicates that the option fails to satisfy that criterion.

Table 12: Overview and scoring of reinforcement quota against the criteria of assessment

Criteria	Rating	Explanation
Efficiency	3-4	<p>This approach moves away from optimising the utilisation of the existing network and instead looks to drive the most efficient network build out in a world in which planning restrictions and financing challenges make predicting the likely volumes of distribution generation highly uncertain. Curtailment is therefore not the end goal but a transitory arrangement / tool.</p> <p>The key issue is, however, the scenario highlighted above where the reinforcement cost is too expensive and the incremental jump in capacity too large to enable early generators to carry the stranding risk. This is because the cost of curtailment and reinforcement would be prohibitively high. In these circumstances, therefore, there is a risk of no generators connecting, notwithstanding the fact that there may be limited headroom in the existing infrastructure.</p>
Certainty	3-4	<p>This provides a relatively high level of certainty to generators as they can model the upper limit of the curtailment levels in the event that the quota is filled. With respect to the mandatory reinforcement option, generators have the certainty that they can reinforce at a particular price. However, there is the uncertainty of whether that charge will actually be levied. With a voluntary reinforcement approach, the converse is true with no certainty as the price of reinforcement or whether it will occur at all, although without the financial uncertainty as to whether the deferred reinforcement charge will be levied.</p>
Simplicity	3	<p>This approach also provides a relatively simple and robust / justifiable methodology within which UK Power Networks is able to set the level of the quota, which avoids making too many assumptions about the internal economics of different generators.</p>
Fairness	4	<p>It is treating all generators equally and has as its ultimate objective a firm connection which will hopefully resonate with generators.</p>
Learning	5	<p>This approach aligns with other successful approaches taken in relation to network build out in other sectors, most notably at transmission level with Connect and Manage which was underpinned by a rationale of trading-off curtailment costs against the cost of reinforcement.</p>

6.5

Option 4 - Capacity Auction

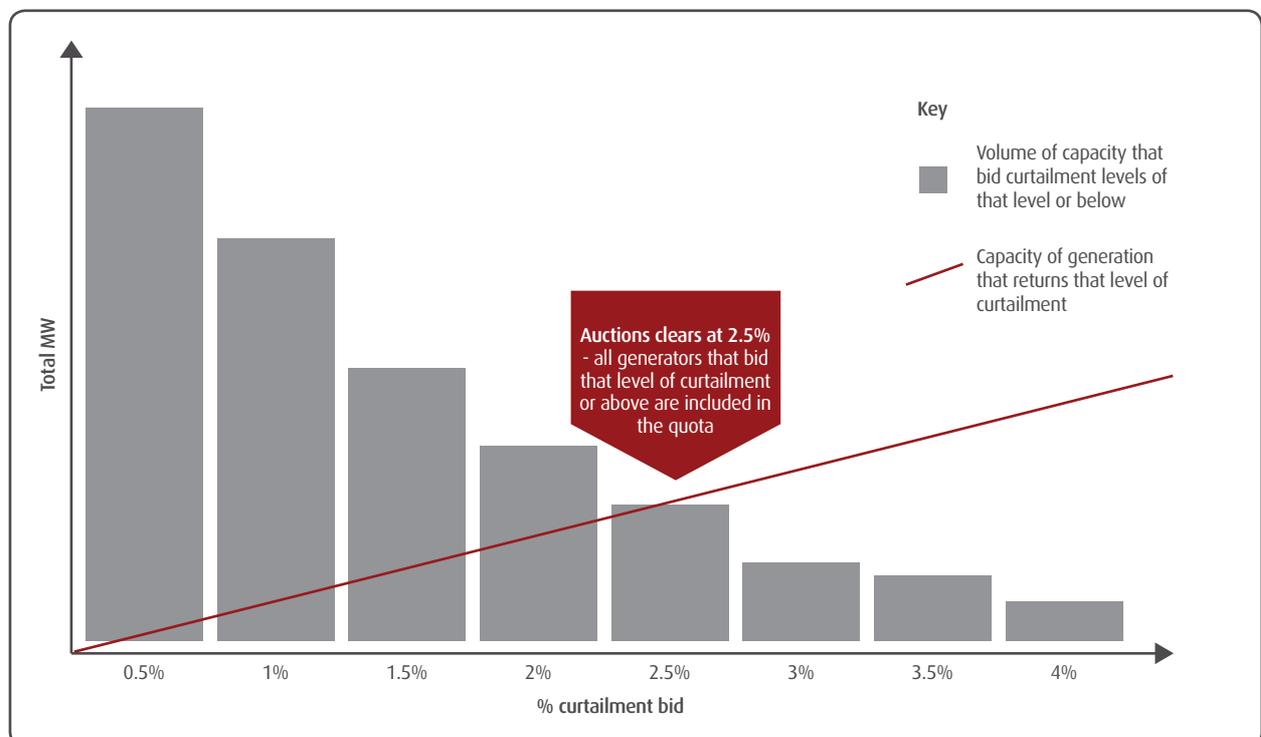
6.5.1 Description

The principle challenge of a capacity quota based approach is determining the level of curtailment that generators can tolerate. While a reinforcement quota could circumvent this problem by setting the quota and reinforcement trigger by reference to the trade-off on reinforcement costs instead, it still suffers from being relatively context specific and may not be applicable in every situation. As such, there is a need for a universal approach for allocating capacity by reference to some level of acceptable curtailment that can be applied in any constrained scenario.

A capacity auction could potentially do just this by combining elements of both vintaging and the capacity quota approach. For each constrained zone, UK Power Networks would advertise

the availability of network capacity under FPP. Over a period of time prior to the auction, UK Power Networks would recruit generators that might potentially be interested in connecting in that particular constrained zone. Once the "time gate" had closed, UK Power Networks would ask each generator to bid the annual level of curtailment that it would be prepared to accept over the life time of its project. The level of demand for connection at different levels of curtailment could then be matched against the maximum capacity quota that returned that level of annual curtailment. UK Power Networks' sole objective in clearing the auction would be matching the bid curtailment levels to the available capacity. Figure 35 below set out how this process might conceptually work.

Figure 35: Clearing the auction of capacity



6.5.2 Application

It is difficult to actually apply this approach in relation to the March Grid Constraint since we do not have visibility at this stage on what the generators that might participate in the FPP process might bid in terms of acceptable curtailment. However, for illustrative purposes, this section simulates a simple auction involving the generators that might connect and feed into the March Grid Constraint. Table 13 below sets out some indicative figures of how this approach might be applied. While the bid curtailment figures are constructed, the rest of the information, including FPP saving and curtailment levels at differing capacities, is grounded in the realities of the case study of the March Grid Constraint.

Those generators with little by way of saving on their FPP connection offer, like Generator A, can only bid low levels of curtailment as with higher levels of curtailment its firm connection offer looks more attractive. On the other hand, generators like Generator C, who have very expensive firm connection offers which they cannot accept, are “captive” to FPP. As such, these generators will therefore theoretically be prepared to accept higher levels of curtailment, at least as high as is possible before the project no longer delivers a target IRR.

Figure 36 opposite plots bid curtailment levels against the available capacity. The generators have been ordered in order

of minimum curtailment bid, with those that bid the highest tolerable levels of curtailment connected first. The blue line shows how the average level of curtailment experienced rises as each generator is connected. Where these two lines cross is the point at which the auction clears. As can be seen, under this simulation, UK Power Networks would be able to connect Generators C, E, D and B (with an aggregate capacity of 14MW). However, UK Power Networks would not be able to offer connections to Generators A and F on the grounds that including them would return a level of curtailment that was above their bid.

6.5.3 Appraisal

Auctioning has the key advantage in that, as explained, UK Power Networks would simply be matching available capacity to the bid curtailment tolerances. In this way, auctioning does not require UK Power Networks to make any determinations in respect of the level of curtailment generators should be able to withstand (as with a capacity quota and reinforcement quota). The success of the approach therefore simply relies on UK Power Networks running a competitive auction. There are, however, a number of issues with this approach. These are set out below.

Maintaining competition

This approach relies upon there being sufficient volumes of

Table 13: Simulated auction results for generators connecting at March Grid

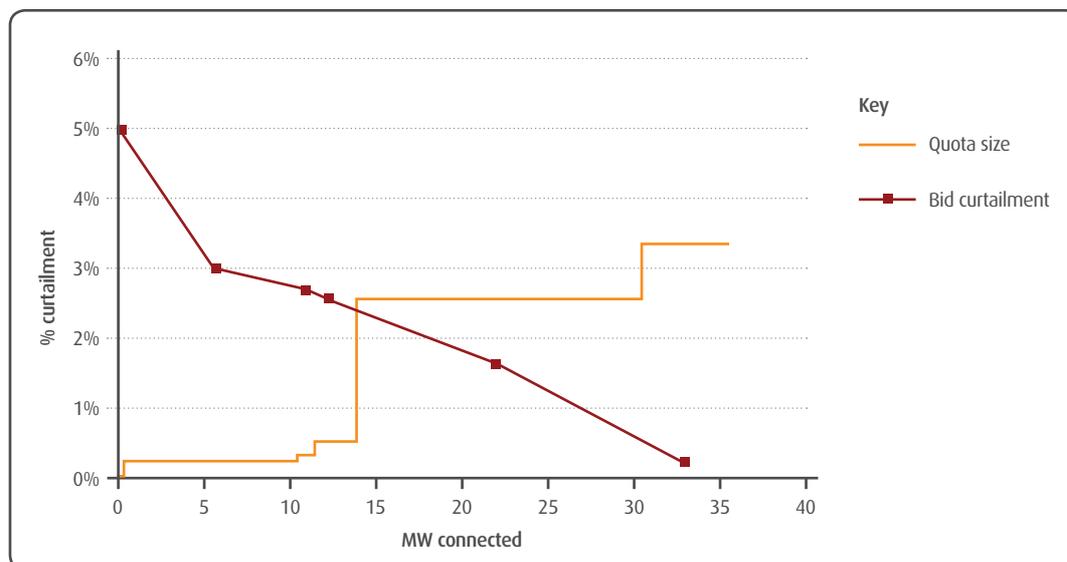
Project	Order	Capacity (MW)	Tech	FPP Savings	Average Curtailment
Generator C	1st	0.5MW	Wind	3500	5%
Generator E	2nd	10MW	Wind	400	3.5%
Generator D	3rd	1MW	Wind	1000	2.7%
Generator B	4th	2.5MW	Wind	550	2.5%
Generator F	5th	16.4MW	Wind	250	1.6%
Generator A	6th	5MW	Wind	80	0.02%

capacity looking to connect at a particular constrained zone. Without sufficient levels of competition, generators will not bid the “true” level of their acceptable curtailment resulting in a loss of efficiency. A lack of competition has hampered price discovery at transmission levels in GB. As explained in more detail in Cambridge University’s report on international and domestic experience⁴⁴, the use of the Balancing Mechanism (BM) to determine marginal constraint costs for generators that were connected under Connect and Manage has been beset by issues where there are not sufficient levels of competition behind a particular constraint. This has led to generators bidding into the BM offers way in excess of their theoretical maximum opportunity cost. There is a risk that auctioning capacity on FPP could have similar issues where only a small number of generators are competing for the available capacity. In reality, this approach has the risk of breaking down into a series of bilateral negotiations. This would turn what had started out as a transparent open auction of capacity into a rather opaque negotiation for access which risks challenge.

Evaluating bids based on curtailment levels only

When auctioning capacity amongst a group of developers, project deliverability could present another issue. How should a bid of 3% curtailment from a project with no planning permission be compared against a bid of 2% from a project that has planning permission and is ready to enter construction once it has secured network access? Evaluating bids from developers with different probabilities of actually delivering their projects as envisaged could create issues in terms of maximising available capacity (i.e. the issue of “attrition” highlighted in respect of vintaging in section 6.2). Indeed, gaming by developers with speculative projects but who are looking to hold an option on capacity could be a particular problem. While this could be mitigated by including stringent eligibility criteria for participation in the bid, this would restrict the level of competition for capacity as the pool of bidding generators would be reduced. Many developers look to secure network access in advance of investing the time and money required to secure a successful planning application.

Figure 36: Matching acceptable curtailment to optimum quota size



⁴⁴ Dr. Karim L. Anaya, Dr. Michael G. Pollitt (2012). Experience of the use of smarter connection arrangements for distributed wind generation facilities.

6.5.4 Overview

Table 14 below summarises the performance of a Capacity Auction against the criteria set out in Section 3. Note that a score of 5 indicates that the option fully satisfies that criterion, while a score of 1 indicates that the option fails to satisfy that criterion.

Table 14: Overview and scoring of Capacity Auction against the criteria of assessment

Criteria	Rating	Explanation
Efficiency	3-4	Provided there was effective competition, matching demand to supply in this way is theoretically an efficient approach. However, generating sufficient demand by having lengthy time gates would need to be traded off against the lack of certainty that this brings for generators. Moreover, project "attrition" could reduce these efficiency gains.
Certainty	2-4	Once the auction had cleared, generators in each quota would not be left with an open-ended quota with no visibility of the actual generators with which it will be pro-rata curtailed. Like with vintaging, the group of generators will be known from the moment that the auction cleared. However, conversely, if long periods of time were specified between "time gates", generators that applied at the beginning could find themselves in limbo with little short terms certainty around whether to continue to invest in their project.
Simplicity	3	This is not a particularly simple approach as the auction would need to deal with a number of complexities in terms of design (e.g. devising an effective communication strategy to maximise competition for capacity). Deliverability is also creates issues, with variability in project viability making the project appraisal process difficult.
Fairness	4	By looking to the generators themselves to bid the curtailment level, this approach is theoretically fairly even handed as it is connecting generators based upon what their stated appetite to take curtailment.
Learning	4	This is a novel approach that would generate useful learning on the appetite for generators to enter into a competitive process.

7

Key Conclusions and
Proposed Approach



7.1

Scoring

Table 15 below summarises how the options scored against the criteria of assessment set out in Sections 5 and 6. For some of these categories, options have been given variable scores given the inherent design trade-off. These scores are intended to provide a guide on appraisal based on the arguments specifically developed in this report rather than represent a definitive conclusion.

Table 15: Option Scoring

Criteria	LIFO	Vintaging	Capacity Quota	Reinforcement Quote	Capacity Auction
Efficiency	1	2	4-5	3-4	3-4
Certainty	5	2-4	2-4	3-4	2-4
Simplicity	5	3	2	3	3
Fairness	1	2	2	4	4
Learning	1	3	5	5	4
Total Score	13	12-14	15-18	18-20	16-19

7.2

Key Conclusions

In light of the extensive analysis and appraisal process set out, we have made the following high level conclusions:

Table 16: Key conclusions

Option	Key Benefit	Key Drawback
LIFO	<p>LIFO is a tried and tested commercial arrangement that is simple to understand and implement.</p> <p>Its key selling point is its ability to insulate prospective connectees from increased curtailment caused by later, unknown, generation.</p>	<p>By allocating capacity on a first-come-first-served basis, early generators will receive a windfall benefit while all curtailment and risk is shouldered by later generators, calling into question the fairness and efficiency from a capacity allocation perspective.</p> <p>With each generator experiencing different levels of curtailment, and with lower levels of connection overall, the likelihood of generators reaching a consensus on shared reinforcement action becomes unlikely.</p>
Vintaging	<p>Vintaging has the undoubted advantage of simplicity and relative certainty for the generators.</p> <p>From the moment that time gate closes, each generator in a vintage will be able to estimate its worst case curtailment forecast assuming that all generation in its vintage actually connect as envisaged.</p>	<p>The lack of control that UK Power Networks has over the size of each vintage could make this approach difficult to administer in practice with uncertain efficiency gains.</p> <p>Generator attrition could further reduce efficiency gains.</p> <p>Long “time-gates” could reduce short term certainty for generators.</p>
Capacity Quota	<p>Capacity quotas have the undoubted advantage of offering a potential universal approach, with the theoretical maximum available generation capacity that could connect in each constrained zone being calculated in advance.</p> <p>Could significantly improve the connection process if applied more widely as available capacity under an actively managed network could be displayed together with the worst case curtailment levels where the desired quota was filled.</p>	<p>Determining the level of maximum curtailment presents some substantial challenges for UK Power Networks in terms of sizing the appropriate capacity limit.</p> <p>Efforts to model the internal economics of the different generator types that might connect in the FPP trial zone has demonstrated that not only is there a wide variance in terms of acceptable levels of curtailment, but that the results are highly sensitive to key assumptions used in terms of capex costs and capacity factor.</p>
Reinforcement Quota	<p>Sizing a quota based on the anticipated trade-off between the cost of curtailment and the corresponding cost of reinforcing the network to alleviate a constraint provides a sound and justifiable methodology on which to determine the size of a quota and the maximum level of curtailment that generators would be asked to accept under FPP.</p> <p>Potentially, drives cheaper firm connection for all generators on a coordinated rather than incremental basis with no need for investment ahead of need.</p> <p>In addition, by setting a quota, rather than just locking in a vintage or specific group of generators, loss of efficiency as a result of generator attrition is not an issue.</p>	<p>Challenge of determining and costing a viable reinforcement plan for each constraint not knowing the DG volumes.</p> <p>This methodology may not necessarily return acceptable levels of curtailment where the reinforcement costs are larger and the headroom in the existing infrastructure is not large enough to bring sufficient volumes of generation forward under ANM (or other smart solutions). As such, it can not necessarily be universally applied.</p>

Table 16: Key conclusions (cont.)

Option	Key Benefit	Key Drawback
<p>Capacity Auction</p>	<p>This approach allows a certain degree of “price discovery”, circumventing the thorny issue of determining maximum curtailment encountered with capacity quotas.</p> <p>Once allocated, an auction of capacity has the benefit of providing a high level of certainty (like LIFO and Vintaging) as the volume of generation to be curtailed pro-rata will be known upfront.</p>	<p>The efficiency of this solution will depend on the level of competition for capacity which for the majority of constraints may be limited.</p> <p>Practically this approach has the risk of breaking down into a series of bilateral negotiations. This would turn what had started out as a transparent open auction of capacity into a rather opaque negotiation for access which risks challenge.</p>

7.3

Summary of Proposal

7.3.1 A Hierarchical Approach

In light of the conclusions set out in Table 16, it is proposed that the smart commercial arrangements governing the connection of generators under FPP should use a multi-tiered hierarchical approach involving:

- Option 3 (Reinforcement Quota) as the primary proposal; and
- Option 4 (Capacity Auction) as a the back-up approach where the size of the quota determined under Option 3 requires generators to withstand unreasonable levels of curtailment and there is no case for strategic investment.

The interaction between these two options is set out below and summarised in Figures 37 and 38:

- The starting point for at any constrained location will be the application of Option 3 (the Reinforcement Quota). As such, for each constrained location, UK Power Networks will determine what coordinated network reinforcement plans might be possible for varying volumes of uncertain DG deployment connecting in any particular constrained zone.
- Using the cost of these reinforcement plans, UK Power Networks would calculate, using the methodology set out in Section 6.4, the reinforcement trigger by reference to the trade-off between the cost of reinforcement and the rising cost of curtailment.
- The commercial proposal offered to generators looking to connect in a constrained zone will be a reinforcement quota based upon the calculation above, unless the quota and reinforcement trigger returns “unacceptably high” curtailment levels.
- Initial thoughts would be to treat worst case curtailment of in excess of 6% as “unacceptable” for these purposes. This would be justified by reference to the initial financial modelling results set out in Figure 24 of Section 6.3.2, which shows that the highest tolerable curtailment level for any generator type under the high capex assumptions

is 6%. However, it is anticipated that this threshold will be further refined as UK Power Networks looks to engage with developers and as other industry participants (i.e. Renewable UK) gain experience in this area.

- For those constraints in respect of which a reinforcement quota based on the full reinforcement cost is not a viable proposition, UK Power Networks will then look at whether there was a potential case for strategic investment in this area.⁴⁵ Factors taken into consideration will be, amongst other things, the availability of resource (i.e. good wind speeds, high solar radiance) and the pipeline of new applications. The extent of the strategic investment would equal the amount required to bring the worst case curtailment levels down to acceptable levels.
- If a case can be made, then a reinforcement quota will be offered with a deferred reinforcement charge from the first-comer generators that, together with the committed strategic investment, funded reinforcement once the quota was full and the reinforcement trigger met.
- If a case cannot be made, then what headroom there is in the existing network infrastructure will be auctioned to those generators looking to connect in that area in the manner envisaged in Section 6.5. ANM and FPP for these generators would therefore represent an enduring solution, with all the long term curtailment risk that this entails.

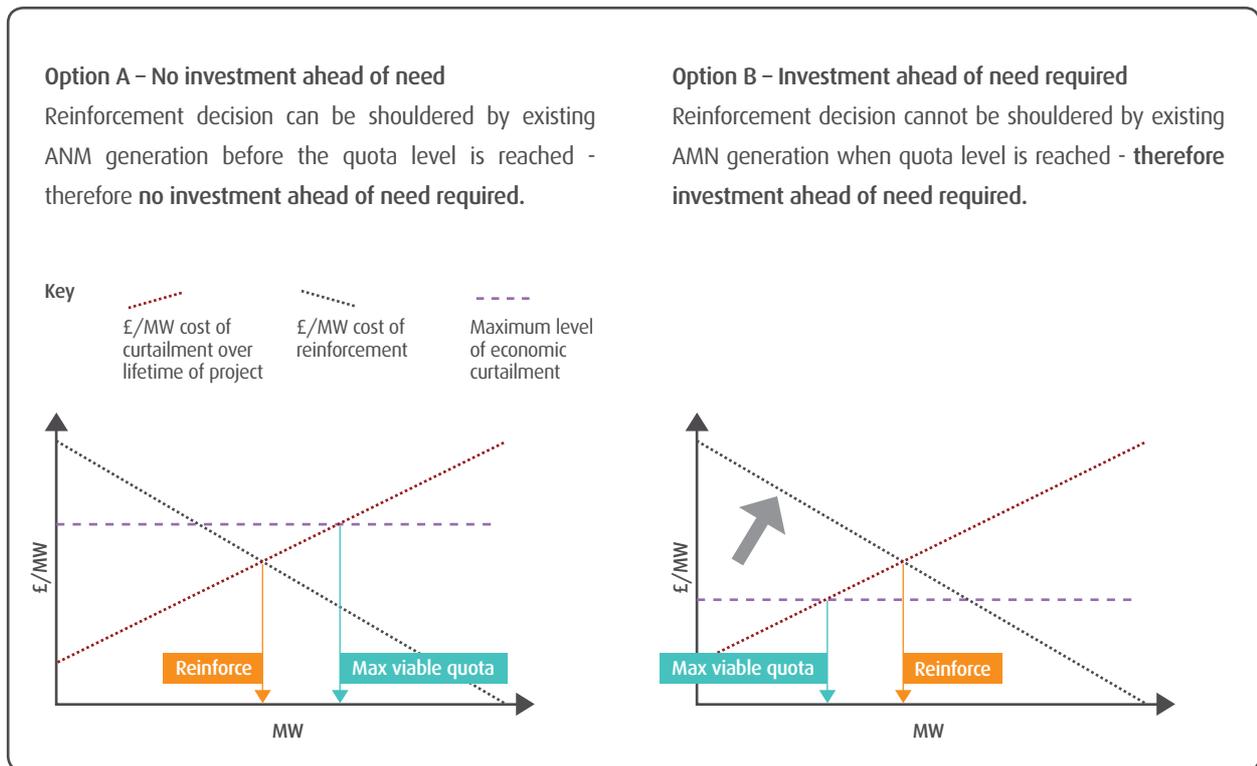
The objective of the FPP project is to provide cheaper and faster connections to generators. This multi-tiered approach acknowledges the dual role that ANM can play in terms of achieving this goal. It can provide a temporary mechanism by which generators can exchange savings on incremental firm connection offers for curtailment, with the option of reinforcing on a coordinated basis once a critical mass of generation has materialised at a later date. It can also provide an enduring solution by which additional headroom in the network assets can be unlocked with generators choosing a permanent

⁴⁵ Under the current price control period DCPR5, funding of this investment would be through the DG incentive.

non-firm connection option with long term curtailment risk. However, in addition, the methodology acknowledges the grey area in the middle, providing a tool for UK Power Networks to quantify the exact level of anticipatory investment needed to open up an area with good renewable resources. If UK Power Networks was able to set the quota at a capacity level that would bring forward the interested generation and allow

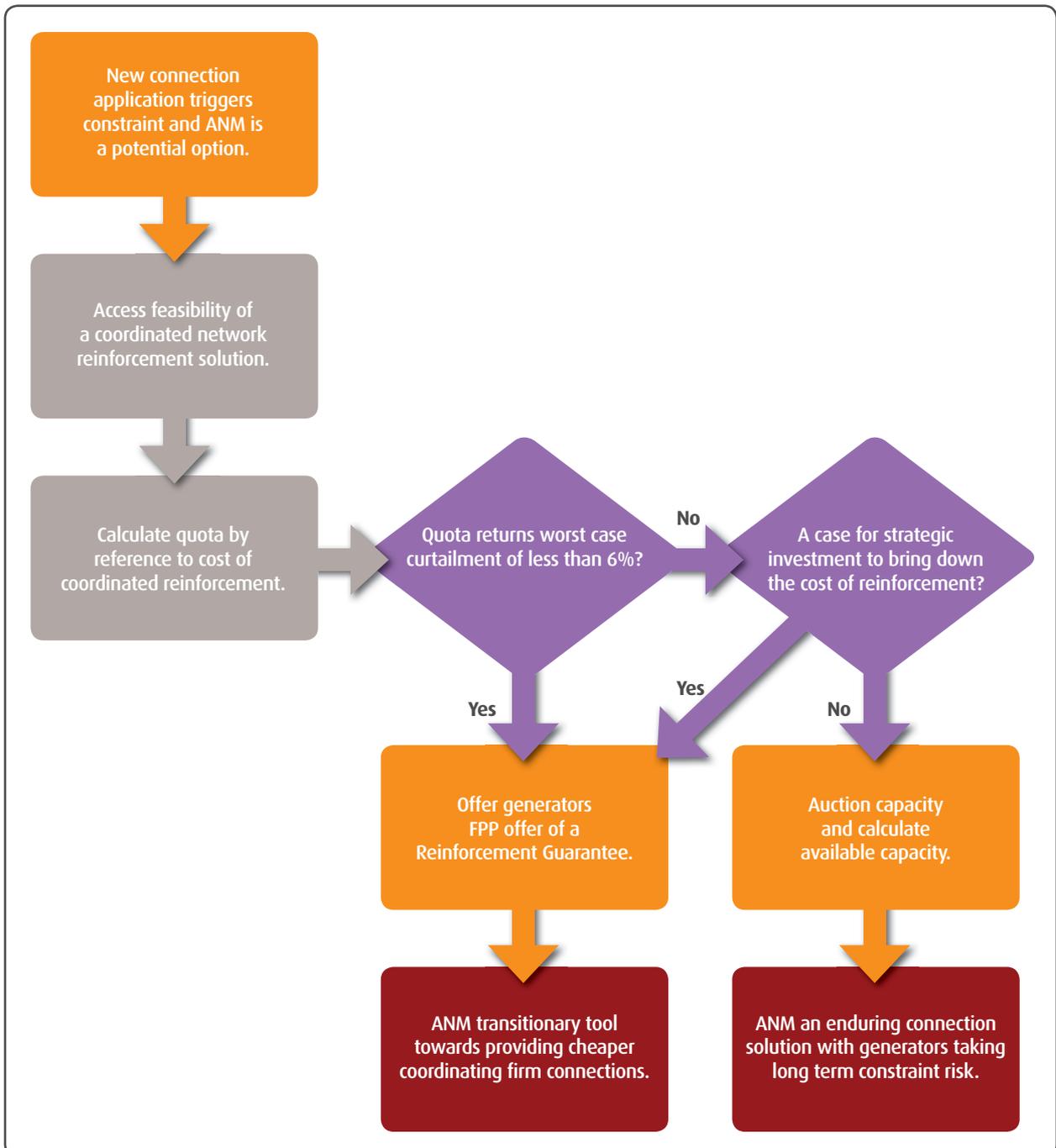
recovery of a significant proportion, but not necessarily all, of the upgrade costs, then in the event that the decision was taken to make that upgrade, the level of stranding risk socialised could be significantly reduced. This more sophisticated quantification of the stranding risk would allow more intelligent investment decisions in network build out. Figure 37 below looks to summarise this dynamic.

Figure 37: Interaction between viable capacity levels and reinforcement cost



The full integrated methodology set out is summarised in Figure 38 below:

Figure 38: Decision tree on application of commercial proposal



7.3.2 Mandatory vs. Voluntary Reinforcement

As highlighted in Section 6.5.3, one of the key questions with the reinforcement quota approach is whether the funding of reinforcement once the quota is full is mandatory or voluntary. From a network efficiency perspective, the mandatory reinforcement option is probably the more optimal. However, the key issue with respect to this approach is that it could create significant financing challenges for generators who would in effect need to put in place a contingent standby facility for the payment of a contingent connection liability. This could significantly increase financing costs. Moreover, they may not know for a number of years whether this charge will in fact be levied, creating uncertainty which may not be welcome. This translates into a corresponding risk for UK Power Networks where it is unable to recover the aggregate cost of reinforcement from the FPP generators already connected because they either refuse to pay or they are unable to pay due to a cash flow constraint.

This issue of recovery risk could potentially be mitigated as follows:

- Gaming by Generators – Wilful default on payment of the deferred connection charge (i.e. “gaming”) could be disincentivised by including a termination right in the connection agreement under which the generators connection is de-energised in the event that they fail to pay the deferred connection charge. This would provide a sufficiently large deterrent to avoid wilful default from generators.
- Insolvency or cash flow constraints - The cash flow issue could be solved by, instead of requiring the Generators to

pay the deferred charge upfront, the cost could be amortised across the remaining life time of their project (as is done already at a transmission level with TNUoS charging). This has a number of advantages:

- ✓ Firstly, the generators should theoretically be left in a cash neutral or cash positive position as the cost of reinforcement should be less than the increased revenues that they receive once firm.
- ✓ Secondly, it allows a more sophisticated and fairer allocation of the reinforcement cost across generators that connected at different times. For example, a generator that has been connected for five years should not necessarily pay the same per MW as a generator that connected 2 years ago as the remaining life of their wind farm is different (i.e. 15 years for the first and 18 years for the second). Moreover, the first generator has experienced 3 more years of curtailment which is a cost to their project.
- ✓ We note that UK Power Networks are still taking credit risk on the generators (and potentially over a longer period of time), however at least the structure of the payment profile lowers the risk of default.

A key next step of the development of the commercial proposal will be to consult with generators on which option between mandatory or voluntary reinforcement would work best for their project. As we have highlighted in the section above, there are advantages and disadvantages with both, and stakeholder feedback will be key to deciding on which to implement as part of the FPP project.



8

Commercial Proposal

8.1

Introduction

While the cornerstone of the commercial proposal is the principles of access which have been considered in some detail in Sections 2 to 7, the FPP connection agreement will also need to deal with a number of other issues which relate to the interruptible nature of the agreement. Sections 8.2 to 8.5 following highlight some of these key commercial issues. In addition, UK Power Networks has created a connection agreement template for the FPP connection.

8.2

The FPP Connection Process

One of the key tenants of the principles of access described is that all generators that are offered connections in the trial zone who could potentially affect curtailment levels of other ANM generators subject to any particular constraint should be ANM controlled subject to the same agreed curtailment rules.

As such, one of the primary obligations of UK Power Networks in the FPP connection agreement will be to ensure that all generators that contribute in some way to a constraint will be ANM controlled. It will therefore be vital that FPP is embedded into the s16 firm connections process to ensure that, for every connection offered to generators in the trial zone, a series of checks are carried out to ensure that no connection is granted to any generator at a point of connection where its output would contribute to a constraint, unless the relevant generator will be ANM controlled and subject to the agreed principles of access. UK Power Networks would still be able to offer the generators an alternative firm connection offer in another unconstrained zone of the network.

The only exception to the rules described above, will be whether there is a threshold of generator size below which it would not be possible or practicable to include those generators within the ANM scheme. The lower that threshold, the easier it will be to predict the output growth of these uncontrollable micro-generators. This is important for the purposes of forecasting likely curtailment through time for generators who are committing to “interruptible” FPP connection offers. Interestingly, one of the key learning points that has emerged from the Orkney smart grid project implemented by SSE has been the risk of underestimating micro-generation growth. This project initially implemented a 50kW de minimis threshold. However, with the introduction of the small scale FIT in 2008, micro-generation growth accelerated and has started to drive higher than anticipated levels of curtailment for the ANM controlled generation that had already connected. As such, SSE has been forced to implement a moratorium on

the connection of further micro-generation while it develops and implements a technical solution that will enable all micro-generation to be brought within the ANM scheme.

In view of this experience, an approach could be that the threshold for mandatory participation in FPP will be 3.6kW on a single phase supply or 11kW on a three-phase supply (the “De Minimis Threshold”). This is effectively the lowest level that UK Power Networks could practicably require generation to be ANM controlled. Generation below this threshold is classified under Engineering Recommendation G83/1-1 (“ER G83”) as Small Scale Embedded Generators (“SSEG”) which is effectively entitled to connect “behind the meter” and therefore, provided it is installed by an approved contractor, UK Power Networks has no control over the manner of their connection. As such, the lowest feasible threshold for mandatory participation in FPP is the ER G83 threshold for the definition of SSEG.

As already discuss above, the principal advantage of this ideal approach is that it provides the greatest level of certainty possible to those generators that are connecting under FPP as to the likely levels of curtailment. However, the obvious disadvantage of this approach is that this will impose a disproportionate cost burden on smaller micro-generators relative to larger projects and it will be technically complicated to integrate many generators to the ANM scheme. The cost of bringing a generator into the ANM scheme envisaged under FPP varies between £20k and £30k. Therefore, imposing this fixed cost on all generation units above the ER G83 threshold could make it prohibitively expensive for smaller generator without the economies of scale to absorb that cost. Alternatively, the threshold will have to be raised, and UK Power Networks will have to make an assumption within the curtailment modelling as to the additional uncontrollable capacity that this will allow onto the system over time. However, the up-shot of this approach, while potentially easier to implement from a technical perspective and more

favourable to micro-generation economics, is that it introduces additional uncertainty for generators assessing whether to connect under FPP.

8.3

Eligibility, Milestones & Longstop Date

Under FPP there is a heightened need to avoid speculative projects reserving capacity in a quota and effectively sterilising the capacity made available under FPP. As such, it is key that the FPP Connection Agreement allows speculative projects to be filtered out and the capacity re-allocated at every stage of project development up to commissioning. As such, we would propose the following obligations be included:

- Firstly, within 3 to 6 months of signing of the connection offer, the developers will need to demonstrate that their projects have received all major planning and environmental consents for the construction, operation and decommissioning of the relevant generating unit. This is especially important for wind projects, for which planning risk is a key concern.
- Secondly, after 6 months following signing of the connection agreement, the developers need to provide evidence that a sufficiently material financial commitment has been made to the project. This essentially benchmarks how robust the project is by reference to the financial commitment of its sponsors and financiers. This is the approach that is proposed for FPP.

SSE on the Orkney smart grid project includes a longstop date for completion. If the generation project is not commissioned by this date, the project is “demoted” to be bottom of the LIFO curtailment order. While this approach has its merits, in that it is simple and easy to police, the only problem is that it could be seen as a fairly draconian by the developers themselves if UK Power Networks had the right, after the developer has made considerable investment into the generation project but for reasons outside its control (i.e. financing constraints, land acquisitions), the construction programme slips such that it is relegated from the quota. As such, the milestone approach tied to a “minimum spend”, looks to strike the right balance between avoiding sterilisation of the capacity and the need to not unnecessarily prejudice generators interests.

8.4

Reporting

For the vast majority of the generators that participate in the FPP trial, this will be their first encounter with ANM and curtailment. One of their primary concerns might be how they can be confident their output has in fact been curtailed in accordance with the principles of access set out in their connection contract. It is therefore important that a robust reporting mechanism is included in the FPP commercial arrangements to building generator trust in the correct application of curtailment.

8.4.1 Form of Reporting

For technical reasons, real time data provision to allow the developers to be able to observe in real time that curtailment has been correctly applied is not possible. As such, the proposed alternative is to provide generators with an ex-post report on the operation of the ANM scheme in a given period. This could be a monthly, quarterly or bi-annual report including the following:

- Current allocated capacity to the quota and shortfall from the reinforcement trigger (where applicable);
- Number and duration of threshold breaches at each constraint location, or possibly some sort of statistical representation;
- Number and duration of curtailment instructions sent to each generator, or possibly some sort of statistical representation;
- Information on communication or other failures that have resulted in curtailment; and
- Information on any other problems and their resolution.

These reports would need to be produced internally for UK Power Networks monitoring purposes in any event. However, the content would need to be presented in such a way for any version provided to generators to avoid giving generator visibility on commercially sensitive information on other generation units on the system. This may therefore require the development of a bespoke report for each developer. In addition to the scheduled report, UK Power Networks could also include a right for the generators actually to request information or one-off reports in relation to specific curtailment events, incident or period of time, where they doubt that the ANM system is functioning properly.

8.4.2 Disputes

There is a risk that a generator disputes the veracity of the information on curtailment provided in the curtailment reports described in section 8.4.1, claiming that curtailment has not been in accordance with the agreed principles (e.g. a fault, or curtailment being applied other than in accordance with the principles of access). The FPP connection agreement will therefore need a dispute resolution mechanism by which UK Power Network's curtailment reports are audited and endorsed by an independent third party expert (i.e. a technical consultant). The Expert would then be able to provide a determination as to whether curtailment was correctly applied, with this decision binding the parties. The cost of such a certification would then be borne by the party in fault. This is a common contractual mechanism for resolving technical disputes.

8.5

Liability for Curtailment Forecasts

As explained, generators will be required to invest behind an FPP connection offer based on its confidence in the curtailment forecasting, in particular the veracity of the assumptions that underpin those forecast. Notwithstanding the fact that UK Power Networks will be assisting generators in the creation of these curtailment forecasts, it is critical that generators understand that UK Power Networks is providing absolutely no guarantee as to whether those forecasts are based on reasonable assumptions. As such, as part of the FPP connection agreement, UK Power Networks must protect itself by including a robust disclaimer of liability for any losses suffered by the generators as a result of curtailment levels being higher than anticipated, or the assumptions used to generate those forecast proving to be incorrect or inaccurate in any way.

Annex 1

FFP Opt-In Offer

1 Summary

This annex summarises how UK Power Networks has engaged to date with those developers identified as potentially benefiting from a Flexible Plug and Play (“FPP”) Solution within the FPP trial area. The FPP project team has been monitoring the generation connections activity in the area and has proactively engaged with seven generation developers seeking connections in the FPP trial area. The seven projects are seeking connection at constrained parts of the trial area network and, as a result, their conventional Section 16 (“S16”) connection offers include significant costs for provision of expensive sole use assets.

In particular this annex is structured into the following sections:

- Paragraph 2 describes how the existing S16 firm connection offers have been varied to allow developers to participate in the FPP project prior to having full visibility of the nature of the FPP connection terms (the “FPP Opt-In Offer”);
- Paragraph 3 provides an updated table on the developers that have been identified as having the potential to benefit from the FPP connection and those that have accepted an opt-in offer and have been recruited into the FPP process;
- Paragraph 4 describes the information that UK Power Networks has provided, or intends to provide, to the developers - alongside their FPP Opt-In Offer - to encourage them to engage in the process. This paragraph also outlines the planned engagement process with developers, out to the expiry of the Opt-In Offers in March 2013.

2 FPP Opt-In Offer

The FPP Opt-In Offer will be available to eligible generators who have made (or who intend to make) a formal application for a Section 16 connection. This will ensure that the benefits of the FPP approach are evaluated on the basis of firm, rather than speculative, generation developments, thereby leading to greater confidence in the validity of the approach as a future business-as-usual alternative.

In view of the fact that the exact details of the FPP connection offer have yet to be determined, and so as to avoid forcing the generator to choose between a firm and non-firm connection until they are in a position to properly appraise the relative merits of the two options, developers will have the assurance of knowing they can revert to opting for a conventional s16 connection offer at any time during the development of an alternative FPP offer by UK Power Networks.

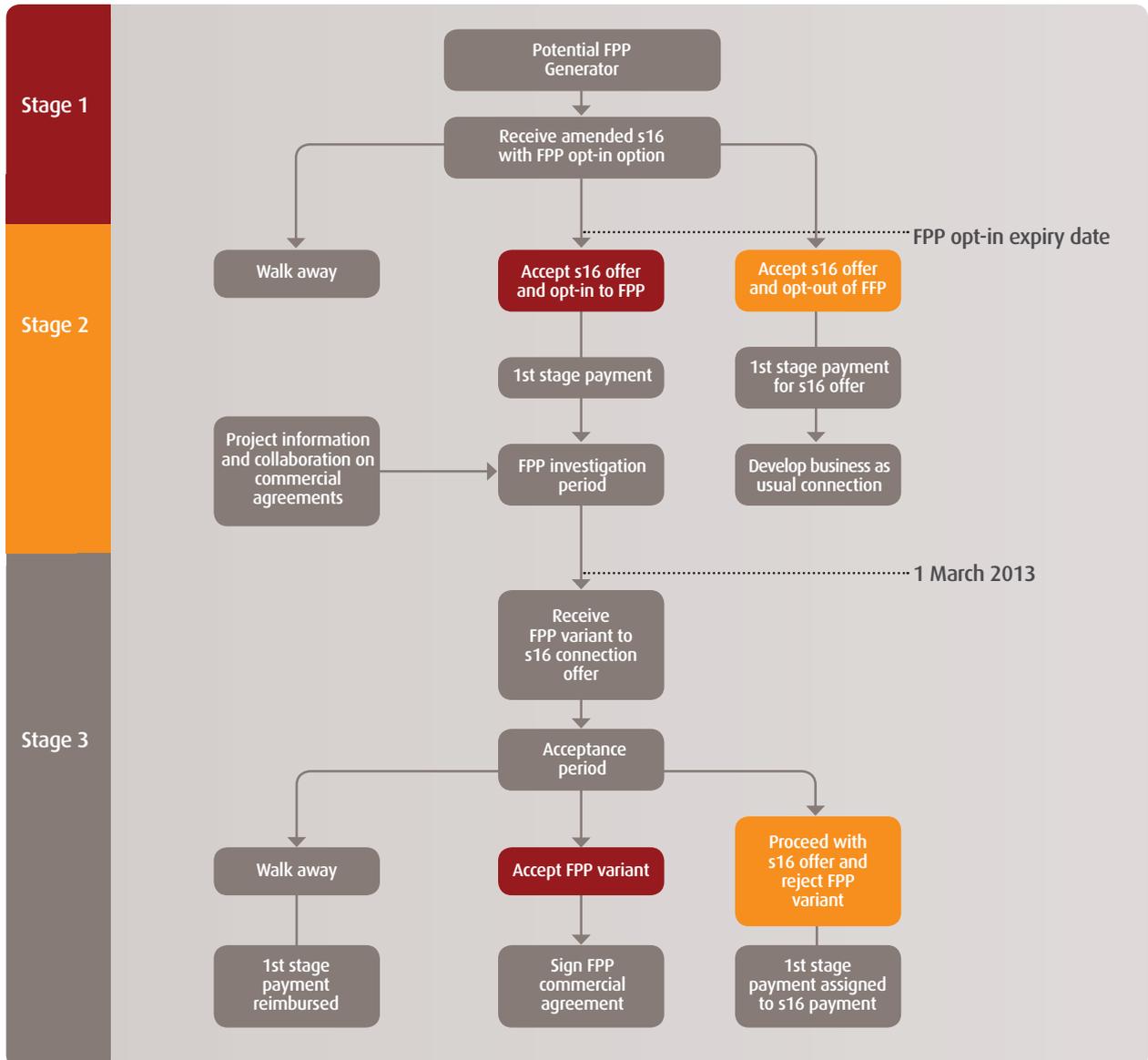
The process to which these developers have been subjected is illustrated in Figure 39.

As illustrated in the diagram, UK Power Networks has set out a process to engage with identified potential FPP-eligible generation projects. The developers identified are presented with an FPP Opt-In Offer that grants them three options during the first stage of the process:

- If the developer does not want to participate in FPP and cannot, or does not want to, accept an FPP firm offer, they can let the offer expire and walk away from the process at the end of the 3 month Opt-In acceptance period.
- If the generator decides not to participate in FPP, they can simply accept an s16 firm offer and opt-out of FPP.
- If the generator is interested in participating in FPP, but wishes to accept an s16 firm offer, they may do so and still opt to participate in FPP. By doing this, the s16 firm offer (i.e. the schedule of works and payment instalments) is effectively suspended. However, the generator is required to pay a small refundable deposit. On 1 March 2013, the generator will be issued with a variation to his s16 firm connection offer which will outline the terms of the FPP Connection (based on the contents of this report). The generator will then be given a month to do one of the following:

- accept the variation and proceed with FPP;
- reject FPP and automatically revert to the s16 firm offer; or
- terminate the offer altogether, in which case the FPP deposit would be reimbursed and the generator is permitted to walk away from the process.

Figure 39: FPP Opt-In Offer



3 Customer Recruitment

A number of developers of generation projects in the FPP trial area, who have submitted formal connection applications, have been identified as potentially benefiting from a FPP solution. These are set out in Table 18 below:

These generation customers have now been engaged by the FPP team, and those who have decided to opt-in the FPP process will be receiving FPP offers in 2013. However, the FPP Project will continue to identify potential FPP generation projects within the trial area until the end of 2014. For this purpose, the FPP team is working closely with UK Power Networks' Connections department to filter all projects within the area that request generation connections and determine the potential for participating in FPP in terms of their location and the technical characteristics of the generation and their connection. All projects that are assessed as being potentially feasible for FPP participation are contacted by UK Power Networks and the FPP project team to enter this engagement process.

The long-term goal of the FPP Project is that consideration of FPP's smart grid technologies and novel commercial arrangements will become embedded in UK Power Networks' approach to the evaluation of options for providing connections

to generation developers. Therefore, integrating these options to the connection and infrastructure planning processes is essential for making FPP part of the business as usual.

4 Customer Engagement

By accepting to opt-in to Flexible Plug and Play, the generation customers referred to above have agreed to wait until 1 March 2013 for UK Power Networks to make an FPP connection offer which will lay out the terms and conditions of the non-firm connection as well as the technical description of the connection design. In the meantime, UK Power Networks has set up an engagement plan with developers to inform them of the FPP process and its various components. This will also provide UK Power Networks with the necessary insights regarding the characteristics of their developments and the developers' views on the commercial package selection and methodology.

The first task to accomplish before presenting generators with an FPP connection offer is to analyse the implications to them of applying the principles of access described in this paper. Once a decision has been made on how terms and conditions will be proposed to generation developers, UK Power

Table 18: Target Projects as of December 2012

Project	Capacity	Technology	Constrained zone	FPP Opt-in offer
Generator A	5MW	Wind	March	Accepted
Generator B	0.5MW	Wind	March	Accepted
Generator C	10MW	Wind	March	Accepted
Generator D	2.5MW	Wind	March	Accepted
Generator E	1MW	Wind	March	Pending response
Generator F	16.4MW	Wind	March	Pending response
Generator G	7.2MW	Wind	Peterborough Central	Accepted

Networks must ensure they understand what their connection agreement will entail and, at the same time, provide a robust indication as to the levels of curtailment to which they might be subjected. These activities will be undertaken during the “FPP Information Period” which is divided into two sections: a) selecting the principles of access and b) conducting the curtailment analysis.

4.1 Information Period

All customers that elect to opt-in to FPP will be presented with a briefing document as a first step to sharing the ideas around curtailment and ensuring that the implications of a non-firm connection are understood. The FPP Briefing Document presents the thinking around commercial packages and principles of access alternatives, and has three objectives:

- Share background information on FPP;
- Provide an overview of the smart technologies that UK Power Networks is considering implementing for connecting that specific generator, and provide information on the technical characteristics of their connection; and
- Lay out the progress that UK Power Networks has made so far in terms of determining the commercial implications and curtailment risk.

Finally, this document also outlines a time schedule of engagement as well as a list of information required by UK Power Networks to evaluate the technical and economic feasibility of each individual project. This list may include wind turbine information, wind data on which they have based their financial projections, capacity factors, layout, etc.

It is important to note that at any time during the FPP Participation Period the developer can: a) serve notice to opt-out of the FPP process, restart the s16 firm connection and hence trigger the s16 first stage payment; or b) walk away

from the connection application altogether at which point the first stage payment will be refunded to the developer.

4.2 Curtailment Analysis

After providing insight to the commercial outline that will be presented to the developers, and having performed analysis of what their connections will look like, UK Power Networks will undertake the task to perform curtailment analysis for each developer. The objective of engaging with developers throughout this process will be to gain their confidence that the modelling tools are reliable and that the assumptions made in the preparing the estimates are adequate for their projects. By describing a realistic worst-case curtailment scenario, developers will be better able to objectively evaluate the benefits of an FPP connection.

4.3 FPP Offer

Once prospective curtailment levels have been presented to generation developers, and a consensus has been reached on the commercial approach for the FPP connection agreement, developers will be presented with the actual FPP connection offer. This offer will detail the related works required to connect the project under the non-firm scheme utilising smart grid technologies, as well as the relevant terms and conditions.

4.4 Progress so far

Pending the publication of this report, five generators (as summarised in table 18) have accepted the FPP opt-in offer and have received a briefing document. Meanwhile, the FPP project team is progressing to provide a forecast of their potential curtailment levels to those generators. During the next three months, the FPP project team will work closely with the participating customers to engage on the commercial terms for the non-firms agreements and develop a commercially attractive

Annex 2

Rationale and Regulatory Pre-Requisites to Underwriting Curtailment Risk

1 Introduction

1.1 Curtailment risk

Under the proposed smart commercial arrangements set out, generators have to accept all curtailment risk. UK Power Networks is giving generators no long-term undertaking as to the likely levels of curtailment through time. Instead, before agreeing to connect, interested generators need to carry out a detailed technical appraisal of the assumptions underpinning curtailment forecasts that they will be exposed to before the reinforcement quota level of capacity is reached, so that they can establish whether they are comfortable with the level of long-term curtailment.

However, through the stakeholder consultation process and review of international experience, there have been questions asked as to whether generators are best placed to manage the risk of curtailment, and also whether the conservative assumptions used to underpin the curtailment forecasting on which these generators will make their investment decision may lead to lower levels of DG connection, and underutilisation of the headroom released by the smart network solutions being deployed as part of Flexible Plug and Play (FPP).

Therefore, the objective of this annex is to explore the possibility of UK Power Networks underwriting curtailment for these generators in more detail, to consider developing for future commercial arrangements for non-firm connections.

1.2 Structure

The Annex is structured as follows:

- Section 2 explores how the proposed initial smart commercial arrangements for FPP could adapt to underwrite curtailment;
- Section 3 discusses why we should consider underwriting curtailment in FPP and the benefits that this could bring;
- Section 4 sets out the issues and aspects of the regulatory regime which make underwriting curtailment unfeasible at present;
- Section 5 proposes a framework to design a regulatory incentive to encourage DNOs to take commercial risk to underwrite curtailment in non-firm connections.

2 How Underwriting Curtailment Could Work

2.1 Fitting with proposed initial smart commercial arrangements

We have proposed that the smart commercial arrangements governing the connection of generators under FPP should use a multi-tiered hierarchical approach involving:

- Option 3 (Reinforcement Quota) as the primary proposal; and
- Option 4 (Capacity Auction) as a back-up approach where the size of the quota determined under Option 3 requires generators to withstand unreasonable levels of curtailment and there is no economical case for strategic investment.

These smart commercial arrangements could contain provisions to underwrite curtailment, and therefore under certain circumstances, they would transfer the risk of curtailment to UK Power Networks, once they have passed the level of curtailment that generators can tolerate. For each of these options, this would have the following effect:

- In arrangements where the reinforcement quota is applied, underwriting curtailment would ensure that generators have a way to keep their revenues 'whole' if curtailment levels exceed those assumed in the sizing of the reinforcement quota (for example if demand assumptions turn out to be incorrect).
- Similarly, in the capacity auction arrangements, underwriting curtailment would ensure that generators have a route to compensation if their bid curtailment volumes are exceeded.

2.2 Commercial approaches for underwriting curtailment

Different approaches exist for underwriting curtailment and making actual payments. Here, we explore two potential models for underwriting curtailment that could form part of either of the smart commercial arrangements:

- **Capped curtailment:** where UK Power Networks compensates generators for curtailment if it exceeds a level forecast at the outset.
- **Capped balancing charge:** where UK Power Networks compensates all generators (firm and non-firm), but recovers the cost of doing so from the non-firm generators in a capped annual “balancing charge”.

We emphasise that underwriting curtailment in FPP maintains the principle of connecting generators where they agree to incur a certain cost of curtailment. This is either provided as curtailment that they offer to tolerate for free, known as their “first loss”, or it is provided where generators are required to pay a balancing charge up to a capped annual amount. Either approach assumes that generators agree to a level of cost associated with curtailment that they can tolerate. It is essential that this is retained, as the savings from being able to offer an FPP non-firm connection accrue primarily to the generators themselves. This is why it is underwriting and not straight paying for curtailment, as it is only providing the means to guarantee generators that their revenues will remain whole if curtailment costs rise above what was agreed to the outset.

2.2.1 Capped Curtailment

Under this approach, UK Power Networks would underwrite curtailment risk for a generator by providing a cap on the aggregate level of curtailment that a generator can expect in any given year (or month). If the generator is curtailed beyond

this level, it will be paid compensation at a level that keeps it whole for its lost opportunity cost and any penalties that it incurs as a result of not being able to export as planned.

UK Power Networks would aim to expend all generators’ caps, following which it would pay on a least cost optimisation by integrating each generator’s Constraint Sensitivity Factor⁴⁶ and the compensation payment per MWh of curtailed output. In this way, non-FPP generation could also be included in the scheme if it was efficient to do so (i.e. if it is cost effective for non-FPP generators to participate and if it reduces the aggregate curtailment costs for any given constraint) – see Figure 40 overleaf.

2.2.2 Capped balancing charge

Under this approach, all generators, FPP and non-FPP, would be paid for any level of curtailment, on the basis of least cost optimisation from the start. As the compensation payable to each generator would reflect their expected lost opportunity cost, this approach would be able to minimise the aggregate cost of connection by constraining the least expensive generators first – see Figures 41 and 42 overleaf.

UK Power Networks would then recover the costs of making these payments from FPP generators only as a form of balancing charge. However, as with the capped curtailment option above, the extent of this balancing charge would be capped to give generators long term certainty as to the worst case financial impact of curtailment on their project. To the extent that total compensation payments exceeded the aggregate total of the capped maximum “balancing charge” of all FPP generators, this amount would need to be absorbed by UK Power Networks.

⁴⁶ Constraint Sensitivity Factor is described in section 5.2.2 of this report.

Figure 40: Capped Curtailment

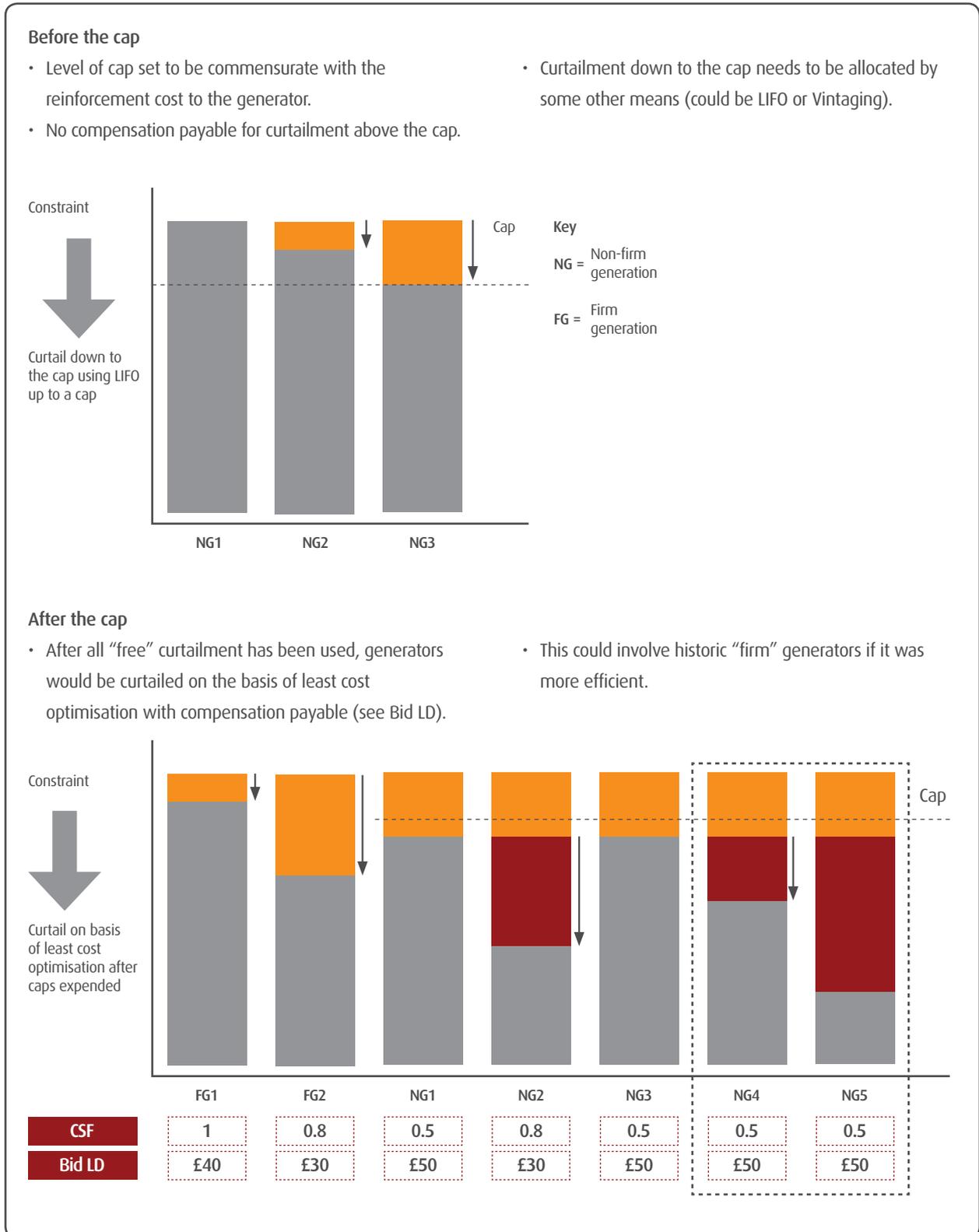


Figure 41: Capped balancing charge – payment flows before the cap is hit

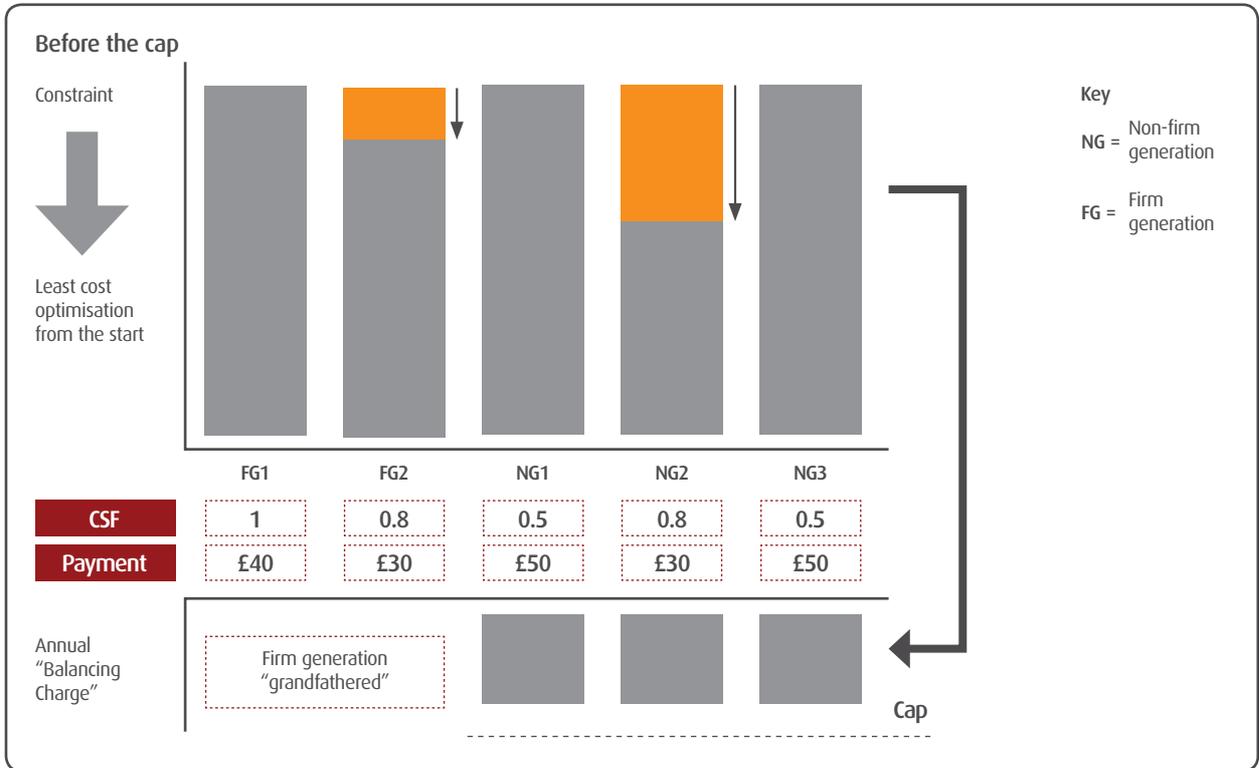
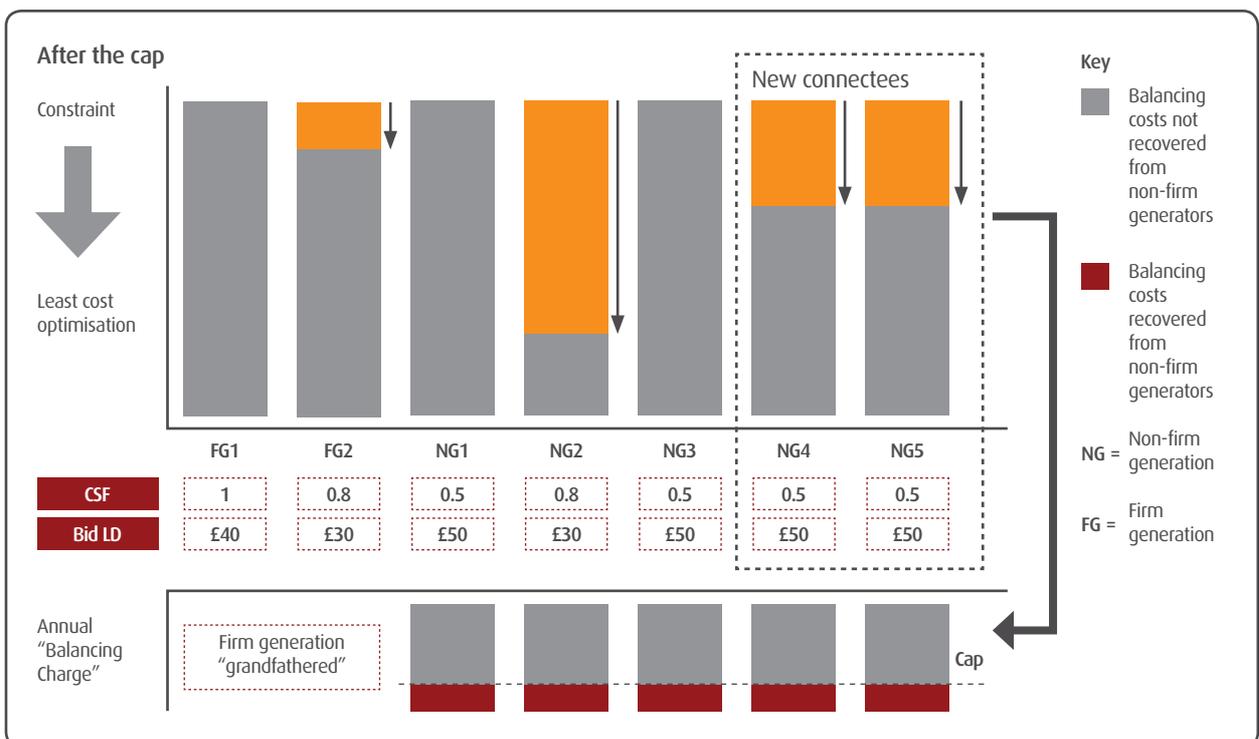


Figure 42: Capped balancing charge – payment flows after the cap is hit



2.3 Compensation Payments

A key design challenge facing both of these approaches is how the compensation payments are structured and the specific rules on when they are paid to minimise disputes and potential for gaming to benefit from payments. Clearly, making payments that are reflective of the actual costs of curtailment to these generators is fair, though this value is difficult to ascertain. While it could be ascertained with real time bidding this is unlikely to be feasible unless implemented on a much larger scale. Moreover, lack of competition behind constraints could give rise to similar problems experienced at a transmission level with generators bidding into the balancing mechanism amounts in excess of their theoretical maximum lost opportunity cost.

As a result, a mechanism for calculating compensation payments would probably need to be hard-wired into the contract up front. These costs would include foregone revenues from electricity sales and foregone government support revenues from the lost production of ROCs, LECs, foregone small scale Feed in Tariffs or payments from Feed-in-Tariffs with Contracts for Difference (from 2014). The value of these revenue streams will vary over time as a result of market forces and government policies. While compensation payments could track the prevailing price of electricity or ROCs in the wholesale market, generators are arguably in a better position to manage market based risks. Therefore, it would probably be appropriate for these generators to agree a fixed payment for curtailment above the first loss level in their contracts with UK Power Networks.

3 Rationale

3.1 Background

In order to accept curtailment risk in the manner envisaged above, while UK Power Networks would no doubt need to be appropriately incentivised to minimise curtailment liabilities (see Section 5), consumers may also need

to be prepared to share some of this risk. As such, proposals to transfer curtailment risk from generators to UK Power Networks and consumers will need to be justified by reference to the savings or other benefits the new arrangements might bring to the wider system.

It is important to note from the outset that any proposal to transfer curtailment risk away from the generators could create an inconsistency when viewed narrowly against the current allocation of costs under the common charging methodology. Box 2 sets out the key principles upon which connection charging is based. In summary, the key problem is that the application of the 'minimum scheme' tends to drive a more incremental rather than coordinated network build-out, the cost of which is principally funded by the generators. As such, by proposing a transfer of risk away from generators in an effort to lower their overall cost of connection, UK Power Networks could be accepting liabilities which, when viewed against the current capital cost allocation of the common connection charging methodology, should properly be payable by the generators themselves.

Therefore, before exploring the obstacles to UK Power Networks implementing arrangements to underwrite curtailment, it is important to justify how this transfer of risk (and potentially liabilities) could drive benefits for wider users.

3.2 Reasons for UK Power Networks to take curtailment risk

Broadly speaking, the justification for a transfer of risk away from generators to UK Power Networks (and potentially to consumers) would need to be framed around two key concepts:

- First, by virtue of its position in the value chain and role in the markets place, UK Power Networks is arguably better placed to appraise and manage curtailment risk than the generators; and

Box 2: The Common Connection Charging Methodology

UK Power Networks and the other DNOs implemented a version of a common connection charging methodology in October 2010 to increase consistency and transparency and to give customers better means to understand and estimate potential connection charges.

The methodology sets out how DNOs should charge for a new connection to its network. In summary, UK Power Networks calculates the connection charge based on the estimated costs of the 'minimum scheme' which is the connection scheme with the lowest overall capital cost solely to provide the required capacity for the connection.

The minimum scheme is calculated from the costs of linking the customer to the network (the extension asset, generally referred to as "sole use" asset) and reinforcing the network to handle the impact that their extra load may have on the network (reinforcement costs).

While extension assets are fully charged to the connecting customer, reinforcement costs are apportioned between UK Power Networks and the customer according to the customer's incremental impact on the network⁴⁷ – unless an exception to the apportionment rule applies, in which case the customer pays for the reinforcement in full (e.g. one of the exceptions is if the customer requests reinforcement in excess of the minimum scheme).

- Second, underwriting curtailment risk would allow UK Power Networks potentially to lower the overall cost of curtailment to the system as a whole.

In this way, by being able to forecast curtailment better and manage its effects through the connection process, ANM control systems, and strategic network planning, UK Power Networks could potentially connect more DG to the distribution network at a lower cost which would unlimitedly benefit the consumer by lowering the overall cost of meeting the EU 2020 renewable energy targets.

3.2.1 Placing risk with the party best placed to manage it

For project developers and their financiers, the long term financial impact of curtailment is crucial to the viability of their projects. As explained above, the FPP commercial arrangements leave all curtailment risk with the generators. As such, one of the primary objectives of the development of these arrangements has been developing a clear and transparent set of rules for curtailing FPP generators in response to a network constraint. This allows the generators

to model the technical characteristics of the network and the output of other generators and simulate curtailment under these specified principles of access. Therefore project developers connecting under FPP will need to conduct a robust technical appraisal of the curtailment forecasting methodology and assumptions to ensure that they are comfortable that the forecasts do not underestimate the amount of curtailment that their projects may be exposed to.

As set out in Figure 43 overleaf, the key inputs and assumptions into forecast will be the following:

- forecast levels of demand growth,
- forecast levels and types of generation (both in terms of existing generators and, in relation to any quota based approach, future generation capacity that might connect up to the cap on capacity),
- forecast levels of micro-generation,
- network topology, reliability and conditions, and
- the impact of weather conditions on the nature and extent of the constraints.

⁴⁷ Costs are apportioned using one of two 'cost apportionment factors' (security or fault level) depending on which factor drives the need for reinforcement of the network.

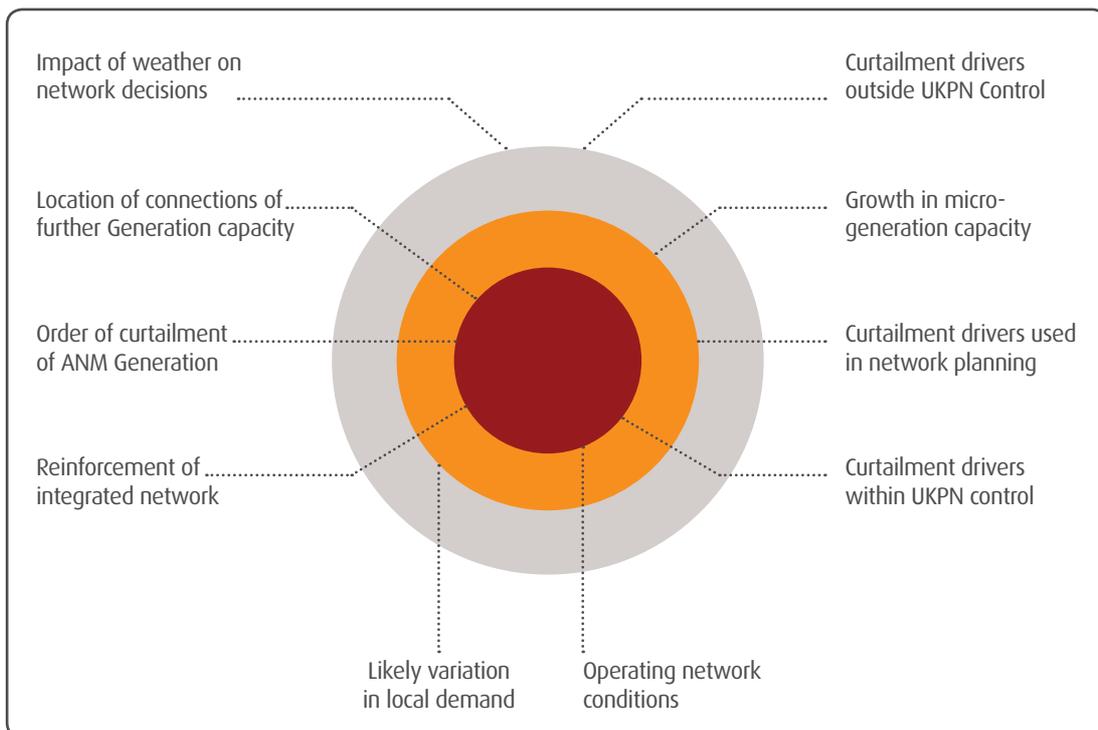
However, all of these inputs are outside of the individual generator’s control. Moreover, generators are not familiar with the underlying drivers or likely behaviour of these inputs. For example, generators will have little visibility on the likely levels of demand growth on the local network, patterns of consumption or uptake of micro-generation. With little familiarity with the dynamics affecting curtailment of their project, generators are likely to use conservative assumptions when it comes to generating the forecasts on which they make their investment decision.

While this conservative approach is necessary to reduce the level of perceived risk for connecting projects, the assumptions taken may not be reflective of the actual levels of curtailment that projects will experience, i.e. the forecasts could overestimate the level of curtailment that projects will actually experience, and underestimate the size of the quota

that can be connected behind the constraint for a given level of curtailment. The result of these assumptions is a lower level of generation connecting behind a constraint than could be feasibly connected for any given level of curtailment.

In contrast, however, UK Power Networks as a DNO has considerable influence over the extent and nature of number of the drivers of curtailment (e.g. how and where generators are connected and the manner in which the network is operated). While a number of the drivers remain outside of UK Power Network’s control, like demand and micro-generation growth, these are nevertheless key assumptions used to underpin its wider network planning. In this way, understanding long term demand, consumption patterns and the impact of the growth of micro-generation on their network is a core part of UK Power Network’s business. This is illustrated in Figure 43 below:

Figure 43: Drivers of curtailment



Hence, if UK Power Networks was able to underwrite curtailment, it might be able to take more realistic assumptions in its curtailment forecasting, provide certainty to developers, which would result in a greater volume of DG capacity that could be connected in any constrained zone for a given level of curtailment.

3.2.2 Enabling UK Power Networks to conduct curtailment in the least cost way

The principles of access being considered as part of FPP and described in the main body of this report look to fuse the order of curtailment with the financial implications of that curtailment on the generators. This is essential as, with no long term guarantee as to the level of curtailment, generators have to forecast curtailment and therefore need a predictable set of rules on which to do so.

However, if UK Power Networks was able to underwrite long term curtailment, the need to fuse technical and financial allocation of curtailment would be less important. As such, UK Power Networks would be less constrained in the manner in which it curtailed the generators to allow it to minimise the aggregate curtailment cost for any given constraint. Two benefits are described below:

- **Optimising network operations** – Wholesale changes in grid topology for maintenance or operational efficiency reasons will affect levels of curtailment by changing the constraints to which different generators are subjected. However, this operational flexibility in running arrangements is fundamentally inconsistent with the principle of curtailment forecasting. This is because providing stable forecasts in a world in which the generator is accepting all curtailment risk will require complex assumptions and undertakings from UK Power Networks as to how it will run its network. Therefore, if generators are not exposed to long term curtailment risk above a capped level, UK Power

Networks would be less constrained as to the manner in which it operated its network.

- **Least cost optimisation** – Curtailing based on a fixed order of constraint (i.e. pro-rata, LIFO) fails to recognise that the cost to each generator of the lost revenue associated with each MWh of lost output will differ depending on technology type and subsidy regime (amongst other factors). The most efficient way to curtail generators would be on a least cost basis, solving any particular constraint by integrating both the generator's Constraint Sensitivity Factor and its cost of curtailment. Underwriting curtailment in the manner envisaged in the capped balancing charge approach described in paragraph 2.2.2 above provides the DNO with the opportunity to do just that. It disaggregates the technical rules of curtailment from the financial impact of curtailment on individual generators to enable the DNO to have flexibility to minimise the aggregate economic cost of curtailment, and then to spread the economic impact evenly across non-firm generators.

3.3 Summary

Underwriting curtailment could expose UK Power Networks - and potentially consumers - to costs in an area where they may not have been exposed to costs previously. In this way, generators with a non-firm connection who are paid to be curtailed are not facing the full costs that they impose on the system, and are having their revenues subsidised as a result.

However, the ability to connect more DG behind any given constraint offers FPP derived savings to more generators, and if rolled out more widely, it could lower the cost of DG deployment as a result. This does not necessarily come at a cost to UK Power Networks and consumers, because as long as UK Power Networks is able to call upon 'free' curtailment cost in the form of generators' first loss, or tolerable level

of balancing charge, it can use its own judgement and controls to manage the level of curtailment that generators are exposed to, and the level of curtailment that consumers are exposed to.

Underwriting curtailment is a contractual arrangement that, as we have explained above, could provide the DNO with more flexibility of how it operates the network. This is a role akin to something that a distribution system operator (DSO) might be expected to perform, and while the need to develop DSO-like arrangements is not necessary under current regulatory obligations, it is important that the DNOs are able to trial arrangements that are likely to be needed by DSO-like institutions in the future. We discuss the obstacles to UK Power Networks developing such arrangements at present in the next section.

4 Obstacles To Underwriting Curtailment

4.1 Introduction

The underwriting of curtailment levels to generators as envisaged in Section 2 involves a level of risk transfer to UK Power Networks. In order to be able to do this, UK Power Networks as a network operator needs to satisfy two key commercial criteria:

- First, is the return commensurate with the additional risk that it is taking on?
- Second, is the balance of risk and return in line with the shareholder expectations and what it already accepts in the rest of its business?

Managing curtailment risk will involve UK Power Networks carrying out a role, and accepting a type of risk, that is qualitatively different from that which is accepted in the course of its business today. Set out below, are two reasons why UK Power Networks, under its existing regulatory arrangements, is not in a position to underwrite curtailment.

4.2 Insufficient incentives to take curtailment risk

The current regulatory framework features insufficient incentives for UK Power Networks to take curtailment risk. It primarily incentivises a DNO to try to outperform its baseline on allowed expenditure, for activities such as capital for reinforcing use of system assets (shared network assets) and operating expenditure. There is a DG incentive in the current price control, which encourages DNOs to connect generation while limiting the need for major reinforcement to earn higher than regulated rates of return, but this is still focused on the DNO's reinforcement investment, and this specific incentive is anticipated to be discontinued for RIIO-ED1 from 2015.

As discussed above, in the context of FPP the majority of the savings created through a transfer of curtailment risk would accrue to the generators rather than UK Power Networks (and wider consumers) through reduced curtailment risk, and allowing extra generators to benefit from or take advantage of FPP benefits. With no use of system savings, UK Power Networks is unable to drive a return for accepting curtailment risk through savings to consumers against its business as usual investment plan.

This is not to say that faster and cheaper connections for DG generators are not incentivised at all under the existing regulatory arrangements. Ofgem's strategy consultation for the RIIO-ED1 price control suggests a number of outputs which could indirectly benefit from the roll-out of FPP. However, the strength of relationship between performance in these incentives and taking commercial risk is unproven, and the level of reward on offer is unlikely to be sufficient to take commercial risk on contractual arrangements where UK Power Networks is exposed to any significant downsides. Such incentives include the Broad Measure of Customer Satisfaction (BMCS), the Average Time to Connect Incentive and the Guaranteed Standards of Performance (GSoP) in Connections.

4.3 Taking DSO type risks without the DSO framework for recovering costs

Even where underwriting curtailment risk does drive a saving (either through avoided cost apportionment on connection charges or through the deferral of wider network reinforcement), equating capex savings to curtailment payments fails to acknowledge that the risk of cost overrun on a construction programme is qualitatively different from the risk of higher than expected curtailment. Whereas with the former, the vast majority of the potential variables are within UK Power Networks' control, the same cannot be said of the commercial risks assumed by UK Power Networks under the contracts envisaged in Section 2. Underwriting curtailment in this manner would involve UK Power Networks taking on DSO types of risks, but without the DSO style framework for cost recovery and incentive mechanisms, so that UK Power Networks is still exposed to considerable commercial risk.

The way the Transmission Systems Operator (TSO) manages curtailment risk is through recovering compensation payments (accepted bids in the Balancing Mechanism) through Balancing Services Use of System (BSUoS) charges levied on network users. At present, the systems operator forecasts these costs every two years, and Ofgem places incentives on it to keep costs within these forecasts. These charges are reconciled against actual costs so that the systems operator is not exposed to excessive over or underspend. For example, if the systems operator over or underspends against its forecast it is exposed to some of the extra cost or saving respectively, subject to a dead-band. The amount the systems operator is exposed to – the 'sharing factors' are 25% for either overspend or underspend for the period 2011-2013⁴⁸.

The DNO regulatory framework does not currently allow for such flexibility to provide for market based risk. It is designed for capital and operating expenditure that can be accurately forecast and then set as baselines by Ofgem during a price

control ahead of an applicable period. The DNO can then face incentives on its over or underspend, and ultimately deliver value for money for its consumers. Some flexibility is provided through the use of uncertainty mechanisms, which allow the DNO to alter its allowed expenditure during the price control (such as volume drivers, which can increase allowed revenues to account for an unexpected volume of, say, connections, according to Ofgem's view of unit costs) though existing uncertainty mechanisms are unsuitable for recovering curtailment payments.

In comparison, a balancing charge would offer DNOs the most flexible means of recovering curtailment payments outside of the price control structure. It could also give Ofgem a number of levers to assess balancing performance and place incentives on the DNO to forecast balancing accurately and minimise the cost of balancing, both for generators and consumers.

However, a new DSO regulatory framework does not need to be established for the purposes of FPP. Under FPP, the DSO would only initially be balancing a very small ring-fenced 'pocket' of its network, which means that a full regime change would probably be excessive at this stage. There are ways to provide for underwriting curtailment under the existing framework without a DSO – for example, costs arising from underwriting curtailment in FPP could be forecast at the beginning of the price control and then updated each year, with fluctuations in costs recovered through a bespoke uncertainty mechanism. Such costs could be treated as 'fast money' enabling UK Power Networks to recover costs quickly, to minimise the costs of raising working capital.

Alongside these work-arounds, it remains important for the existing DNO regulatory framework to be flexible so that smart contractual arrangements can evolve ahead of the need for a formal DSO in the future.

⁴⁸ Ofgem, 2011. National Grid Electricity Transmission System Operator Incentives from 1 April 2011, [online].

4.4 Conclusions

Overcoming these obstacles relies on making the regulatory framework flex to accommodate new commercial arrangements. Clearly, if UK Power Networks is to move towards underwriting curtailment for generators in order to facilitate earlier connections of DG and co-ordinated reinforcement, there is a need to design a specific incentive to encourage DNOs to perform DSO style roles in the future. In the case of FPP, a specific incentive is needed for the ‘balancing act’ of making UK Power Networks both:

- take curtailment risk for FPP generators with the aim of connecting higher quantities of DG more rapidly; while
- minimising exposure for consumers to additional costs arising from it underwriting curtailment for generators.

The specific incentive would need to be different to the previous DG incentive, which focused on ensuring that use of system assets were in place or reinforced adequately for expectations of future DG connections. Instead it could focus on the additional DG that could be connected as a direct result of underwriting curtailment, and could be linked to the savings created for these individual generators’ connection costs. This is explored in the next section.

5 Incentive Design

As discussed in Section 4, a specific incentive would be required to encourage UK Power Networks to underwrite curtailment risk in FPP connections, but also minimise the potential costs for consumers of doing so. While this mandate sounds quite specific, the principles could be adapted wherever it is appropriate for DNOs to take commercial risk on behalf of other parties in the future in the absence of an incentive mechanism built around a DSO role. In this section we propose a high level framework for building an incentive for FPP connections, covering key issues such as potential upside, risk sharing and paying for the incentive.

The specific incentive would need to form part of a larger package focused on DNOs’ efforts to connect DG using smart arrangements which make connections faster and cheaper. While it is interesting to note that DNOs will need to consider whether the current regulatory arrangements would appropriately incentivise DNOs to build the ‘vanilla’ FPP connection agreements (as proposed in the main body of this document) into their business as usual practices, this annex is concerned primarily with the design of a mechanism to incentivise appropriately DNOs to take on and then successfully manage curtailment risk to connect more DG than would be possible under vanilla FPP.

5.1 Principles for design

5.1.1 Objective

Underwriting curtailment is a means to an end, not an objective in itself. As we discussed in the Rationale section, the main benefit to underwriting FPP curtailment is the possibility of being able to connect more DG more rapidly on a constrained network, and to operate the network more efficiently, than would otherwise be the case with curtailment risk left with the generators.

However, underwriting curtailment is basically a risk transfer exercise from generators to UK Power Networks and potentially to consumers. By underwriting FPP curtailment, UK Power Networks could potentially allow more generation to be connected than under vanilla FPP, but in doing so it risks exposing consumers to the costs of curtailment. Therefore, the incentive should also pursue an objective to minimise costs passed to consumers.

As such, the incentive should be designed so that:

- It is paid for by the main beneficiaries, generators
- At the first cut, UK Power Networks is exposed to any curtailment risk, with costs offset against its incentive, and

- It provides for a form of sharing mechanism such that consumers are able to underwrite curtailment risk to cap UK Power Networks' potential exposure.

5.1.2 Upside

It is a robust principle to link the value of UK Power Networks' incentive to the additional benefit that underwriting curtailment provides. The additional benefit would arise from the extra capacity that UK Power Networks can connect behind a constraint in two ways: first, the additional DG capacity that connects as a result of underwriting curtailment benefits from a cheaper and faster FPP connection, where it otherwise may have had to connect through a more expensive minimum scheme. Second, if all generators decide to reinforce at a point in the future, as there is greater capacity before reinforcement is triggered, the individual contributions to reinforcement would be lower, and the level of stranding risk that these generators are exposed to on their reinforcement would be reduced.

Focusing on the benefit arising for the additional DG capacity, an incentive could be calculated as follows:

- UK Power Networks could calculate the capacity it would have been able to connect without underwriting curtailment (i.e. using vanilla FPP)
- It would then calculate the amount of capacity it is able to connect by underwriting curtailment, netting the two to give the additional capacity it has connected,
- It would assess the cost of connecting the additional capacity if it had not been able to connect them through FPP, (i.e. the minimum scheme);
- Then it would assess the total cost of connecting the additional capacity through FPP with underwriting curtailment, including capital costs, and lost revenue from curtailment;
- Its incentive could be a portion of the saving in connection costs that it has received for these additional generators.

- For example, if underwriting curtailment allows UK Power Networks to connect 40MW of DG where it could only connect 30MW with vanilla FPP arrangements, it would assess the cost of connecting the extra 10MW (including the NPV of the generator's lost revenue from curtailment) against the cost of connecting these generators firm through a minimum scheme (i.e. a 'conventional' scheme not utilising vanilla FPP smart technology). The incentive could be a fixed percentage of that saving, and could be charged to generators in their connection costs (see 'Paying for the Incentive' below).

This is not to say that such an incentive would not come without its challenges. For example, there would be particular difficulties calculating how much generation UK Power Networks would be able to connect, unless this was a specific question as part of the connection agreement discussions. Further, the cost of a minimum scheme is often bespoke, and may not have been viable for the additional generators anyway. The real saving would therefore be between the additional generators' willingness to pay for a connection and the all-in cost that UK Power Networks has been able to achieve to connect the generation.

The benefit for all generators if they decide to reinforce in the future is more difficult to calculate as a counterfactual is harder to form. While the reinforcement cost in £/MW may be known, the reduction in stranding risk is a function of the number of further future connections, which is impossible to quantify at the point of connecting the first FPP generators shouldering reinforcement risk.

5.1.3 Curtailment risk

UK Power Networks should be exposed to costs arising from underwriting curtailment risk first, ahead of consumers

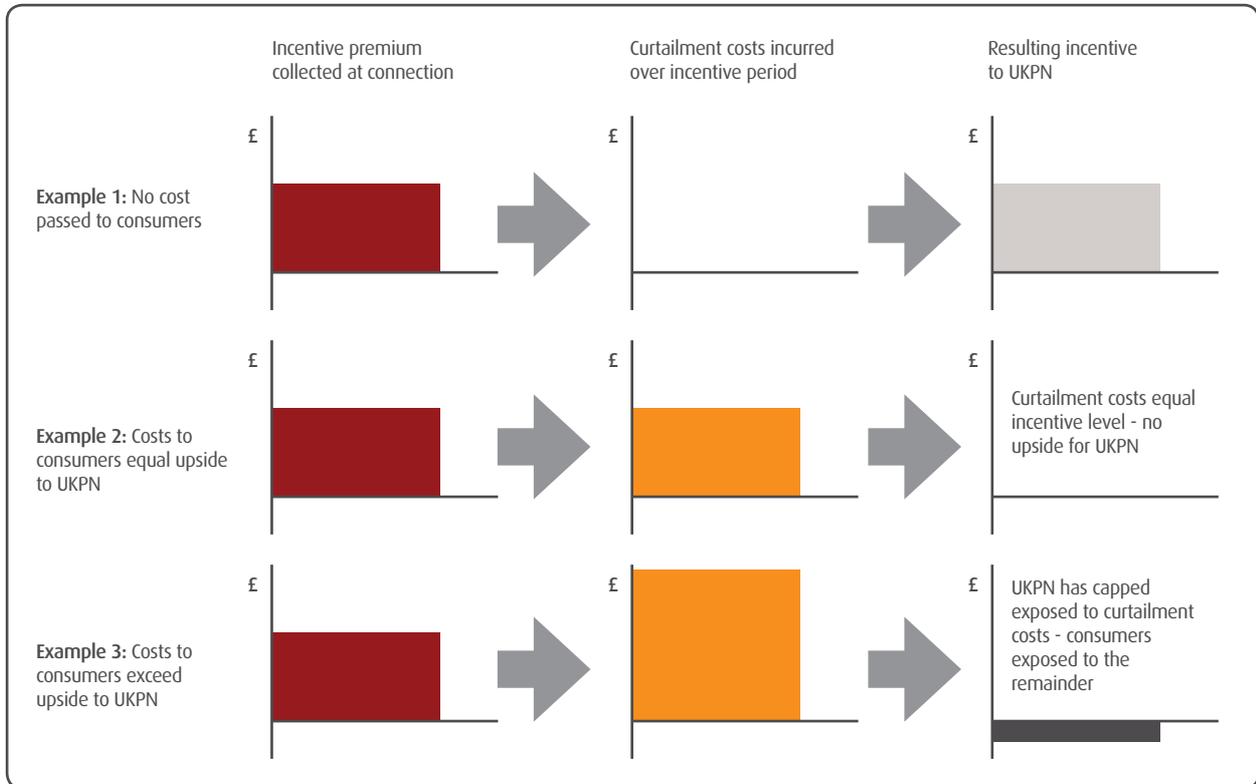
being exposed. Costs could be offset from the incentive that it collects from DG connections, and only then would consumers be exposed to any further costs.

A credible way to achieve this would be:

- By first netting curtailment costs off of any potential upside for UK Power Networks, and
- Then exposing UK Power Networks to a sharing factor of curtailment payments (basically a portion of payments that it is not able to recover from consumers).

This would create a dynamic form of a cap and collar regime, meaning that UK Power Networks' maximum downside exposure is the total of the full amount of upside on offer from the incentive, plus a sharing factor of further curtailment costs (but only down to a certain level, such as a percentage of total allowed revenue - similar to how some of the RII0-ED1, output incentive rates are set). This arrangement could ensure a degree of conservatism in UK Power Networks' decision making (see Figure 44 as an example).

Figure 44: Illustration of how curtailment costs passed to consumers can be deducted from UK Power Networks' incentive



5.1.4 Mitigating against the risk of spiralling curtailment costs

There is a chance that curtailment payments could turn out to be far higher than forecast - potentially higher than UK Power Networks' incentive and any cap on its exposure - meaning that consumers could start to bear an undesirable level of curtailment costs. However, UK Power Networks could use reinforcement as a mitigant against these costs – it could ask generators for voluntary reinforcement contributions, and fund any remainder itself, to recover from future connections at a later date.

5.1.5 Paying for the incentive

All generators connecting through FPP should contribute to the incentive (rather than just the incremental capacity that can be included in a quota by underwriting curtailment risk) because they all benefit from UK Power Networks underwriting curtailment risk.

It follows that UK Power Networks could collect its incentive (as a percentage of the saving for generators) directly from all FPP generators as part of their connection charge under FPP as a margin, or 'curtailment risk' premium. Generators should be willing to pay this if it is a fair level, and if the total connection charges they face including this premium still produce a saving compared to the cost of a minimum scheme for a firm connection.

5.1.6 Applicable period

Savings for generators are produced as soon as they are connected, while curtailment costs can be incurred over time - perhaps years later. It is important that the incentive has some longevity, so that curtailment costs can still be offset from UK Power Networks' incentive if consumers are subject to curtailment costs. This is the compromised alternative to a regularly set incentive to curtail efficiently, such as a balancing charge.

However, in recognition that UK Power Networks cannot forecast every future factor that will influence the level of

curtailment on the network, it is appropriate for the incentive to have a fixed end date. After this date, if UK Power Networks is still underwriting curtailment, then the end date would effectively mean that curtailment costs can no longer be offset against its incentive, i.e. its incentive is protected. However, this could have the unintended consequence of putting curtailment risk wholly with consumers after the incentive end date – in which case it may be preferable to make arrangements to underwrite curtailment time limited altogether. The date for the end of the promise, and the termination of the incentive, could align with UK Power Networks' expectations of future connections on the network, or align with another significant milestone more generally – like the end of beginning of a new price control period.

5.1.7 Accounting issues

If the potential upside available to UK Power Networks is related to the savings it is able to produce for generators, then as discussed in the 'Upside' paragraph, it will be important to define a baseline cost that would have been incurred without underwriting curtailment, so that a saving can be calculated.

However, this calculation could be problematic, and could create perverse incentives for UK Power Networks when it is calculating the reinforcement quota (as the more capacity it can connect through underwriting curtailment, the more of a saving it can visibly 'deliver'). It is likely that an intermediary would be required, such as Ofgem – though this could be administratively burdensome to be applied across many different projects.

If this is deemed the case, a notional upside incentive could be considered for rewarding risk transfer instead, though then the value of the incentive would be challenged, as it is likely

to either over or undervalue actions to underwrite curtailment across different projects.

6 Conclusions

Underwriting curtailment could enable a more efficient use of network capacity and facilitate more DG connections than is possible under both traditional minimum scheme connections, and the initial smart commercial arrangements being designed for FPP.

This annex has explored the uncertainties, which are mainly regulatory in nature, that prevent these arrangements from constituting part of the current principles of access for FPP. These uncertainties are too deeply embedded in the regulatory arrangements for UK Power Networks to offer underwriting curtailment as part of the smart commercial arrangements at this stage, though there are some key analyses and discussions with Ofgem that would enlighten the potential for such arrangements to be used in the future.

As such, it is unlikely that underwriting curtailment will be able to form part of business plans for RIIO-ED1 because of the deadline for consultation and then submission in summer 2013. Time is extremely limited for UK Power Networks to shore up the regulatory treatment of underwriting curtailment, and then to trial underwriting arrangements under FPP.

However, the passing of these deadlines should not prevent the development of regulatory and commercial arrangements to underwrite curtailment to apply in the future. Ideally, these benefits would be quantified, and if they prove to provide significant benefit for the deployment of DG, Ofgem could consider allowing regulatory work-arounds for underwriting to form part of FPP arrangements in the future.

Annex 3

Generator Modelling - Methodology and Assumptions

In section 6 of the main document, the appraisal of the Capacity Quota option includes results on the maximum curtailment that generators might be able to bear. This is based on financial modelling of generic renewable generation projects of the type and scale which might connect in the FPP zone. This section describes the modelling approach and results of this analysis.

1 Modelling Approach and Scenarios

Conceptually, the maximum curtailment that any generator will tolerate under an FPP connection agreement will be the lesser of:

- the maximum curtailment before the relevant project fails to meet a minimum level of financial viability (e.g. a target internal rate of return (“IRR”)); and
- the maximum curtailment before the project fails to meet the rate of return that the project would expect to have returned had it paid for an s16 firm connection.

Both of these curtailment limits require a cash flow model

of generator costs and revenues. The model takes the form of a standard Discount Cash Flow (DCF) model, shown schematically in Figure 45.

As the capacity quota is based upon the premise that it can be set in isolation from the actual generators that are looking to connect in that particular moment in time, it is important that UK Power Networks looks at the sensitivity of different “generic” generator types to the curtailment. This is a function of a number of factors, namely, technology type (i.e. driving capex and opex costs as well as likely capacity factors), subsidy regime that a generator falls within (driving revenue loss as a result of curtailment) and the extent of the cost savings from the non-firm connection. In view of this potential variation, and to ensure that the capacity quota approach can be a truly generic methodology that does not unfairly favour one technology type over another, the modelling approach used modelled a wide spectrum of generator types. These are set out in Table 19 below.

Figure 45: Generator financial model

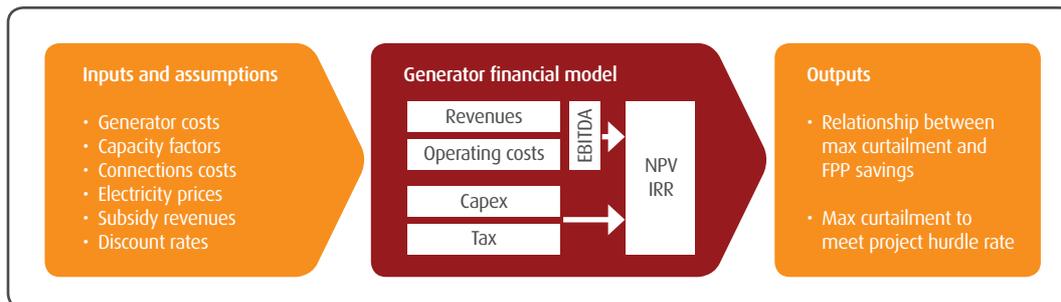


Table 19: Key generator assumptions

Type	Capacity (MW)	Capacity factor	Subsidy regime
Wind_1	1	30%	Small Scale FIT
Wind_2.5	2.5	30%	Renewables Obligation
Wind_10	10	30%	Renewables Obligation
Solar_1	1	15%	Small Scale FIT
Biomass_10	10	100%	Renewables Obligation

2 Modelling Assumptions

The values and sources for key assumptions are presented below. The projects modelled are intended to be representative of typical projects, and it is clear that individual projects could have costs and revenues that differ materially from these assumptions.

Generator costs

Generator costs were sourced from the Arup report⁴⁹ commissioned by DECC as part of the RO banding review, and from the Parsons Brinckerhoff reports⁵⁰ on the costs of technologies eligible for small scale Feed In Tariffs. Table 20 shows the capital cost assumptions used in the modelling.

The costs have been adjusted to remove generic connection costs (assumed to be 5% for wind and solar and 2% for biomass). To incorporate specific connection costs, a typical FPP connection cost of 114 £/kW was used.

In addition to the fixed operational costs, for biomass we also assume a Short Run Marginal Cost of generation of 50 £/MWh, which accounts for the cost of biomass consumed.

Revenues

The revenue assumptions for generators comprise:

- Electricity
- FIT or RO
- LECs
- Embedded benefits

The values of these for each generator are shown in Table 21.

We assume that RO generators sign PPAs under which they receive 90% of the value of power, ROCs, LECs and embedded benefits. We assume that generators under small scale FITs choose to opt out of the FIT export tariff and instead sign a PPA, with a 10% discount on Power, LECs and embedded benefits.

Electricity prices were sourced from Redpoint Energy's GB Power Market Report (April 2012).

Table 22 on page 116 summarises the modelling assumptions used.

Table 20: Generator capital cost assumptions (excluding connection costs) and operational cost assumptions

	Capex (high) £/kW	Capex (medium) £/kW	Capex (low) £/kW	Open £/kW/year
Wind_1	2280	2090	1710	30
Wind_2.5	1765	1471	1115	30
Wind_10	1729	1448	1125	57
Solar_1	1152	1032	967	22
Biomass_10	3794	3275	2745	168

⁴⁹ Arup report https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/42843/3237-cons-ro-banding-arup-report.pdf

⁵⁰ Parsons Brinckerhoff solar PV cost update https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/43083/5381-solar-pv-cost-update.pdf
Parsons Brinckerhoff non-PV cost update https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/42912/5900-update-of-nonpv-data-for-feed-in-tariff-.pdf

Table 21: Revenue assumptions

	Scheme	Power	FIT generation tariff	ROC value (buyout + recycle)	LECs	Embedded benefits
Wind_1	FIT	varies annually	95	-	5.24	5.5
Wind_2.5	FIT	varies annually	44.8	-	5.24	5.5
Wind_10	RO	varies annually	-	40.39	5.24	5.5
Solar_1	FIT	varies annually	71	-	5.24	5.5
Biomass_10	RO	varies annually	-	67.17	5.24	5.5

Table 22: Key generator assumptions

Input assumption	Source/value
Electricity prices	Sourced from Redpoint's GB Power Market Report (Reference Case)
Subsidy revenues: FITs	Current published tariffs as on Ofgem E-serve website
Subsidy revenues: ROCs	<ul style="list-style-type: none"> • Buyout price: assumed constant in real terms at 40.71 £/MWh • Recycle revenue: assumed constant in real terms at 4.07 £/MWh • RO bands from recent RO Banding Review
Subsidy revenues: LECs	Assumed constant in real terms at 5.24 £/MWh
Embedded benefits	<p>Sourced from Redpoint's GB Power Market Report (Reference Case). Embedded benefits comprise</p> <ul style="list-style-type: none"> • Avoided demand Transmission Use of System (TNUoS) charges • Avoided Balancing Services Use of System (BSUoS) charges • Avoided transmission losses <p>Total value = 5.5 £/MW</p>
Power Purchase Agreements (PPAs)	<p>RO generators: 10% discount on power, ROCs, LECs and embedded benefits FIT generators: 10% discount on power and LECs</p>
Generator start date	2014
Generator capital and operational costs	<p>Generation costs reports for DECC:</p> <ul style="list-style-type: none"> • Arup, Review of the generation costs and deployment potential of renewable electricity technologies in the UK, Oct 2011 • Parsons Brinckerhoff, Solar PV Cost Update, May 2012 • Parsons Brinckerhoff, Solar PV Cost Update, July 2012
Connection costs	<p>Range of FPP and firm connection costs sourced from UKPN project data. T</p> <ul style="list-style-type: none"> • Typical FPP connection cost of 114 £/kW • Range of s16 firm costs from ~80 to ~3400 £/kW
Generator capacity factors	<p>Consistent with curtailment modelling</p> <ul style="list-style-type: none"> • Wind: 30% • Solar: 15% • Biomass: 100%
Inflation	2.75%
UK Corporate tax rate	<ul style="list-style-type: none"> • 26% (2012) • 25% (2013) • 24% (2014) • 23% from 2015 onwards
Post Tax real hurdle rate	10%

Annex 4

Curtailement Modelling - Methodology and Assumptions

Smarter Grid Solutions (SGS) has conducted all curtailment forecasts for this report and will be providing curtailment scenarios for the specific generators throughout the FPP project. The purpose of this Annex 4 is to provide a summary of the methodology applied when doing these analyses. It will also specify the assumptions used for the example of March Grid that has been explained throughout this document.

1 Introduction To Curtailment Forecasting

ANM relies on the ability to manage the output of generators as a way of dealing with the different network constraints. SGS conducts curtailment assessment by taking into account the network configuration that affects the power generator connecting to the ANM scheme. This includes considering different constraints in the network such as power flow or voltage level, the layout of transformers, overhead lines or underground cables, and any new technology implemented by the FPP project. The curtailment modelling should also take into account possible faults and the sudden loss of equipment.

2 Curtailment Estimates Calculation

As with all modelling tools, curtailment estimates require input data and assumptions. The more accurate the assumptions are, the better the outputs.

2.1 Input Data

The main input data for a curtailment assessment is time series data for loads, generation or other power input/output elements. For the results presented in this report, time series data on load profiles has been extracted from UK Power Network's data historian. It is sensible to use data that covers full years as this ensure a balanced representation of all four seasons.

It is important to retain correlation between generator output and load profiles. For example, load is higher in winter when wind power is also higher. Also, since all generators considered

in the report are wind farms, to give a conservative assessment of curtailment it is assumed that they have fully correlated profiles (i.e. when wind power is high in one location it will be high in all locations within the study area).

2.2 Assumptions

The main assumptions needed for the curtailment assessment are typically related to the following areas and may have an impact on the input data:

- **Network Configuration** - Changes in the present network may be planned and should be taken into account.
- **Demand/Generation growth** - UK Power Networks has long-established methods for forecasting changes in demand and holds information on new connection applications for demand and generation.
- **Production Factor of new generators** - The profile used for the new generators is based on historical data.
- **Limits and Operating Margins at constraint locations** - The limits of the network depend on what changes are implemented, as part of the FPP project, or separately. Operating Margins are specified before deployment of the ANM scheme but assumptions are necessary at the time of curtailment assessments. UK Power Networks and SGS are the best positioned to advise on these assumptions.

If different assumptions are to be explored then this will create a set of scenarios to be studied in the curtailment assessment.

2.3 Results

Results from each scenario are presented individually. These results will illustrate the expected overall behaviour at the constraint location and then show the estimated impact on generator output. The generator analysis can be extended with probabilistic assessment to generate additional results. The modelling tools can compare generator's output without the ANM scheme in place as well as a worst case scenario

of all generators in place connected and generating at the same time. This will provide developers with an idea of the different behaviour of their power plants and their curtailment throughout time. Numerical results of the curtailment forecasts include estimates of energy generation, production factor and percentage of time that curtailment applies.

SGS also conducts probabilistic assessment with the objective to provide developers, and their financial parties, certainty around the curtailment estimates. This prediction is typically given in the form of exceedance probabilities for annual energy production (AEP). P90 is the annual energy production that is reached with a probability of 90%, or the probability that an annual energy production of P90 is not reached is 10%.

3 Information Required from Developers

As mentioned above, the more information provided to the modelling the more accurate the results will be. To achieve this, the developers identified as potential FPP generators,

have been required to provide information regarding the technology used in their generation plants, manufacturers, generator size, connection capacity, reactive power capabilities, control system compatibility with the ANM scheme, expected energy output, amongst others.

4 Principles of Access

Finally, for the curtailment estimates to be accurate, the rules of curtailment regarding the order in which different generators connecting to the same network are constrained need to be determined so they can be modelled. As the report points out, the different principles of access can be modelled and has helped inform the advantages and disadvantages of some of these set of rules.

5 March Grid Case Study Assumptions

For the March Grid case study that is used throughout the report, the initial forecasting assumptions chosen have been:

Table 23: Forecasting assumptions

Parameters	Code	Options
Network Configuration	NC2	Existing network configuration
Capacity Factor of New Wind	CF2	30%
Principle of Access	POA1 and POA2	As applicable (LIFO or pro rata)
Limits	LS1	34 MVA
Operating Margins	OM2	10%
Generators	GE1	As applicable: <ul style="list-style-type: none"> • GE3 (fixed blocks of 1MW) for all forecast figures except figure 15 • GE2 (fixed blocks of 5MW) for figure 15



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