Economic evaluation of the Active Network Management (ANM) scheme at the Dunbar GSP

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Cover image credit: Hoprgishiels windfarm (Community Energy Scotland)

Contents

1. Terms and abbreviations

ANM	Active Network Management
ARC	Alternative Renewable Connections
BAU	Business As Usual
CBA	Cost Benefit Analysis
CES	Community Energy Scotland
CMZ	Constraint Managed Zone
DER	Distribution Energy Resources
DNO	Distribution Network Operator
DSR	Demand Side Response
DSO	Distribution System Operator – evolution of the DNO role to provide a greater degree of data sharing, network capacity optimisation and the facilitation of flexibility markets
ENA	Energy Networks Association
ERF	Energy Recovery Facility
ESO	Electricity System Operator
EV	Electric Vehicle
GSP	Grid Supply Point
GVA	Gross Value Added
GVA Effect	Calculated level of GVA from income or turnover
GW	Giga Watt
GWh	Giga Watt hour
LCNF	Low Carbon Network Fund
LCT	Low Carbon Technology
LIFO	Last In, First Off
MW	Mega Watt
MWh	Mega Watt hour
NIC	Network Innovation Competition
Ofgem	Office of Gas and Electricity Markets
RIIO-ED2	2023-2028 five-year business plan submitted to Ofgem by each DNO
ROCs	Renewables Obligation Certificates
Shallower Network Charges	A proposal under the Ofgem Network Access and Charging Significant Code Review that, in certain cases, reduce the up-front charges paid by new connection customers
SCR	Significant Code Review: A comprehensive review by Ofgem of the network access and charging regime
SGS	Smarter Grid Solutions
TO	Transmission Operator

2. Executive Summary

Between 2012 and 2016, SP Energy networks and partners implemented an Active Network Management (ANM) scheme on the Dunbar Grid Supply Point (GSP) to enable four new projects, totalling 50MW of generation, to connect to an export constrained network, and one existing 48 MW windfarm to upgrade from its previous inter-trip constrained connection to an ANM flexible connection.

Active Network Management

Active Network Management systems are distributed control systems that continually monitor the limits in a given area on the network (normally a GSP or BSP) and then allocate the maximum amount of capacity to customers in that area. Schemes operate in real-time and monitor inputs, outputs, network flows and voltages at key points within the controlled zone. If the network is approaching limits, the ANM controller instructs actions to be taken. These could be changes in network topology or changes in the power into or out of the network, depending upon the characteristics of the particular system.[1]

ANM is therefore a step up from more basic alternative connections, such as inter-trip connections, that simply curtail individual customer connections based on a pre-set capacity and/or time limit parameter. To do this, ANM control systems are highly automated and protect the network by responding on a second or sub-second basis. This requires some pre-set logic to determine the order in which individual customer assets are curtailed. In the case of early and legacy ANM schemes, such as Dunbar, this is usually based on a queue management or priority approach. More sophisticated approaches could incorporate additional market price drivers, or an approach that determines the best technical combination of assets, to fully optimise network capacity utilisation and operation.

ANM can therefore allow more customers to connect within a given constraint area, or allow customers to connect new capacity or better utilise existing capacity ahead of the necessary network reinforcement.

The Dunbar ANM scheme was one of a number of early stage ANM schemes that was funded as a Low Carbon Network Innovation Fund (LCNF)[2] trial and delivered within the Alternative Renewable Connections (ARC)[3] project. A parallel ANM scheme was also trialled at the Dumfries and Galloway GSP. The ARC project tested a number of technical and commercial innovations exploring how ANM could be more widely deployed and used to connect Distributed Energy Resources (DERs) ahead of planned network reinforcement in constrained areas.

[1] https://www.spenergynetworks.co.uk/userfiles/file/ESDD-01-009.pdf
[2] https://smarter.energynetworks.org/projects/spt2004/
[3] https://www.spenergynetworks.co.uk/pages/arc_accelerating_renewable_connections.aspx

The Dunbar ANM scheme has now been discontinued, network upgrades having been made in 2021 and customers moved unto firm connections. As the scheme has ended, Regen was asked by SP Energy Networks to evaluate the economic and carbon benefits of the scheme, and to assess lessons learnt for how ANM approaches might evolve and continue to add value in the coming years, in light of; the emergent Distribution System Operator (DSO) functions, use of 3rd party flexibility solutions, regulatory changes and ambitious timescales to decarbonise the entire electricity system.

2.1. Summary economic evaluation

Five projects were connected to the ANM monitoring and control system on the constrained Dunbar GSP between 2015 and 2019, well ahead of a planned network reinforcement in 2021. Due to funding sources, and in particular the need to secure Renewable Obligation Certificates (ROCs), four out of five of these projects would probably not have gone ahead at all if they had had to wait until 2021 for a firm connection. The remaining project, the Aikengall Community Wind Farm, was upgrading from an existing inter-trip constrained connection to ANM.

Table 1 Major projects connected to the Dunbar ANM scheme, 2015-2020

Project name	Export capacity	Date commissioned
Aikengall wind farm	48 MW	2015
Dunbar ERF (Energy from waste facility)	36 MW	2018
Hoprigshiels wind farm	7.5 MW	2017
Kinegar wind farm	5.0 MW	2017
Ferneylea wind Farm	1.5 MW	2019

Regen's analysis showed that the implementation of ANM at Dunbar led to some clear economic and carbon benefits including enabling total capital investment of an estimated £200m, the creation of 56 FTE long term[4] jobs, £75k of community benefits funding per year and an estimated carbon saving of 98 thousand tonnes.

The economic analysis, summarised in Table 2, has followed the guidelines for Impact Appraisal and Economic Evaluations suggested by Scottish Enterprise.[5] Full details of the methodology, assumptions and basis of these estimates are provided in Part 1 and the appendix of this report.

Table 2 Economic and carbon benefits of the ANM scheme at Dunbar GSP

Over the 6 years of the scheme from 2015 - 2020	
Total capital investment in connected projects:	£200m
Amount of distributed energy resources connected:	50MW
Total GVA added to the economy:	£61m

[4] 'Long-term' is ongoing, employment linked to the operational activity of the project
[5] Scottish Enterprise https://www.evaluationsonline.org.uk/evaluations/help/guidance.htm

...of which local (induced):	£7.75m
Total FTE years added to the economy:	376
Total direct FTEs per year:	56 (52 from the ERF)
Total indirect and induced FTEs per year:	121
Total tonnes of carbon emissions avoided	98,000
Total community benefit raised per year	£75k
Additional energy generation enabled	653 GWh
After 25 years of project operation for the 4 projects that were enabled by ANM connection	
Total tonnes carbon emissions avoided	0.55m
Total expected community benefit to be raised	£1.75m

Figure 1 Dunbar Energy Recovery Facility (Credit: Viridor)

The export reinforcement work at Dunbar GSP was completed as planned in 2021, many of the benefits however could be extrapolated for the life of the projects since, according to the feedback from project developers, the four new projects would almost certainly not have proceeded if the ANM scheme had not been in place.

The benefit contribution of the largest project, Aikengall Community Windfarm, which was commissioned ahead of the ANM scheme, was only measured in terms of the increased energy generation and revenue that the ANM scheme enabled.

In terms of replicability of these benefits to other and future ANM schemes, three important points should be considered

1. Much of the direct employment linked to the Dunbar scheme comes from just one project, the Viridor Energy Recovery Facility (ERF), with 52 out of the 56 full time equivalent (FTE) jobs per year and as such, these levels of employment would be unlikely in other ANM schemes. But outside of employment, the contribution from all the projects to the local economy during construction and operation (plus the structured community benefit fund contribution offered at £5000/MW/year) is substantial. In the case of the Hoprgishiels project, some of the project revenue was used by co-owner, Berwickshire Housing Association to fund an ongoing social housing programme, leading to the creation of 30 FTEs for the 25 year lifetime of the project.[6]

2. A key driver for projects to join the scheme and to get an early connection was the timetable set by the closure of the ROC subsidy scheme in 2017. Generators were therefore prepared to accept a degree of curtailment risk and uncertainty which a post-subsidy developer might be less willing to bear. Future customer appetite to accept an ANM scheme connection, and what this means for the developer of an ANM "customer offer" is discussed in Part 2 of this study.

3. The Dunbar ANM scheme had a definite end date, at the point at which GSP upgrades were made in 2021. There was therefore a natural limit on the duration of constraints and a commitment that customers would eventually be given a firm connection. This therefore addressed some of the concerns raised about open-ended ANM schemes.

2.2. Scheme performance and operation

All five of the projects connected to the Dunbar ANM scheme experienced curtailment and loss of generation and revenue, but overall the feedback from stakeholders was positive. The curtailments they were expecting and went on to experience, were still far outweighed by the benefits of being able to connect quickly and secure important revenue streams: in the case of most of these projects that was ROCs, which were phased out in 2017.

The curtailments were managed according to a Last In First Off (LIFO) arrangement, which is the simplest approach to protecting the network, but not necessarily the fairest or most sustainable. Alternative approaches to queue management are discussed in section 8.2.

Generators who were interviewed did not object to the principle or operation of the LIFO queue. Dunbar was an early stage ANM scheme and the main reservation expressed was around the range of estimates they were given about the level of curtailment to expect and the uncertainty this entailed. Providing greater forecast certainty has been a key area of ANM innovation and development.

[6] Information supplied by CES based on an assessment by Scottish Enterprise

Generators also commented that the level of curtailment seemed to increase over time. This experience is borne out by curtailment data produced by Smarter Grid Solutions (SGS), see figure 2, and reflects the timetable under which new projects higher up the LIFO queue joined the ANM scheme.

ANM customers were provided with a comprehensive quarterly report showing ANM interventions and levels of curtailment experienced. Curtailment data provided by SGS, (the primary supplier of the Dunbar ANM control system) showed that during 2020, when the scheme was in full operation, those at the top of the LIFO queue typically experienced low levels of curtailment of around 3% of time. Those at the bottom of the queue, and therefore first to be curtailed, might experience up to 13% time curtailment.

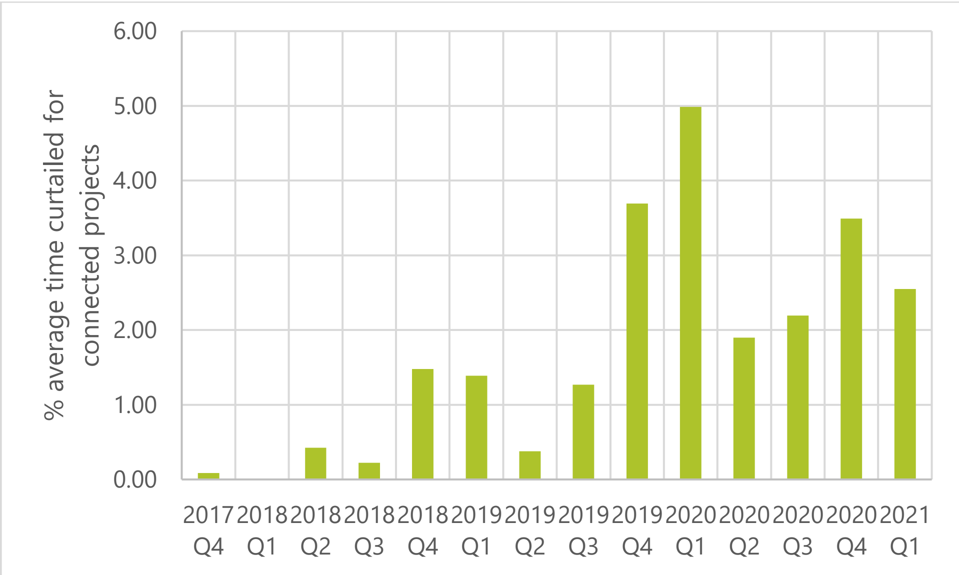

Figure 2 Percentage of generation curtailment time (all project average). Source data : SGS

It should be noted that understanding the generation time curtailment does not give an accurate estimate of lost energy generation because, without additional loss monitoring, it is difficult to estimate what an asset might have generated. Understanding the level of lost generation is however important in order to perform a full whole system cost benefit analysis, that might then provide the basis to trigger network reinforcement.

For variable assets like wind and solar, one might assume that, because generators are being curtailed, levels of generation must very likely be high, and therefore an estimate could be based on peak asset capacity. Another approach, in the absence of site specific wind or solar irradiance data, would be to base an estimate on a generic generation profile. This issue is common with other network outage impact assessments, and the requirements for DNO's to perform whole system CBA analysis. [7] [8]

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[7] https://www.spenergynetworks.co.uk/news/pages/why_sp_energy_networks_are_considering_flexibility.aspx

[8] https://www.spenergynetworks.co.uk/news/pages/why_we_need_a_flexible_future.aspx

ANM schemes do come with costs, both to the customer who must ensure they have the correct hardware onsite to participate, typically costing around £30k, and the network operator. DNO costs to implement ANM vary with the complexity of the network area being controlled. In addition to the hardware costs, although the system is automated, there is a responsibility to report back to each customer on the performance of their connection.

The core challenge for DNOs is to assess when the costs of implementing and running an ANM scheme, plus any flexibility services that might be required to manage energy flows will cost more than reinforcement works.

2.3. Innovation and research

The ANM scheme at Dunbar was a partnership project that included local authority, community energy, industrial and academic partners to ensure that key learning from the trial was captured. ANM is now routinely offered by most GB DNOs and its use has stimulated a significant amount of industry research and development, with several companies, SGS included, seeing substantial growth in the last decade to support its deployment. The Dunbar scheme was testing a number of specific commercial and technical features, and Strathclyde University alone published three academic papers about the work at Dunbar. These papers have themselves been cited ten times by other papers.

ANM itself has continued to develop since these early schemes, and continues to feature in Innovation trials for SP Energy Networks and other DNOs, working with industry to understand how it can be used to accommodate more flexible and faster responding distributed assets, like battery storage.

2.4. Future development of ANM

The customer experience of the Dunbar ANM scheme highlights some of the key areas where ANM schemes will need to improve in order to create an attractive proposition for future generation customers. Many of these areas are already the subject of policy changes and innovation projects including work currently being undertaken by the ENA Open Network[9] project and several DNO funded trials.

The direction of travel is to make ANM schemes a more attractive customer proposition by reducing, and better managing, curtailment risk, and by enabling customers to potentially trade their capacity/constraint position to produce a more optimal economic outcome.

Key areas under development include:

- Better curtailment forecasting, transparency and planning of ANM approaches within Constraint Managed Zones (CMZ)
- Alternatives to the LIFO queue management that to allow greater fairer access across ANM participants

[9] For example, ENA Open Networks ANM Flexibility Consultation https://www.energynetworks.org/industry-hub/resource-library/on21-ws1a-flexibility-consultation-2021-overview-(30-jul-2021).pdf

- Extensions to queue management to enable, or facilitate, market based solutions including capacity or constraint trading between ANM participants
- Changes to ANM propositions to provide customers with more certainty of curtailment outcomes including possible energy loss or time limits, that would pass at least some curtailment risk back to the network operator
- The role ANM could play under a shallower network access charging model as proposed by Ofgem's Access and Network Charging Significant Code Review[10]
- Integration between the operation of ANM and CMZ schemes on the distribution network and the operation of transmission network and system operation controls
- Market models that will allow an ANM approach to work with, and potentially facilitate, other flexibility solution providers
- Whole system approach to Cost Benefit Analysis (CBA) that will help to determine the appropriate use and end-point of an ANM scheme based on the point at which a network investment and/or flexibility solutions would be economically optimal.

The management of the 'queue' of projects connected to ANM schemes, and therefore the order in which they are curtailed, has been closely scrutinised in the intervening years, along with calls for more transparency and fairness. SP Energy Networks and several other DNOs are exploring how the LIFO system can be adapted to give customers more confidence in their connection capacity[11]. Curtailment caps and the ability to commercialise position in that queue are two features already being trialled.

ANM is just one connection solution that can be chosen by customers wishing to connect. It is never the only solution offered. A key question for the future of ANM is whether changes to connection charges that have been proposed for introduction in 2023, as part of a wider Network Access and Charging Significant Code Review (SCR)[12] that is being undertaken by Ofgem, will make ANM connection offers more or less attractive to generation customers.

There is still a lot of uncertainty about how the SCR will be implemented. At face value, the reduced up-front costs for new connections under a "shallower" network access connection charge methodology may encourage new connection customers to only opt for a firm connection making an ANM option less attractive. In practice however, and depending how the detailed policy changes are implemented, if network operators are enabled to plan and optimise the timing of network reinforcement and use of flexibility options, this may open an opportunity for ANM approaches to provide interim solutions. Thereby allowing renewable generation assets and other net zero enabling technologies such as Electric Vehicle (EV) chargers to connect earlier, and in advance of network reinforcement or flexibility solutions being in place.

ANM has not been without its critics. In recent years there has been a significant push from across the industry for DNOs to develop and utilise alternative forms of flexibility to manage

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[10] https://www.ofgem.gov.uk/publications/access-and-forward-looking-charges-significant-code-review-summer-2019-working-paper
[11] https://www.energynetworks.org/creating-tomorrows-networks/open-networks/
[12] https://www.ofgem.gov.uk/publications/access-and-forward-looking-charges-significant-code-review-consultation-minded-positions

network constraints, including services provided by embedded generators, battery storage and customers that are able to provide demand side response (DSR).

To encourage and develop the provision of flexibility services all DNOs have begun to publicise areas of network constraint and to run procurement auctions to contract flexibility services. SP Energy Networks has itself procured a wide range of flexibility services[13] and has helped to create an active flexibility market as part of evolving DSO[14] function.

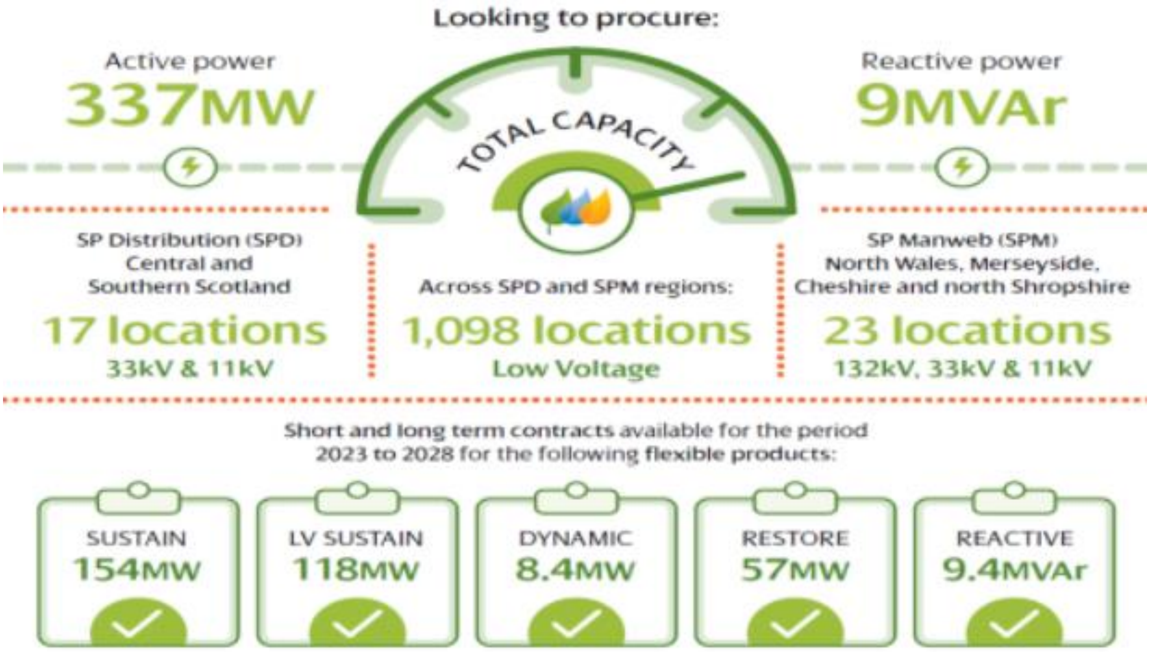

Figure 3 Example of the flexibility services being procured by SP Energy Networks in 2020 (Source, SP Energy Networks)

Flexibility services providers, and Ofgem officials, have however expressed a strong concern that the use of ANM may crowd-out and inhibit the growth of 3rd party flexibility services because ANM could be used to provide DNO's with a cheaper, uncompensated and possibly unlimited, source of flexibility. This risk is especially true in cases, unlike Dunbar, where open-ended ANM schemes have been implemented without any curtailment limitation, or

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[13] SP Energy Networks https://www.flexiblepower.co.uk/sp-energy-networks

[14] In in last tender round SP Energy Networks procured over 140 MW of flex services. https://www.spenergynetworks.co.uk/news/pages/140mw_flexibility_tenders.aspx

indication of when the scheme may transition to a firm connection offer, enabled by network investment or the use of other flexibility services.

So far, ANM schemes and flexibility service provision have tended not to directly compete with each other, as most ANM schemes have been concerned with generation led constraints, while most flexibility service contracts have targeted demand led constraints. This could change in the future if the industry moves towards wider use of CMZs that may have a number of different constraint levels and different approaches to network management for both generation and demand.

There is also a key question of how constraint management and the use of flexibility services on the distribution networks are integrated and aligned with the actions taken by the Transmission Operator (TO) and Electricity System Operator (ESO) to manage system balances and operational constraints on the transmission network.

In essence ANM is a technical solution that could be applied and used under a variety of operating models and markets. It is very likely therefore that, as well as technical and performance enhancement, the use of ANM will need to be further adapted to ensure that future schemes:

- Provide customers with a fair and beneficial connection offer, without binding the customer into an open-ended arrangement in which all curtailment risk and uncertainty is born by the customer
- Are based on a clearly defined end date, or a set of evaluation criteria and processes under which that end date will be determined using the principles of a whole system CBA that includes the cost of curtailment to the customer and the availability of alternative flexibility solutions
- Allow the development of alternative flexibility solutions including the ability of customers to trade their capacity/curtailment position with each other, and to make use of alternative flexibility services either directly or via a DSO facilitated market
- Ensure that the operation of ANM within the distribution network is fully integrated and aligned with the actions taken by the ESO and TO to ensure overall system balancing and transmission network operation.

In the future therefore we are likely to see the use of ANM develop in the context of the new role for networks as DSOs tasked with optimising the use of network capacity, facilitating the development of flexibility markets and working in collaboration with transmission networks and system operators to drive forward the transition to net zero. If the SCR 'minded to' decision to adopt shallower network connection charging is implemented, and is accompanied by additional enabling actions, this will add an additional impetus for distribution networks to optimise network capacity utilisation.

2.5. Conclusion

The UK faces an incredible challenge to reach net zero by 2050 and to meet its interim commitment to reduce carbon emissions by 78% by 2035. Decarbonising electricity is a critical step to achieve this for the energy sector, and to enable the decarbonisation of transport, heat and industrial processes that will soon be electrified.

In any credible net zero pathway that means substantially increasing the capacity of onshore wind, solar PV, hydro and other renewable energy technologies, alongside the planned expansion of offshore wind.

By 2035 the UK needs to reach circa 70 GW[15] of onshore renewable generation capacity however, while renewable energy deployment rates peaked in 2017, they have dramatically dropped since then to the point that very few new projects are being built. Instead, a large pipeline of projects[16] , with planning and network connection agreements in place has been created; many within SP Energy Networks' licence areas in Scotland and North Wales/North West England. Getting that pipeline of projects deployed as quickly as possible to build momentum in the energy sector and its supply chain, and rapidly reducing the carbon intensity of electricity, is now critical and securing network capacity will be a key enabler to

ANM is just a technology solution and one approach to manage network constraints. It is not a silver bullet to address every network issue, nor can it deliver net zero but, as the Dunbar ANM scheme has shown, when applied in network constraint areas it can help to accelerate the deployment of renewable energy technologies. In the Dunbar case study this was clearly demonstrated adding 653 GWh of electricity and saving nearly 100 thousand tonnes of carbon dioxide emissions.

In the coming 2023-2028 RIIO-ED2 price control period ANM could play a vital role. Reviewing the draft ED2 business plans that have been published it is clear that, while networks are committed to delivering net zero and the deployment of low carbon technologies, there is still some caution across the industry about making large scale strategic investments in network capacity ahead of need. This is especially the case for capacity to support new generation. This caution has been principally driven by Ofgem's existing assessment framework for business plans, their concern about "stranded assets" from what they might consider premature investment, and also their desire to avoid increases to current consumer bills.

In this environment of cautious investment in new network assets, and a focus instead on maximising the use of existing capacity, ANM could provide an important interim solution to accelerate renewable generation deployment by squeezing additional capacity from existing network infrastructure. This could then allow DNOs time to build a more compelling, and certain, whole system business case for investment and/or to facilitate the development of longer term flexibility-based solutions and markets. This role is however predicated on the ability of DNO's to deliver its wider DSO functions and to ensure the appropriate use of ANM.

As a case study in whole system planning and the value of collaboration between the distribution and transmission networks, the Dunbar scheme has demonstrated how improving data flows and providing better visibility of network connected assets, can allow

[15] Committee on Climate Change Balanced Pathway Net Zero Scenario.
[16] Across GB there are circa 3 GW of solar, 6 GW of battery storage and 5.5 GW of onshore wind with planning permission in place. There are also estimated to be a further 14 GW of solar projects with a grid connection agreement

networks to deliver strategic investment, while also offering higher levels of service to customers and value-for-money to consumers.

Whilst not all ANM schemes will realise the level of benefits found at Dunbar GSP, it is clear that ANM (and the data, monitoring and control innovation that it has engendered) could be applied more widely across the UK. It is also part of the range of smart energy and flexibility solutions in which the UK is now becoming a world leader, opening up export opportunities for UK based technology companies, and service providers. The Dunbar scheme has itself drawn the attention of Avangrid, a US based utility within the Iberdrola group and, as an interesting postscript to this study, Smarter Grid Solutions, the main software technology provider for the Dunbar scheme has now been acquired by US based Mitsubishi Electric Power Products Inc[17].

[17] https://www.businesswire.com/news/home/20210820005037/en/Mitsubishi-Electric-Closes-on-Deal-to-Acquire-Smarter-Grid-Solutions

3. Introduction

3.1. Background to the Dunbar ANM project

The Scottish Government has set a target to achieve net zero of all greenhouse gases by 2045, set under the Climate Change (Emissions Reduction Targets) (Scotland) Act 2019.[18] As part of achieving this target, by 2030 the Scottish Government want renewable energy generation to account for 50% of energy demand across heat, electricity and transport, equating to around 17GW of new capacity. As of December 2020, around 14GW of renewable electricity generation is in the development pipeline, of which 2.9 GW is already accepted to connect in SP Energy Networks Scotland licence area.[19] This new capacity will be a mix of centralised generation and smaller, decentralised plant.

The network in some DNO areas, including those of SP Energy Networks, has reached its limit for accommodating new capacity, or exporting up to the transmission network a result of the rapid increase in new generation assets connecting in recent years. Once the limit has been reached, any new project wanting to connect faces a proportion of reinforcement costs, possibly even triggering significant reinforcement costs at transmission level. In 2010, SP Energy Networks were reporting a 'queue' of projects waiting to connect where connection was reliant on transmission reinforcement.

The Dunbar GSP is located in an area of high wind resource, and industrial demand, but in 2012 had already maximised its export capacity. No new generation was able to be connected unless excess generation could be curtailed, especially if the industrial demand was low, and reinforcement, although planned in recognition of the areas importance for generation, was not due to happen until 2021. As such, the GSP was a prime candidate to trial an ANM scheme and hopefully unlock more renewable energy generation connections years ahead of reinforcement.

In 2012, SP Energy Networks in partnership with SGS, Community Energy Scotland and Strathclyde University, with support from East Lothian Council, and Scottish Borders Council, were awarded £7.62m of LCNF funding to undertake a trial of ANM in the heavily constrained area of Dunbar and North Berwick. The trial was to test new commercial and technical innovations that might reduce barriers for low carbon generation to connect in areas of network constraint, building on the learning from previous schemes in Orkney and elsewhere. The 'Accelerating Renewable Connections' project ran from January 2013 to December 2016 and delivered a raft of innovations that underpin the Dunbar ANM scheme and wider impacts cross SP Energy Networks. In all, 13 projects unlocking 100MW of capacity were connected as a result of the trial, but this study is focused on the five core projects that connected to the Dunbar GSP.[20]

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[18] https://www.gov.scot/publications/local-energy-policy-statement/pages/10
[19] https://www.spenergynetworks.co.uk/pages/embedded_capacity_register.aspx
[20] https://www.regen.co.uk/wp-content/uploads/Ross-Anderson_REGEN-Edinburgh_25092018-with-Storm-Ali-Update-1.pdf

More information about the full ARC project can be found the SP Energy Networks website.[21]

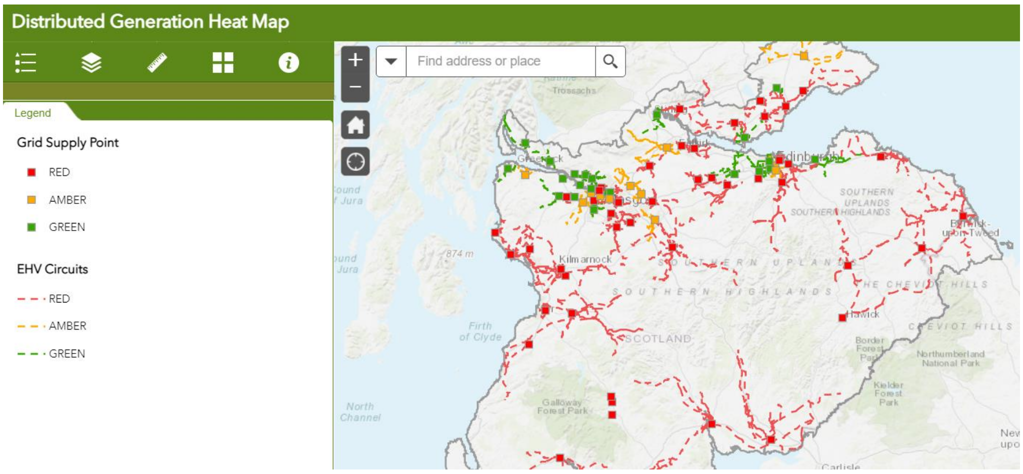

Figure 4 SP Energy Networks online thermal constraint map (Source, SP Energy Networks)

3.2. Purpose of this study

The Dunbar ANM scheme has now been discontinued, with network upgrades having been made in 2021 and customers moved onto firm connections. As the scheme has now ended, Regen was asked by SP Energy Networks to evaluate the economic and carbon benefits of the scheme, and to assess lessons learnt for how ANM approaches might evolve and continue to add value in the coming years, in light of; the emergent DSO functions, use of 3rd party flexibility solutions, regulatory changes and ambitious timescales to decarbonise the entire electricity system.

The purpose of this report is to provide:

- a high-level evaluation of the economic and carbon emissions impacts of the Dunbar ANM scheme
- a qualitative and quantitative assessment of the performance of the scheme and the impact it has had for generation customers and their stakeholders
- a critical review of the scheme's use of technical and commercial innovation, subsequent business-as-usual (BAU) adoption and it's replicability
- a wider discussion of the relative merits of ANM including its challenges and limitations, and the future role that ANM could play alongside, or integrated with, other forms of flexibility, and other investment strategies, in a smart net-zero energy system.

As part of this study Regen has undertaken desktop research and interviews with the project owners and stakeholders involved to perform a high level qualitative and quantitative assessment of the impact of the Dunbar ANM scheme and its potential replicability.

Regen would like to thank participants in this study, including Viridor, Smarter Grid Solutions, SP Energy Networks, Community Energy Scotland, East Lothian Council, and Scottish Borders Council, who have provided valuable input and insight, and also content and data which is

[21] https://www.spenergynetworks.co.uk/pages/arc_accelerating_renewable_connections.aspx

referenced throughout. Regen would also like to thank Scottish Enterprise for their input and guidance on the methodology used for the economic evaluation. Thanks also to the partners in the original ARC project, from which several diagrams and other data has been replicated. The comprehensive technical and learning reports from the ARC project are available here.

Part 1: Impacts and economic evaluation

4. The ANM scheme in Dunbar

The ARC project was focused around a trial area of East Lothian and the Scottish borders, with the ANM scheme setup around the transmission constraint on the Dunbar GSP.

Most of the connections to this GSP are rural towns forming population hubs, but there are some large manufacturing centres, including the Tarmac cement plant at Dunbar, which can draw significant load.[22] The presence of the cement plant and its variable demand, against which generation could be optimised, is an important part of the overall ANM scheme

There are also some substantial generation assets in the area with Torness nuclear power station and several significant wind farms that had connected in the early 2000's. The geography of the area means there is attractive wind and solar renewable energy resource which project developers were and are looking to pursue. In 2012, depending on the balance of demand and generation, there was no headroom export capacity left on the Dunbar GSP and the substantial distribution and transmission reinforcement was not due to take place until 2021.

Figure 5 ARC trial area (Source, SP Energy Networks)

[22] https://www.spenergynetworks.co.uk/userfiles/file/SPEN_ARC_Learning_Report_1.pdf

4.1. Drivers for the ANM scheme in Dunbar

Traditionally, distribution network assets have been fitted to handle generation at transmission level and feed this out to demand customers. As the level of Distributed Energy Resources (DERs) have increased in recent decades, this 'fit and forget' model has become less effective and has required DNOs to become more active in managing bi-directional electricity flows.

Many DERs are renewable energy generators with variable output, which presents both a challenge and opportunity to DNOs who are seeking to support the maximum capacity for the greatest value to the customer.

Previously, connecting new assets to the distribution network called only for a maximum demand calculation. With network connected DERS, the export capacity of the GSP to the transmission network becomes equally important, but given the output of renewable generators is variable, risks underusing capacity when they are not operating at full capacity.

The central question being asked with the ARC trial and specifically the Dunbar ANM scheme was: 'How could the TO have confidence about GSPs exporting into the transmission network when they have more generation capacity than they are rated for?'

The Dunbar 132/33kV GSP was already an exporting GSP prior to the project, with 110 MW of distributed generation connected for a local demand of just 30 MVA in 2008.[23] With this imbalance and an expectation of additional generation projects wanting to connect in future, a requirement was identified via the Statement of Works (SoW) process for a transmission network upgrade, of around £20m to take place in 2021.

Shortly after the SoW requirement, three additional projects asked SP Energy Networks for a connection, totalling an additional 50 MW of generation.

The Dunbar GSP therefore had sufficient capacity to support additional DER, but not to export it, making it a suitable location to trial ANM. In addition, the local area had some other useful features:

- The existing 48MW Aikengall Community Wind farm, connected in 2009, had connected under an inter-trip contract. It could therefore be curtailed based on pre-set modelled time and capacity limits. There was therefore an opportunity to switch this customer to an ANM contract, delivering real-time control of output to minimise the level of curtailment and increase energy output
- The existing generation already had overload protection; an important hardware requirement that made it easier to install an ANM scheme in the area

However, new projects were still being developed and making their way through the planning permission process and approaching SP Energy Networks for connections. The largest of these was the Viridor Dunbar Energy Recovery Facility (ERF), who were seeking a 36MW connection. With the transmission constraint in place, using normal reinforcement approaches this project would have to wait for the transmission level reinforcement to take place in 2021 before being

[23] https://www.spenergynetworks.co.uk/userfiles/file/SPEN_ARC_Learning_Report_2.pdf

able to connect and export. Although this was the largest, there were other wind and community energy projects seeking to connect:

Table 3 Major projects connected to the Dunbar GSP ANM scheme

Project name	Export capacity	Year of first planning permission submission[24]	Year of connection to the ANM scheme	Year that a firm, full connection would have been available, after reinforcement
Aikengall community Wind farm	48 MW	2005	2015	2021
Dunbar ERF	36 MW	2009	2018	2021
Hoprigshiels community Wind farm	7.5 MW	2009	2017	2021
Kinegar Wind farm	5.0 MW	2009	2017	2021
Ferneylea Wind Farm	1.5 MW	2012	2019	2021

All of the wind projects were reliant on Renewable Obligation Certificates (ROCs) as a significant, source of revenue. The Renewables Obligation scheme was scheduled to close to new generation in 2017, giving a hard deadline to projects that needed to apply, and begin construction activities, within a grace period in order to secure them.

SP Energy Networks undertook detailed modelling to explore how the GSP might perform with existing generation under firm connections, the Aikengall wind farm moving to ANM and new projects connected with ANM, both for normal conditions and 'n-1': i.e. an unexpected failure or outage. In close consultation with the SO and the TO, SP Energy Networks submitted a proposal for an ANM scheme at Dunbar GSP.

[24] https://data.gov.uk/dataset/a5b0ed13-c960-49ce-b1f6-3a6bbe0db1b7/renewable-energy-planning-database-repd

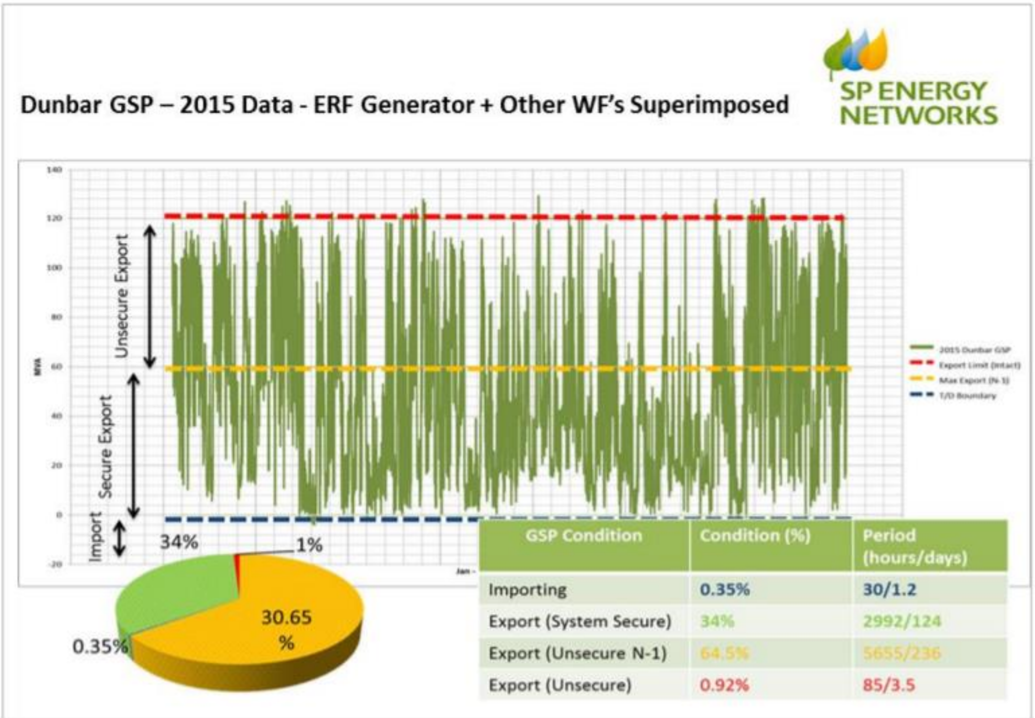

Figure 6 Modelled performance of Dunbar GSP (Source, SP Energy networks and SGS)

4.2. The ANM alternative connection in brief

Active Network Management is well established control protocol, first used in 2009 and is one of a suite of 'flexible connections' at a DNO's disposal (see table below). Five out of six UK DNOs now have at least one ANM scheme active in their licence areas,[25] with the expectation that more of these 'alternative connections' will be used in the coming years to squeeze capacity out of the network in tandem with network and transmission reinforcement.

Table 4 Types of flexible connection offered by most DNOs in the UK

Type of flexible connection	Description
Timed Capacity Connections	Fixed curtailment at an agreement schedule
Export limits	Automated limits at customer substation level that limit export to an agreed threshold
Local management schemes	Network feeder management. Data is taken from the customer and capacity reduced to address voltage or current issues, inline with the connection agreement
Remote Intertrip	Capacity temporarily reduced to a pre-agreed set-point, which might be anywhere from full capacity to zero
Active Network Management	Capacity temporarily reduced for a cluster of customers

There is no standardised approach to any of the above alternative connection arrangements and different DNOs will implement them according to their own standard operating procedures. As such, the customer journey for ANM varies across the UK.

[25] https://energystrategyuk.com/2020/10/28/active-network-management-anm

In 2012, although ANM had already been used elsewhere, the Dunbar scheme was aiming to develop tools to better forecast and model potential curtailments and create a more robust solution for customers as well as explore how the technical requirements could be incorporated into internal procedures.

5. What economic impact did the trial have?

5.1. Summary impacts

A key benefit from an ANM is that it allows projects to connect quickly, rather than waiting for network reinforcement which may be scheduled for several years ahead. For some projects, this delay might mean they lose planning permission or funding streams, making them unviable. Others such as the Aikengall Community Wind farm joined the scheme to replace their existing, intertrips connection with participation in an ANM which could facilitate more export. The table below shows when the schemes connected to the ANM scheme (in green), along with their measured annual export. In the case of Aikengall, only the estimated extra export that was facilitated through connecting to the ANM scheme was considered. This 'extra-over' export was estimated by comparing actual export from 2015 onwards to the average annual export experienced whilst on the intertrips arrangement.

Table 5 Exported generation (GWh) per year from projects connected to the Dunbar GSP ANM scheme

	2012	2013	2014	2015	2016	2017	2018	2019	2020
Aikengall (intertrips until 2015)	0	0	0	34	-5	30	13	16	23
Dunbar ERF							0	202	225
Hoprigshiels						18	21	20	0
Kinegar						12	12	13	11
Ferneylea								4	4

Our approach to the economic evaluation of the Dunbar ANM trial has been to assess each of the five projects for the *extra* generation, employment and gross value added they have provided the economy over the life of the scheme; i.e. from the date of their connection through ANM to when the network was upgraded and their connection offers became firm.

Table 6 Economic and carbon benefits of the Dunbar GSP ANM scheme

Over the 6 years of the scheme from 2015 – 2020	
Total capital investment in connected projects:	£200m
Amount of distributed energy resources connected:	50MW
Total GVA added to the economy:	£ 61m
...of which local (induced):	£ 7.75m
Total FTE years added to the economy:	376
Total direct FTEs per year:	56 (52 from the ERF)
Total indirect and induced FTEs per year:	121
Total tonnes carbon emissions avoided:	98000
Total community benefit raised per year	£ 75k

Generation delivered as a direct impact of the ANM scheme[26]:	653 GWh
After 25 years of project operation for the 4 projects that were enabled by ANM connection	
Total tonnes carbon emissions avoided	0.55m
Total expected community benefit to be raised	£ 1.75m

5.2. Analysis of economic impacts

5.2.1. Approach

For this analysis we used Scottish Enterprise approach to economic evaluation[27], basing our estimates for employment figures, GVA and carbon emissions avoided on the annual turnover and MWh generated in the case of the four wind farms and annual MWh generation and average gate fee revenue for the Dunbar EFR plant.

Scope

Aikengall Community Wind Farm had been operating with an Intertrips connection since 2009. As such, the economic benefit from switching to the ANM connection was any *extra-over* generation that could be attributed to this scheme.

Through interviews with project owners, we have established that the other four projects (Dunbar ERF, Hoprigshiels, Kinegar and Ferneylea) would have been very unlikely to go ahead without ROCs, and hence connection before the closure of the RO. As such, the full impact of their 25 year project life can be attributed to the ANM scheme.

Table 7 Treatment of each project ANM enabled revenue in the evaluation

	Revenue estimation approach	Source	Revenue attributed to ANM
Aikengall Community Wind farm	Renewables Obligation Certificates (ROCs) issued, average annual day ahead baseload electricity wholesale price	Ofgem renewables and CHP database, Ofgem wholesale market indicators £/MWh	Additional energy/revenue over the annual average prior to connection
Hoprigshiels			
Kinegar			
Ferneylea			
Dunbar ERF – electricity generation			

[26] This is the full exported generation from Dunbar ERF, Hoprigshiels, Kinegar and Ferneylea and the estimated generation from Aikengall that would normally have been curtailed through the use of the intertrip.
[27] https://www.evaluationsonline.org.uk/evaluations/help/guidance.htm

Dunbar ERF – waste gate fees	Tonnes waste processed and average annual gate fees	Stakeholder interview & public data on average gate fee price £/tonne[28]	All within study period

Note: The turnover for Dunbar ERF was verified using publicly held data from Companies House

All five projects migrated or connected to the Dunbar ANM scheme in different years. Therefore, only the activity from their point of connection to when the network was reinforced was in scope. The first project to connect was Aikengall Community Wind farm (48MW) in 2015. The final project to connect was Ferneylea (1.5MW) in 2019. Transmission and network reinforcement work was completed in 2021.

Table 8 Estimated turnover per year of each major project connected to the Dunbar GSP ANM scheme

	2012	2013	2014	2015	2016	2017	2018	2019	2020
Aikengall	£ -	£ -	£ -	£ 1.4m	-£ 0.2m	£ 1.4m	£ 0.8m	£ 0.7m	£ 0.8m
Dunbar ERF							£ -	£ 34m	£ 40m
Hoprigshiels						£ 0.8m	£ 1.2m	£ 0.9m	£ -
Kinegar						£ 0.5m	£ 0.7m	£ 0.6m	£ 0.4m
Ferneylea								£ 0.2m	£ 0.1m

There were other projects also connected to Dunbar GSP at this time, through the ANM scheme, namely the Ruchlaw Mains Farm PV, an 80kW extension to an existing solar PV project. However, this project was primarily focused on procedural innovation that enabled greater onsite consumption and voltage management rather than export, so has been excluded from this study.

Further details about the economic evaluation approach can be found in the appendix.

5.2.2. Project Investment

Table 9 Investment in the major projects connected to the Dunbar GSP ANM scheme

Project	Headline investment cost

[28] https://www.letsrecycle.com/prices/efw-landfill-rdf-2/efw-landfill-rdf-2019-gate-fees

Aikengall	N/A – project was already built
Dunbar ERF	£177m (published)
Hoprigshiels	£12m (estimated)
Kinegar	£8m (estimated)
Ferneylea	£2.4m (estimated)
Total	**£200m**

Where published project investment figures were unavailable, an estimation was made using cost of generation figures published by BEIS per MW installed capacity.[29] See Appendix for further details.

5.2.3. Employment

The impact of the ANM scheme on employment was undertaken using guidelines published by Scottish Enterprise. This approach looked at different types of employment associated with the operational activity of the project. A second approach (outlined below) was used to consider jobs created during the construction of the projects.

Employment can be defined in several ways, from a simple headcount to number of employees on permanent, full-time contracts. We have used FTE Years (i.e. an employment unit of one FTE working for one full year) to provide a comparator between projects connected to the ANM scheme, as this fairly accommodates the differing lengths of time those projects were connected.

Types of FTE

Three different types of employment need to be considered in an evaluation of economic activity:

Table 10 Types of FTE Employment considered in the evaluation

Direct Employment	Directly linked with the core activities of the organisation, without taking into account intermediate inputs necessary to facilitate those core activities
Indirect Employment	Upstream or support work that facilitate the core business
Induced Employment	Money earned and spent by direct and indirect employment. A substantial proportion of this is often spent locally to place of employment

Operational FTE employment

29 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/566567/BEIS_Electricity_Generation_Cost_Report.pdf

For the purposes of this study, each of the three employment types was estimated based on turnover, using factors for different industrial sectors published by Scottish Enterprise. See appendix 1 for our methodology. In the case of the Dunbar ERF project, by far the largest employer, turnover based employment estimates were also sense checked against the actual declared headcount employees. The Dunbar ERF plant employs circa 55 people[30], which is a close match to the modelled direct FTEs.

Table 11 Headline employment estimates for each major project connected to the Dunbar GSP ANM scheme, from connection to the scheme until 2020

Project	Year operational	Year connected to the ANM	Direct FTE Years	Indirect FTE years	Induced FTE years	Direct FTEs per year	Indirect FTEs per year
Aikengall	2009	2015	7	11	4	1	2
Dunbar ERF	2018	2018	105	168	58	53	84
Hoprigshiels	2017	2017	4	7	2	1	2
Kinegar	2017	2017	3	5	0	1	1
Ferneylea	2019	2019	0	1	0	0	0
Totals			**120**	**192**	**65**	**56**	**90**

Short term employment (construction)

Short term employment related to the construction of the projects is challenging to quantify. Almost certainly, the £200m of investment either created or safeguarded employment for the contractors and supply chain companies that delivered materials, equipment, services and labour to the project sites. However, ascertaining how much of this activity was in the local, national or international sphere is hard to quantify.

Using industry benchmarks[31] [32]and rule-of-thumb calculators[33], it is likely that £200m of investment safeguarded or created over 2400 short term FTEs, over the project lifecycle, although many of these may be for international or national supply chain companies rather than a local workforce.

5.2.4. Gross Value Added

[30] Reference figures provided by Viridor
[31] https://www.building.co.uk/download?ac=1664616
[32] https://www.arcom.ac.uk/-docs/proceedings/ar2012-0317-0326_Forbes_El-Haram_Horner_Lilley.pdf
[33] https://counterplan.com/free-construction-jobs-calculator/

Table 12 GVA estimated for each major project connected to the Dunbar GSP ANM scheme, from year of connection until 2020

	Year operational	Year connected to the ANM	Total direct GVA added	Total indirect GVA added	Total induced GVA added
Aikengall	2009	2015	£ 1.6m	£ 1.4m	£ 0.3m
Dunbar ERF	2018	2018	£ 25m	£ 22m	£ 7m
Hoprigshiels	2017	2017	£ 1m	£ 0.9m	£ 0.1m
Kinegar	2017	2017	£ 0.8m	£ 0.7m	£ 0.09m
Ferneylea	2019	2019	£ 0.1m	£ 0.09m	£ 0.02m
Totals			**£ 28m**	**£ 25m**	**£ 8m**

Gross Value Added is an important measure of economic output, as it is directly used to measure the contribution from a sector or industry to Gross Domestic Product (GDP). It gives a clear £ amount for the goods and services generated, minus the cost of all the inputs and raw materials. For the purposes of this study, each of the three GVA types (direct, indirect and induced) was estimated based on turnover, using factors for different industrial sectors published by Scottish Enterprise. See appendix 1 for our methodology.

5.2.5. Carbon

There were substantial benefits in the reduction of greenhouse gas emissions by connecting these projects to the network. The extra generation provided by the windfarms directly offset electricity otherwise provided by the UK energy mix at the standard carbon intensity, which in 2017 was an average of 351 tonnes CO2/MWh. The greenhouse gas emissions from Dunbar ERF are less clear cut to establish, as the waste being incinerated would otherwise go to landfill, in turn generating methane gas which is 28-34 times more impactful on the climate than carbon dioxide. According to waste and bioenergy experts Tolvik, there is a *net* benefit from burning waste in a Combined Heat and Power (CHP) Energy from Waste (EfW) plant of 0.05 tonnes CO2e/tonne of waste when compared to landfilling.[34]

The total carbon emissions avoided through generation connected to the ANM scheme (6 years) was over 98,000 tonnes (an average of 16.3ktonnes per year, the equivalent of the average carbon emissions emitted by just over 9000 people in Scotland)[35]

[34] https://www.tolvik.com/wp-content/uploads/2021/05/Tolvik-UK-EfW-Statistics-2020-Report_Published-May-2021.pdf
[35] https://www.bbc.co.uk/news/uk-scotland-scotland-politics-42555450

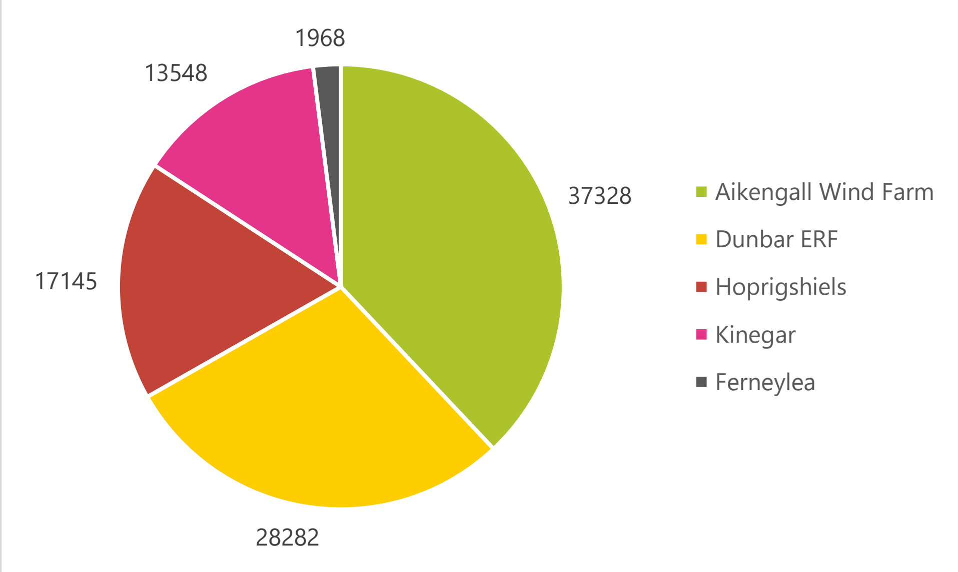

Figure 7 Equivalent tonnes carbon emissions avoided from generation connected to ANM scheme and waste diverted from landfill

Given that most of these projects would not have gone ahead without the ANM scheme, impacts from the 25-year operating life can be considered a direct benefit. The lifetime equivalent carbon emissions savings from 25 years of operation of the projects (or just the additional generation in the case of Aikengall) are **over 553,000 tonnes.**

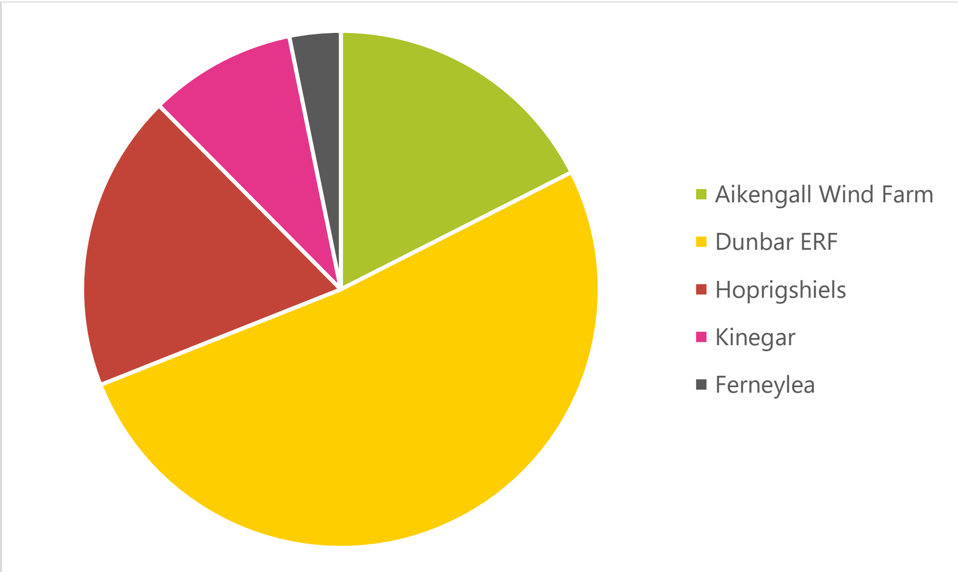

Figure 8 Equivalent tonnes carbon emissions avoided from the lifetime generation of projects connected to the ANM scheme and waste diverted from landfill

Carbon emissions avoided are calculated from:

Table 13 Carbon emissions estimation approach used in the evaluation

For each of the wind farms	The annual generation attributed to ANM * the average annual grid intensity for each year taken carbon intensity factor published

	by BEIS. (i.e. electricity that was avoided from being generated at the average grid carbon intensity factor)
For Dunbar ERF	There is significant debate in industry about the emissions from landfill that are avoided by incinerating the waste. The consensus reported by Tolvik is that there is a net *saving* in emissions of 0.05t CO2e per tonne of waste treated by an CHP ERF when compared to landfilling.
For all projects:	For the 25-year projections, the average annual carbon saving for each project is reduced 3% year on year to account for the grid average carbon intensity reduction over time. Over the last decade, on average grid carbon intensity has reduced by 3% each year.

5.2.6. Research, knowledge transfer and supply chain development

One of the benefits of the ARC project was to share learning with academia and industry, helping improve understanding about management of the distribution / transmission boundary with a changing mix of customers. Strathclyde University was an ARC project partner and published three papers that directly reference the ANM scheme at Dunbar:

Table 14 Academic papers directly referencing the ANM scheme at Dunbar GSP

Academic paper title	Authors	Direct Citations in other papers
Coupling Demand and Distributed Generation to Accelerate Renewable Connections: Options for the Accelerating Renewable Connections Project, **April 2014**	Simon Gill, Milana Plecas, Ivana Kockar	7
Distributed Generation on 11kV Voltage Constrained Feeders, **Sept 2014**	Simon Gill, Milana Plecas, Ivana Kockar	3
Background Analysis for Local Power, Local Benefit Project, **Feb 2015**	Simon Gill, Milana Plecas, Ivana Kockar	0

This collaboration between network operator, academia and industry is a critical element in building futureproofed low carbon systems that can accommodate more generation in a short space of time without reinforcement. Nearly 400,000 academic papers and articles have been published on the subject of ANM since 2017.[36]

The scheme at Dunbar has directly contributed to this body of knowledge with the three papers being directly cited by at least ten others.

It is challenging to evaluate how much of the £200m or so project investment was spent locally, in Scotland or more widely.

For many types of construction project, including industrial sites and onshore wind projects, labour costs typically accounts for 35-40% of project costs[37], which if accurate would suggest some £80m of the £200m estimated project costs would have been spent on construction workforce. This benchmark appears to still be valid for construction with more offsite equipment such as windfarms.[38]

In addition to the construction costs and as ANM and flexibility control approaches become more commonplace, so does the need for specialist organisations to develop, install and run the hardware and software required. One such company, Smarter Grid Solutions (founded in 2008 and originated from Strathclyde Universities Institute for Energy and Environment) joined the ARC project to develop the real-time software needed to handle the connections and develop user documentation about its use. At the time, the company was already delivering software solutions to support and improve network management, but 2012-2016 saw a step-change in pursuing smarter monitoring and control equipment that could unlock capacity.

ANM, along with a raft of other flexibility tools and approaches, has led to many technology and service providers expanding and playing a critical role in the supply chain, that not only benefit their own supply chains, but provide confidence and competition that benefits network customers and accelerates decarbonisation.

Smarter Grid Solutions was acquired by Mitsubishi Electric Power Products Inc. in 2021.

5.2.7. Community benefit

Connecting projects comes with tangible benefits for the local communities. For wind energy projects in Scotland, a community benefit fund of £5000/MW capacity *per year* has recommended by the Scottish Government since 2014 to support community groups and projects. This has largely been endorsed by industry since the publication of the Good Practice Principles for Community Benefits from Onshore Renewable Energy Developments[39]. In the case of the Dunbar ANM scheme, three of the new projects were wind with a total capacity of 14 MW, resulting in a combined annual contribution to community projects of £70,000, index linked. Over the lifetime of these schemes, this will result in at least £1,750,000 being shared out amongst community causes. Aikengall, although already built before the community

36 https://scholar.google.com/
37 https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2012/RE_Technologies_Cost_Analysis-WIND_POWER.pdf
38 https://gwec.net/wp-content/uploads/2021/04/Jobs-Note-April-2021-2.pdf
39 https://www.gov.scot/publications/scottish-government-good-practice-principles-community-benefits-onshore-renewable-energy-developments/pages/2/

benefit good practice came into being, was of course community owned and so would be contributing even more into community benefit.

In the case of Hoprigshiels windfarm (7.5MW), one of the scheme's owners, Berwickshire Housing Association, has stated it will generate around £20m in revenue: enough to build an extra 500 houses. Community Energy Scotland, as co-owner, will generate around £10m which it will use to further its work in developing community energy in the country. This is in addition to the £37,500 per year that the project will be providing to two local benefit funds, administered by Cockburnspath and Cove Community Council and Oldhamstocks Community Association. The former also gets £22,000 per annum from the Kinegar windfarm, currently majority owned by Foresight Group. These funds have been designed to be as flexible as possible allowing the administering community groups themselves to decide how best to use them. Typically, the funding has been used for discretionary grants from £250-£5000, hardship grants, supporting the village shop and Post Office and assistance for vulnerable groups.[40]

The Dunbar ERF also provides community benefits with a focus on employment and training, providing support for local business and education through a partnership with the Engineering Development Trust.

[40]https://www.localenergy.scot/projects-and-case-studies/searchable-register-of-community-benefits/developer-details/?id=2135&developerId=248

6. Performance and operation of the Dunbar scheme

6.1. Stakeholder feedback

Out of the five projects which connected to the Dunbar ANM scheme, representatives from two were spoken to in-depth and asked about their views of the scheme, their customer journey and about the potential future role for ANM control. In addition, there were in-depth interviews held with the team at SGS and SP Energy Networks, Community Energy Scotland and both East Lothian and Dunbar Councils to better understand some of the points raised by the customers.

Key takeaways:

1. **LIFO** – The Last In, First Off approach is the simplest route for connecting customers and apportioning curtailment, but remained the root of some issues. Although position in the LIFO stack is determined by the *date of connection offer acceptance*, the build date of that project might not follow the order of precedence. This meant that the level of curtailment experienced by customers might increase considerably over the years as projects ahead of them in the

2. **Access** - ANM enabled most of the projects to go ahead. Almost all of the projects were reliant on securing ROCs as a revenue stream and needed to connect before the incentive scheme came to an end in March 2017, four years before the planned reinforcement works.

3. **Curtailment** – Before committing to the flexible connection, customers were given a report that modelled the likely levels of curtailment. Despite detailed and intensive modelling undertaken by SGS, the complexity of the system meant that estimated of curtailment ranged from 5-20%. For our interviewees, the limited duration of the ANM scheme (three or four years for most of them) meant that even up to 20% curtailment might be acceptable when compared with 20 years of ROCs.

Overall, customer feedback was positive about the Dunbar ANM scheme, and about the use of ANM schemes in general. From a customer viewpoint, ANM is an important option when considering how to progress a project. Timing and simplicity are what set ANM connections apart from other connection options, such as connect and manage, site-side flexibility or even simply waiting for reinforcement. As has been previously highlighted, if it had not been for the ANM option at the Dunbar GSP, it is likely that none of the projects excepting the existing Aikengall Community Windfarm, would have gone ahead at all.

Interestingly, the level of curtailment was less of a concern to the stakeholders than had been expected. Primarily, even relatively high levels of curtailment on an already variable export are simply viewed as a cost of doing business, and the benefit of connecting years ahead of reinforcement, and securing ROC subsidies, outweighed the additional risk of limiting export. Of course, this ANM scheme was time limited reverting to a firm connection in the early 2020's. Customers may have perceived curtailment differently if the level of curtailment had been enduring.

There was clear feedback, however, that the customer experience of ANM could be improved. Specifically, better understanding of the LIFO stack and when other customers are likely to connect and take their position in the queue would provide better forecasting for connected customers. Although this information was available, information about other LIFO queue customers was not part of the reporting pack provided. One of the main issues stakeholders had with this scheme was the change in curtailment level, as new projects connected, sometimes years after other projects lower in the stack.

There was however some debate about whether customers would prefer a more sophisticated queue management arrangement, or whether customers would prefer to enter into a market based arrangement to trade capacity. There was perceived to be a definite trade-off between a more economically optimised approach and the added complexity that this would bring. The nature of the Dunbar ANM scheme, and the type of customers who participated, was probably not suitable to trial for this type of approach.

6.2. Curtailment

Prior to connected to the ANM scheme in Dunbar, each project had detailed modelling to estimate the potential levels of curtailment at their position in the LIFO stack. Importantly, this study, which was completed by SGS, was provided to them ahead of accepting the connection offer and was a critical input for customers to make a decision to join the scheme.

Modelling how much curtailment there may be on a network is very challenging. Even on hierarchical networks, estimating the varying energy flows over time for many years into the future is based on a long list of assumptions about the climate, business practises and the assets themselves. This becomes even more challenging for high interconnected, or 'meshed' networks.

The ANM connection agreement at Dunbar GSP did not come with a minimum guaranteed level of connection, and the modelling provided to projects came with a large range of potential curtailment: 5-18% in some cases.

Monitoring of the actual curtailments experienced by the projects is complicated by the fact many of these projects were new-build and therefore prone to take *themselves* offline for periods of time. Broadly, however, the top LIFO position saw curtailment in the first full quarter that had all five projects connected saw curtailment time of about 3%. The bottom LIFO position in the same quarter experienced curtailment of 13% of time.[41]

Measuring curtailment in terms of time is of limited value, as of course many of the generators have variable output and so the lost generation during curtailment time is difficult to assess.

It is now standard practise for DNOs to provide ANM customers with regular reports outlining the performance of their connection and curtailment events. The ENA produced detailed

[41] Summary analysis of curtailments on the scheme provided by SGS

guidance in 2018 outlining how each DNO handles ANM curtailment and reliability, including their reporting to customers.[42] In this guide, the ENA suggests that although it is not possible to quantify lost generation through curtailment with 100% accuracy, DNOs could go some way to estimating lost generation through looking at weather data, generation profiles prior to curtailment etc.

6.3. Cost of deploying and operating the ANM Scheme

ANM is relatively low cost to install and operate by DNOs, with an illustrative estimate being around £50-100k per GSP area[43].

For the customer costs will vary depending on the size of the project. As a rough estimate, ANM schemes typically have around £30k of hardware and software costs required to enable remote access to circuit breakers, with £3.5k/MW/yr in maintenance and support. It should however be noted that larger generation projects may already have a requirement to install much of the hardware and software needed and so the incremental costs to operate ANM will be less.

[42] https://www.energynetworks.org/industry-hub/resource-library/open-networks-2018-ws1-p7-good-practice-guide.pdf

[43] Illustrative figures provided by SGS

Part 2: Dunbar learning and the future for ANM

7. Innovation and learning from Dunbar ANM

7.1. ANM Innovation at Dunbar

The ARC project trialled several technical and commercial innovations to improve distribution to transmission flow management, but not all were present at the Dunbar GSP. For a full account of the technical and commercial innovations used on the ARC project, see the project website.[44]

Two technical tools were installed at the Dunbar GSP as part of this scheme:

1. **Multi Generator, Multi constraint ANM:** Devices were installed to control multiple generators against single or multiple network constraints. The device can regulate generator real power export to mitigate voltage and thermal constraints. Voltage and current can be measured at the site, or at remote measurement points
2. **Smart network design:** Using enhanced data sets from improved network visibility monitoring, to enable enhanced network modelling will permit network and system planners to deviate from a conventional design approach and enable adoption of smarter connection solutions.

Through the implementation of these two technical innovations, the scheme produced some core learnings that have since been endorsed by other schemes and operators, or have spawned further trial activity:

- Visibility of connected generation at distribution level should be available to both SO and transmission operator
- The advent of ANM control to manage distributed generation should not distort the balancing mechanism. This could be the case if the GBSO instructs an asset under a relevant GSP within a DNOs network, in isolation of the ANM system. The ANM system could render the balancing instruction obsolete by releasing greater capacity to ANM connected generation
- ANM systems connected at distribution voltages should complement necessary transmission protection systems. Further work needs to be undertaken to establish a methodology of an ANM system receiving a dynamic set point or GSP export limit from the incumbent transmission owner or GBSO; and
- DNOs should be able to connect a greater level of connection capacity to their network and implement flexible connection solutions to manage generation export within existing network limits prior to the need to make an application to the GBSO to upgrade the transmission network. This would only occur when the level of constraint experienced by the distribution connected customers cannot absorb the level of forecast constraint. This relies upon a design methodology that considers the actual contribution of connected generation in respect to MWh as opposed to a design standard that relies upon maximum generation / minimum demand network limits.

[44] https://www.spenergynetworks.co.uk/pages/arc_accelerating_renewable_connections.aspx

In the five years since the ARC project completed in 2016, ANM control has benefitted from many technical and commercial improvements, and there have been a raft of new ANM schemes setup around the country. ANM control approaches continue to develop as new technologies and markets change how our networks are used. DNOs are investing in innovation projects and trials to fine-tune how ANM can be operated to benefit customers connected to the schemes and those on the wider networks.

The Open Networks project, headed by the Energy Networks Association (ENA) has looked closely at how ANM could be improved to meet a customer and network operator need that is not wholly met by other control approaches. A key output of this activity has been the Curtailment Process and ANM reliability Good Practice Guide. [45]

7.2. Replicability and learning from the Dunbar scheme

ANM is now routinely offered and used by DNOs in the UK as an alternative, flexible connection that permits generation projects to connect in constrained areas. In many cases, like the Dunbar scheme ANM is offered as an interim connection agreement ahead of a planned reinforcement. There are however instances of "open-ended" ANM connections being used without an explicit date, or commitment, that a reinforcement will be made.

Five out the six GB DNOs now have GSPs with ANM active, or in development and it is estimated that around 1.3 GW or 2% of total GB generation is connected within an ANM scheme[46]

ANM is relatively low cost to install and operate by DNOs, at around £50-100k per GSP area[47], and relatively low cost for customer operationally, although this will depend on the size of the project, ANM schemes typically have around £30k of hardware and software costs required to enable remote access to circuit breakers with £3.5k/MW/yr in maintenance and support.

In addition to the setup and operational costs of the scheme, there will also be revenue lost through curtailment of generation, when compared to a full, firm connection for the project. To date, generation customers do not get compensated for lost generation, as they may do if connected to the transmission network, this cost and the risk of curtailment is therefore wholly borne by the customer. This is an important point which would of course impact the CBA of ANM for a DNO, if compensation for 'out of service' curtailments had to be provided.

Table 15 Generation connected to ANM schemes in GB 34 Source: Cornwall Insight[46]

Level of ANM in GB, 2020	Capacity of ANM enabled generation (MW)
Scottish Power Energy Networks	152
Scottish and Southern Energy Networks	160

[45] https://www.energynetworks.org/assets/images/Resource%20library/ON18-WS1-P7%20Good%20Practice%20Guide%20v1.1%20(REPUBLISHED).pdf

[46] Optimal coordination of active network management schemes with balancing services markets, NG-ESO Cornwall Insight and WPD, 2020

[47] Illustrative figures provided by SGS

Electricity North West	0
Northern Powergrid	770
UK power Networks	114
Western Power Distribution	108
Total volume of generation on ANM schemes	1.3 GW
Proportion of distribution connected generation	**?? – Regen to confirm**
Proportion of total GB capacity connected to an ANM scheme (1.3 of 75.8 GW[48])	**2%**

The Dunbar ANM trial scheme is one of a number of early schemes that was developed in response to the upsurge of renewable energy deployment in the period between 2012 and 2017. As already highlighted, the Dunbar scheme has a number of specific features added to the benefit proposition for its customers which need to be considered:

1. Much of the direct employment linked to the Dunbar scheme comes from just one project, the Viridor Energy Recovery Facility (ERF), with 52 out of the 56 full time equivalent (FTE) jobs per year and as such, these levels of employment would be unlikely in other ANM schemes. But outside of employment, the contribution from all the projects to the local economy during construction and operation (plus the structured community benefit funds set at £5000/MW/year) is substantial. In the case of the Hoprgishiels project, some of the project revenue was used by Berwickshire Housing Association to fund an ongoing social housing programme, leading to the creation of 30 FTEs for the 25 lifetime of the project.[49]

2. A key driver for projects to join the scheme and to get an early connection was the timetable set by the closure of the ROC subsidy scheme in 2017. Generators were therefore prepared to accept a degree of curtailment risk and uncertainty which a post-subsidy developer might be less willing to bare. Future customer appetite to accept a ANM scheme connection, and what this means for the developer of an ANM "customer offer" is discussed in PART 2 of this study.

3. The Dunbar ANM scheme had a definite end date, at the point at which GSP upgrades were made in 2021. There was therefore a natural limit on the duration of constraints and a commitment that customers would eventually be given a firm connection. This therefore addressed some of the concerns raised about open-ended ANM schemes

7.3. Curtailment management

Modelling of networks both meshed and hierarchical has improved since 2012, giving confidence to both customer and DNO about the level of curtailment that might be expected

48 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1006701/DUKES_2021_Chapter_5_Electricity.pdf

49 Information supplied by CES based on an assessment by Scottish Enterprise

at any GSP with ANM. However, there is still risk that those estimates will be exceeded and currently this risk is carried by the customer alone.

There is significant activity in the sector from Ofgem, ENA, Elexon and others exploring how curtailment could be either capped or shared better. This would provide valuable certainty to customers but the operation of these schemes is likely to be for challenging for DNOs to manage. This is intrinsically linked to wider changes in the electricity network including the targeted charging and access review and the DNO to DSO transition. How the future of ANM might be impacted by these changes is picked up in the following chapter.

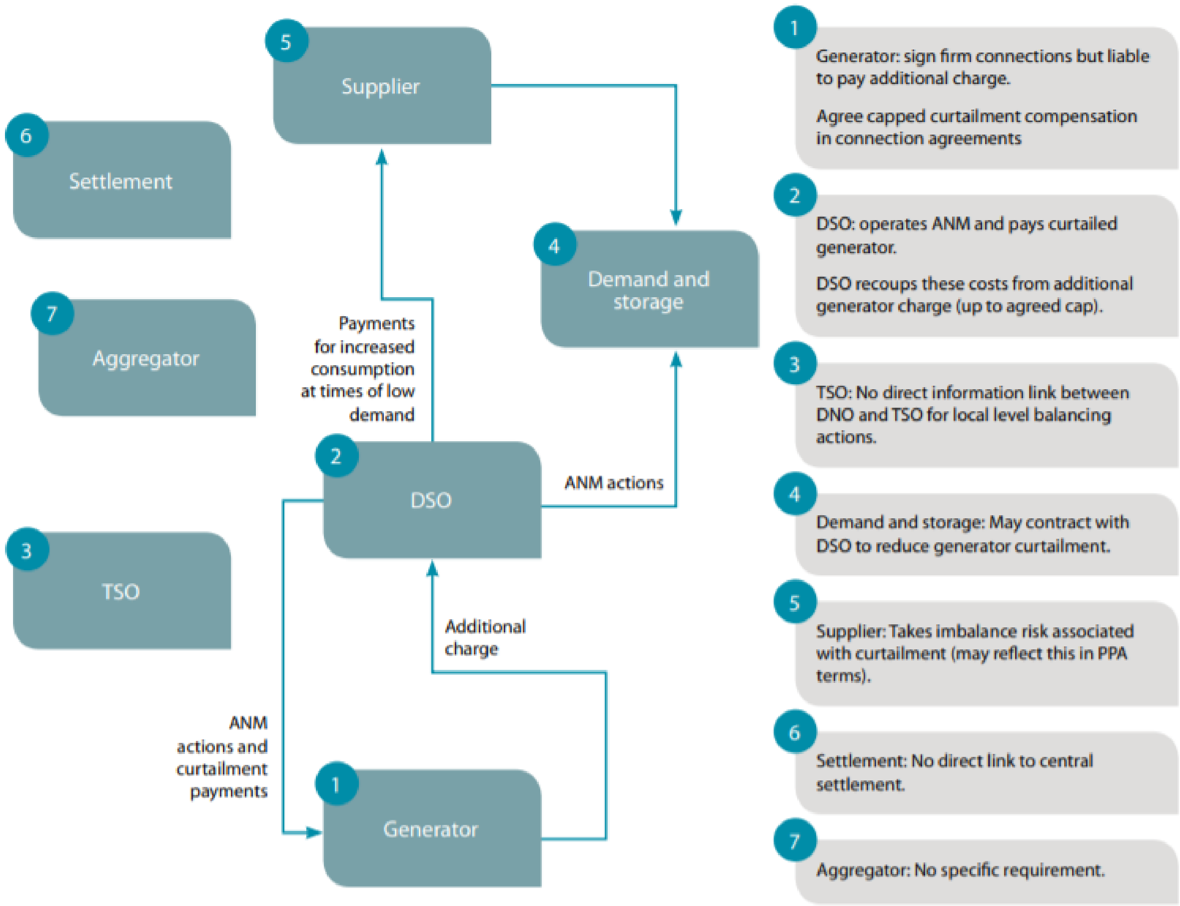

Figure 9 Illustration of constraint payment process (Source, Elexon, 2015)

As reported in the ENA's 2021 report on product 3 of the Open Networks Project: Principles to Review Legacy Flexible Connections (ANM) contracts[50], four out the five DNOs that currently offer ANM already provide ANM customers with information on the specific constraint they are impacted by, including location or substation identifier and the position in the LIFO queue. UKPN have gone further, stating that if they curtail the customers for any reasons other than those identified in the connection contract, the customer is eligible to the DGNU Payment (Distributed Generation Network Unavailability Payment).

50 https://www.energynetworks.org/industry-hub/resource-library/on21-ws1a-p3-anm-legacy-contracts-review,-stakeholder-feedback,-and-recommendations-(12-may-2021).pdf

The ANM scheme deployed at Dunbar GSP used a commercially bound merit order of access to the network using Last in First Off (LIFO) principles. This meant that the last generator to enter the LIFO stack was the first to be curtailed. The position of the generator within the LIFO stack was, during the ARC project, secured based on the date planning permission was granted for the project. This differs from other schemes, where other DNOs have granted positions in the stack based on the date that the connection offer was accepted. The advantage of using planning permission in order to set the LIFO stack position was that it prevented generators from blocking out access to those generators who were ready and willing to connect in the shortest possible timescales and negates the opportunity of creating a secondary network access queue.

As SP Energy Networks moved to implement similar schemes as part of our wider network roll-out they recognised that securing the position in the LIFO stack based on planning permission grant date also has downsides. The SPEN Business as usual (BaU) policy, developed towards the end of 2016, implemented a staged connections process for flexible connections. This ensured that customers connecting to the network were clear as to when their position in the LIFO stack was to be secured and that capacity which could productively be used by others was not tied up when projects stalled.

How customers are added to ANM curtailment order queues is similar across DNOs, with some variation about whether curtailment is phased or instantaneous. All five DNOs operate LIFO stacks, with only some older, legacy schemes in UKPNs licence area using a Pro-rata principle of access, which curtails customers in proportion to their contribution to the constraint.

At a broader level however, DNO management of distribution networks constraints whether through flexible connections, ANM schemes or the provision of local flexibility, has historically sat outside of the balancing and settlement arrangements which operate at a national level.[51] The ESO has therefore been largely unsighted to the actions DNOs are taking at distribution level and at the same time, suppliers with offtake agreements with DERs are exposed to imbalances caused by DNO activity.

While ANM and flexible connections were a relatively small proportion of the market, the volumes of local balancing had little impact on the balancing and settlement process. But as ANM and other flexibility solution become more prevalent, these local balancing operations will have to be accommodated at national level. This requires sophisticated data sharing and the coordination of actions at the distribution / transmission boundary.

While ANM does not provide an integrated solution for DSO/ESO coordination, it has tested the concept of real-time constraint management and the monitoring, control and data collection technology that could enable this to happen.

There is a three-way challenge that remains to be resolved (and is explored more fully in the next chapter):

1. How to keep ANM queue management simple and transparent

[51] https://www.elexon.co.uk/wp-content/uploads/2015/03/Active-Management-of-Distributed-Generation_March2015.pdf

2. How to improve fairness for future projects around queue position and protect against gaming, for example, the risk that a dispatchable generator could deliberately target high generation periods in order to trigger a constraint and then receive a payment to turn-down its generation
3. Keep the operational risks around queue management proportionate for a DNO/DSO

7.3.1. ANM with different generation (and demand) technologies

The Dunbar scheme benefited from having an energy from waste plant as well as a number of windfarms. Including a range of different generation (and demand) loads within an ANM scheme has a number of advantages in terms of load; diversification, queue management and increasing the opportunity for customers to potentially trade capacity.

The Dunbar scheme did not include battery storage or a dispatchable generator such as a gas reciprocating engine. Inclusion of battery storage within an ANM offers an even greater opportunity to optimise capacity utilisation by exploiting the battery's flexibility to provide both generation and demand load. Battery storage and other flex providers within the constraint managed area offer flex services to the ANM partners and may also become part of a long term flexibility solution to replace the ANM.

Battery's do however bring added complexity:

- Because they may be providing a variety of services and targeting different business models, battery behaviour can make it more difficult to model and estimate future curtailment within the ANM
- With very high ramp rates (extremely fast response times), and voltage swings (the ability switch from charge to discharge in milliseconds), batteries can potentially exceed the ability of early stage ANM monitoring and control technology to respond to network constraints. ANM technology therefore needs to continue to innovate match the performance and respond times of batteries and other smart technologies. This is not unique to ANM schemes but is becoming a more general requirement for networks to accommodate 'smart' technologies
- Batteries and other flexibility providers are also very likely to be providing services to other customers, including, for example Transmission Operators and ESO network services. This again highlights the potential risk of conflicting response actions and the need to distribution network controls to be aligned and integrated with transmission and system operations.

8. What is the future for ANM?

There isn't a final answer about the future development of ANM, nor should it be seen as a complete solution. ANM is a set of tools, which are still developing, and a new approach to manage network constraints whilst provide a customer connection which will also be subject to change and evolution. In the wider context of flexibility and the evolving role of the DSO, ANM is one of a number of solution that may be deployed in isolation or as part of a more holistic package of measures.

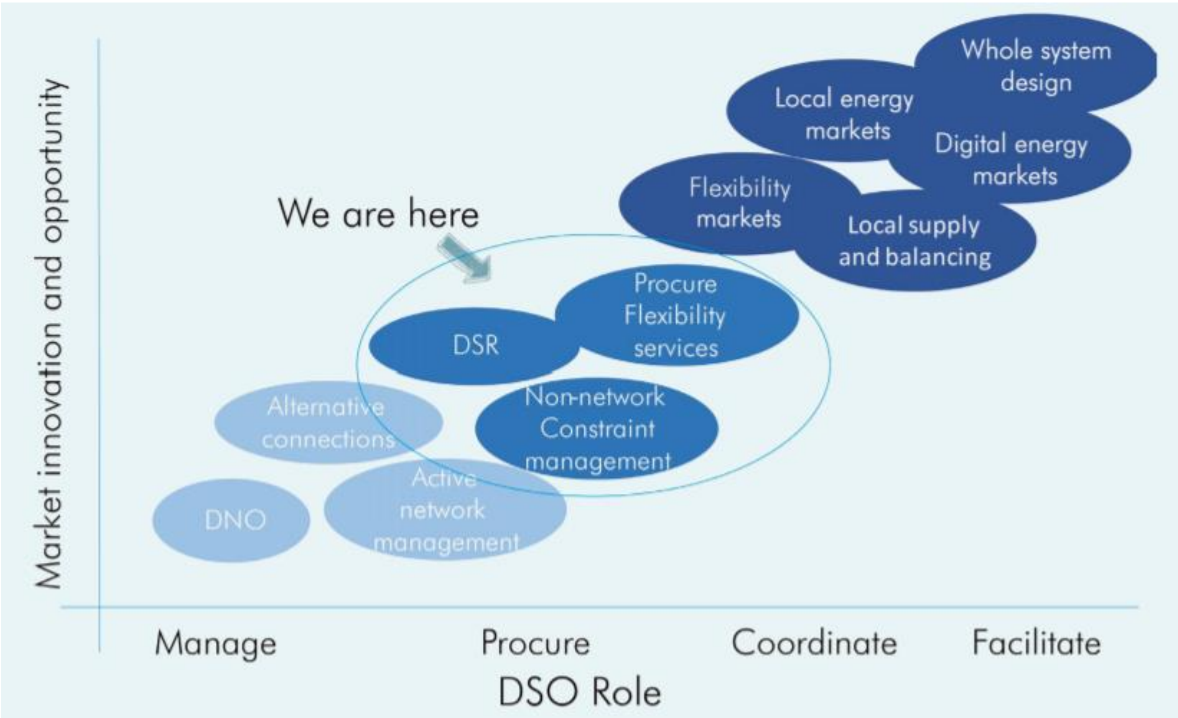

Figure 10 Direction of travel from DNO to DSO (Source, Regen)

Looking to the future ANM faces four major area of innovation challenges and opportunity:

1. Ensuring that ANM (and the use of constraint management zones) accelerates the deployment of low carbon technologies and does not become a "no-go" sign for project development or a blocker for needed network investment

2. Creating an attractive customer proposition so that new connection customers are attracted by ANM based solutions in the context of a post-subsidy world of merchant risk and the potential shift to shallower connection charges. That means that ANM contracts need to be transparent and fair for the connection customer.

3. Ensuring that ANM, and other network management actions, taken on the distribution network are aligned with the operation of the whole energy system at transmission and system level.

4. Ensuring that ANM does not crowd out, or prevent, the development of other flexibility solutions

Taken together these innovation challenges are likely to lead to significant changes in the way ANM schemes are established and managed leading to.

- Changes to ANM propositions to provide customers with more certainty of curtailment outcomes including possible energy loss or time limits, that would pass at least some curtailment risk back to the network operator
- ANM schemes that have curtailment limits, service levels and or term limits, with the implication of some form of compensation payments
- Alternatives to the LIFO queue management that to allow greater fairer access across ANM participants. With extensions to queue management to enable, or facilitate, market based solutions including capacity or constraint trading between ANM participants
- Greater data sharing and transparency with etter curtailment forecasting, transparency and planning of ANM approaches within Constraint Managed Zones (CMZ)
- With a higher degree of risk sharing between customers and networks, empowerment and incentivisation of DSOs to implement these approaches
- Greater integration between the operation of ANM and CMZ schemes on the distribution network and the operation of transmission network and system operation controls
- Market models that will allow an ANM approach to work with, and potentially facilitate, other flexibility solution providers
- Whole system approach to Cost Benefit Analysis (CBA) that will help to determine the appropriate use and end-point of an ANM scheme based on the point at which a network investment and/or flexibility solutions would be economically optimal.

8.1. Supporting strategic investment to achieve net zero

In a best practice application, ANM is one approach that can allow earlier connection for customers while allowing networks to plan and optimise the delivery of strategic investment. The Dunbar case study was a good example of this in practice. ANM should not however be allowed to become a become a blocker on investment where this is needed.

The answer to the question of how and when ANM based solutions should transition to a longer term reinforcement or flexibility solution relies on the ability (and incentive) of DSOs to take a whole system approach to cost benefit analysis and decision making. Whole system in this case also including the benefits to generation customers and wider society in the form of energy generation, revenues and carbon savings.

Networks and regulators ought therefore to be tracking ANM schemes coming to fruition, and ensuring that there are more examples of a transition to investment or flexibility

The processes, capability and policy framework to deliver this whole system approach is not yet fully in place.

8.2. Complimentary tools in the box – working with flexibility

There has been a huge amount of activity in recent years to enable and promote local flexibility services that can be used at local and national level to respond to the increasingly variable output of the UK generation mix. A key question is whether these flexibility services, that are procured on a cost basis, be used to balance out new connections in constrained areas of the network and remove the need for an ANM?

Flexibility services providers, and Ofgem officials, have expressed a strong concern that the use of ANM may crowd-out and inhibit the growth of 3rd party flexibility services because ANM could be used to provide DNO's with a cheaper, uncompensated and possibly unlimited, source of flexibility. This risk is especially true in cases, unlike Dunbar, where open-ended ANM schemes have been implemented without any curtailment limitation, or indication of when the scheme may transition to a firm connection offer, enabled by network investment or the use of other flexibility services.

So far, ANM schemes and flexibility service provision have tended not to directly compete with each other, as most ANM schemes have been concerned with generation led constraints, while most flexibility service contracts have targeted demand led constraints. This could change in the future if the industry moves towards wider use of CMZs that may have a number of different constraint levels and different approaches to network management for both generation and demand.

As ever more complex tools and approaches to balancing the electricity system are layered on top of each other, this question about the relative value and purpose becomes more and more relevant. The emergence and bedding-in of the DSO function over the next five years will bring these questions to the fore as our energy system continues to decentralise and come more bi-directional.

The ENA has been working on how this patchwork of approaches and tools might fit together to deliver *optimised* solutions. Specifically on the difference between flexibility services and ANM, they have articulated this in their recent paper, 'Flexibility Connections: Explainer and Q and A'[52]

[52] https://www.energynetworks.org/industry-hub/resource-library/on21-ws1a-open-networks-flexibility-connections-explainer-and-q-and-a-(19-aug-2021).pdf

Table 16 Key differences between ANM and Flexibility services (Source: ENA, 2021)

Function	Flex connections (ANM)	Flexibility Services
Used for Thermal Constraints	Yes	Yes
Used for Voltage Constraints	Yes	Yes
Used for Fault Level Constraints	No	No, but being tested
Controls Real power	Yes	Yes
Controls Reactive power	No, but capable	Yes
Export Turn-down	Yes	No
Export Turn-up	No	Yes
Import Turn-down	No	Yes
Import Turn-up	No	Yes
Current Likely utilisations periods	Times of high renewable output and low demand	Peak demand, planned outages, network faults

Technically, there is a clear need for both ANM and flexibility services working together to manage capacity on the network and connect more MW of generation sooner. The use and demand for these services should play an important feedback loop into investment strategy. DSOs will need to make an economic assessment when ANM+Flex starts to cost more to operate and in constraints for projects than paying for reinforcement (and the scheduling of those works) .

With greater scope to keep connecting generation even in constrained areas, the order of reinforcement works may become less hierarchical. Distributed Future Energy Scenarios (DFES), Local Area Energy Plans (LAEPS) and the DNOs own investment strategies are attempting to visualise the same features, and greater flexibility in where to invest provides an opportunity for more strategic planning.

8.3. Changes in network charging

Ofgem are undertaking a comprehensive review of network charging, reflecting the increasingly distributed nature of assets connecting to the network, and seeking to identify how to decarbonise the electricity system at the lowest cost whilst protecting consumers. The review is made up of two closely linked reviews, Access and Forward-looking Charges Significant Code Review[53] and Targeted Charging Review. Both of these have important implications for the future market appetite for ANM when compared to other connection approaches.

A significant change that could impact directly on the use of ANM is Ofgem's minded-to proposal to move to a "shallower" network connection charging methodology.

Currently, projects wanting to connect to a constrained area must pay upfront for the assets needed to connect them to the network, plus a proportion of any reinforcement costs. This

53 https://www.ofgem.gov.uk/publications/access-and-forward-looking-charges-significant-code-review-consultation-minded-positions

approach was designed to provide a price signal that encouraged developers to avoid constrained areas. Ofgem are now considering whether than approach is in the best interest of consumers, especially in light of increasing contribution to generation from distributed assets and more heat and transport being electrified.

In the event of a 'shallower charging regime', a generator only pays for the section of distribution network necessary to directly connect their project to the network. Any other reinforcement costs are recouped through use of system charges. Currently, this is the regime that operates on the transmission network, but not the distribution network.

There is still a lot of uncertainty about how the SCR will be implemented. At face value, the reduced up-front costs for new connections under a "shallower" network access connection charge methodology may encourage new connection customers to only opt for a firm connection making an ANM option less attractive.

In practice however, and depending how the detailed policy changes are implemented, if network operators are enabled to plan and optimise the timing of network reinforcement and use of flexibility options, this may open an opportunity for ANM approaches to provide interim solutions. Thereby allowing renewable generation assets and other net zero enabling technologies such as Electric Vehicle (EV) chargers to connect earlier, and in advance of network reinforcement or flexibility solutions being in place.

It should be noted that Ofgem has published a 'minded to' position on network charging, but the process of reforming network charging is still in its early phases.

8.4. ANM and the role of the DSO

In its 'Key enablers for DSO and the Long-Term Development Statement' published in 2019, Ofgem clearly articulate that different approaches to flexible connections and markets have made it unclear what the remit of the DNO is to flexibility providers or aggregators. Whilst Ofgem recognise that ANM is entirely the DNOs responsibility, there is scope for it to be dispatching flexibility assets itself, working with flexibility assets and markets in a complimentary way.

Referencing the ENA Open Networks project, Ofgem can see the potential for conflict if DNOs own and operate one of the links between generators and markets – something they are keen to address before it becomes a significant issue.

No decision on how to address this overlap of influence have been taken, with Ofgem only recently closing the consultation on this and other aspects of dispatch and control of flexibility access, but it is clear that operating ANM can be way of introducing *more* flexibility assets into the market on-top of simple curtailment.

As well as supporting the use of secondary markets to commoditise capacity, it is likely that Ofgem will encourage reporting on the level of curtailment experienced by customers, helping provide transparency to the effectiveness of ANM over other approaches.[54]

SP Energy Networks recently updated their DSO strategy recently[55] which provides details on the use of ANM, constraint Managed Zones (CMZs) and other network management tools as core tools in decarbonising the networks. As the strategy makes plain, SP Energy Networks are deploying wide scale ANM across the Dumfries and Galloway network area in one of the biggest rollouts of its type and are expanding the use of CMZs in the next investment period, known as RIIO-ED2 to an additional 22 locations.

[54] https://www.ofgem.gov.uk/sites/default/files/2021-06/%281%29%20Ofgem%20Access%20SCR%20-%20Consultation%20on%20Minded%20to%20Positions.pdf

[55] https://www.spenergynetworks.co.uk/userfiles/file/SPEN_ED2_DSO_Strategy_Report_July_2021.pdf

9. Appendix

9.1. Evaluation approach

The economic evaluation approach used in this study was based on guidelines published by Scottish Enterprise. This approach providing guidance on estimating employment, and GVA. Carbon impact, investment, research and community benefit were estimated using industry standard calculations and benchmarks, outlined below.

Project Investment

Project investment figures provided estimates for supply chain spend and jobs safeguarded or created. These were derived from published figures where possible and calculated where published figures were unavailable.

Table 17 Investment in projects connected to the Dunbar ANM scheme

Project	Headline investment cost	Source
Aikengall	N/A – project was built before ANM	
Dunbar ERF	£177m	Estimated build cost published on Viridor website[56]
Hoprigshiels	£12m (Estimated)	Capacity (MW) x £1.61m (construction cost for onshore wind in £/MW, as published by BEIS)[57]
Kinegar	£8m(Estimated)	
Ferneylea	£2.4m (estimated)	
Total	**£200m**	

Turnover

Turnover was calculated based on two types of revenue stream: wholesale electricity price and in the case of Dunbar ERF, gate fees.

For the electricity revenues, annual generation was multiplied by the annual average baseload contract day ahead in £/MWh, as published by Ofgem:[58]

Table 18 Annual average baseload day ahead electricity price £/MWh

2012	2013	2014	2015	2016	2017	2018	2019	2020
45	51	42	41	43	46	58	44	37

[56] https://www.viridor.co.uk/who-we-are/latest-news/2015-news/green-for-go-at-177m-dunbar-erf/

[57] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/566567/BEIS_Electricity_Generation_Cost_Report.pdf

[58] https://www.ofgem.gov.uk/energy-data-and-research/data-portal/wholesale-market-indicators

For electricity revenues, these figures were multiplied by the MWh generation per project, found from publicly available ROC database.

For Ferneylea, which did not receive any ROCs, generation was calculated per year from the capacity of the wind farm (1.5MW) and the average capacity factor of similar windfarms in the area, calculated to be 0.31.

Employment

FTE figures for direct, indirect and induced employment were estimated using figures for the project turnover and Supply, Use and Input-Output tables published by Scottish Government for each two-digit SIC code.[59]

Factors used:

Table 19 Employment factors and multipliers used in evaluation

Example year 2017	SIC code	Type 1 Employment Effect Factor	Type 1 employment multiplier	Type 2 Employment Effect Factor	Type 2 employment multiplier
Wind projects	35.1 Electricity	3.7	2.6	4.5	3.1
Dunbar ERF	35.1 Electricity	3.7	2.6	4.5	3.1
Dunbar ERF	38,39 Waste Remediation and management	6.6	1.9	8.2	2.4

Turnover, in £m, is multiplied by the Type 1 employment effect to produce direct and indirect employees and the Type 2 employment effect to produce direct, indirect and induced employees.

Direct employees (FTE) are found by dividing the Type 1 (Direct and Indirect) values by the Type 1 employment multiplier.

In the case of the Dunbar ERF, revenues from waste activities and electricity generation were combined and the factors for the 35.1 Electricity SIC code were used to calculate employee numbers. The FTE numbers generated were similar to those published by Viridor (52 against 55 published).

Short term employment (construction)

Short term employment related to the construction of the projects is challenging to quantify. Almost certainly, the £200m of investment either created or safeguarded employment for the contractors and supply chain companies that delivered materials, equipment, services and

[59] https://www.gov.scot/publications/input-output-latest/

labour to the project sites. However, ascertaining how much of this activity was in the local, national or international sphere is hard to quantify.

Using industry benchmarks[60] [61]and rule-of-thumb calculators[62], it is likely that £200m of investment safeguarded or created over 2400 short term FTEs, over the project lifecycle, although many of these may be for international or national supply chain companies rather than a local workforce.

Gross Value Added

GVA figures, (direct, indirect and induced) were estimated using figures for the project turnover and Supply, Use and Input-Output tables published by Scottish Government for each two-digit SIC code.[63]

Factors used:

Table 20 GVA factors and multipliers used in the evaluation

Example year 2017	SIC code	Type 1 GVA Effect	Type 1 GVA multiplier	Type 2 GVA Effect	Type 2 GVA multiplier
Wind projects	35.1 Electricity	3.7	2.6	4.5	3.1
Dunbar ERF	35.1 Electricity	3.7	2.6	4.5	3.1
Dunbar ERF	38,39 Waste Remediation and management	6.6	1.9	8.2	2.4

Carbon

Carbon emissions calculated based on generation figures per annum.

Annual average carbon intensity figures, kgCo2e/kWh, are published by BEIS:

Table 21 annual average carbon intensity factors, kgCO2e/kWh

2012	2013	2014	2015	2016	2017	2018	2019	2020
0.46	0.44	0.49	0.46	0.41	0.35	0.28	0.26	0.23

The average reduction year on year in carbon intensity is 3%. For years 2021 – 2038, an estimation for the likely carbon intensity was generated, dropping 3% a year from the 2020 figure.

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[60] https://www.building.co.uk/download?ac=1664616
[61] https://www.arcom.ac.uk/-docs/proceedings/ar2012-0317-0326_Forbes_El-Haram_Horner_Lilley.pdf
[62] https://counterplan.com/free-construction-jobs-calculator/
[63] https://www.gov.scot/publications/input-output-latest/

Onshore Wind projects

The generation from wind projects is zero carbon. The carbon emissions savings, therefore, arise from what *would* have been emitted had that generation occurred at the average grid intensity.

For each wind project, the years they were connected to the scheme up to 2020 used published carbon intensity factors. For the remainder of their project lifetime (25 years) the projected carbon intensity, as described above, was used.

In the case of Aikengall, only the *extra* generation that was exported due to the ANM scheme was counted for carbon. This *extra-over* generation was estimated by comparing the annual generation after connection to the ANM scheme with the average annual generation recorded before connection.

Dunbar ERF

Carbon emissions from EfW plants are less straightforward to estimate, as the alternative option for the waste is landfill.

Using data published by Tolvik[64], an industry benchmark used to estimate the carbon impact of producing electricity by burning waste when compared to landfill is a net reduction in CO2e emissions of 0.05CO2e/Tonne waste. This figure was used and multiplied by the annual waste processed figures, provided to us by Dunbar ERF.

Research, knowledge transfer and supply chain

Stakeholder interviews and the Google Scholar search engine were used to find academic papers and citations of paper that referenced the Dunbar GSP ANM. Interviews with SGS provided insight into the growth of network control supply chain companies.

Community benefit

Community benefit was calculated based on the standard £5000/MW per year for onshore wind projects, over the 25 year typical lifetime of these projects.

Dunbar ERF has not published figures for community benefit funds, but has published detailed of its partnership with the Engineering Development Trust.

[64] https://www.tolvik.com/wp-content/uploads/2021/05/Tolvik-UK-EfW-Statistics-2020-Report_Published-May-2021.pdf

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