



Innovate
UK



INSIGHTS PIECE

Six ways to navigate grid constraints

To aid successful development of small-scale
renewable electricity generation projects that support
2030 net zero ambitions

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Delivered for Innovate UK's Net Zero Living Programme by The Carbon Trust



Who we are

The Carbon Trust's mission is to accelerate the move to a decarbonised future. As climate pioneers for more than 20 years, we partner with leading businesses, governments and financial institutions to accelerate their route to net zero. We are your expert guide to turn your climate ambition into impact. To date, our global network of 400 experts has helped set over 200 science-based targets and guided more than 3,000 organisations and cities across five continents on their route to net zero.

What we do

We provide solutions to the climate crisis. We support organisations globally as they accelerate towards net zero. From target setting, net zero pathways, assurance and footprinting, to policy advice, strategy setting and programme delivery, we seek smarter ways to turn intent into impact, where sustainability and economic realities go hand in hand.

This document

This Insights piece on navigating constraints on the distribution network has been developed through Innovate UK's Net Zero Living Programme. This £60 million Programme is helping local authorities and businesses work together to deliver new solutions that improve local services and open markets for economic growth.

What it is

Practical guidance to support the deployment of small-scale embedded generation projects in 'constrained areas' of the distribution network.

Who is it for

This document is for local authorities across the UK who are new to developing embedded generation projects. Whilst the intended audience is local authorities, the information provided is relevant to any organisation developing a small-scale embedded generation project.

Why it is needed

Many local authorities have set ambitious net zero targets and are looking to show leadership in their local area by developing renewable electricity generation projects. Current grid constraints across the electricity network mean that projects often face significant costs and timescales for connection. Grid Connection Reform and the government's Clean Power 2030 Action Plan are looking to amend the connection process in Great Britain for projects that impact the transmission network, to help accelerate the connection of projects critical to the net zero agenda. Smaller embedded generation (below relevant thresholds) sits outside of this process, which provides an opportunity for these assets to connect more quickly, however constraints at the distribution network level can still impact these projects. This document provides guidance to developers of these smaller embedded generation assets to support them to design and develop projects that avoid potential connection delays and accelerate implementation.

Definitions

Bulk Supply Point (BSP)	A substation within the distribution network where voltage is further stepped down (typically to 66kV or 33kV).
Clean Power 2030	Refers to an ambition of the UK Government as set out in UK Government's Clean Power in 2030 Action Plan ¹ and NESO's Clean Power 2030: Our Next Steps ² . The key aims are to ensure: <ul style="list-style-type: none">• Clean sources produce at least as much power as Great Britain consumes in total• Clean sources produce at least 95% of Great Britain's generation, and• Average carbon intensity is <50 gCO₂/kWh.
Distribution Network	The lower-voltage part of the electricity system that delivers electricity from the transmission network to homes and businesses.
Distribution Network Operator (DNO), now sometimes called Distribution System Operators (DSOs)	The companies which own and operate the distribution networks.
Electricity Network Association (ENA)	Industry body for energy network operators in the UK and Ireland (including DNOs/DSOs), ensuring alignment on technical and regulatory issues.
Grid Supply Point (GSP)	The point at which electricity is taken from the transmission system into the distribution system and stepped down in voltage (typically to 132kV).
National Energy System Operator (NESO)	Transmission system operator and carries out strategic planning of the GB energy system.
Off-grid	An electricity system that is not connected to the national electricity system.
Power Purchase Agreement	A contract between a generator and offtaker of electricity governing the terms relating to the purchase of electricity.
System Operator for Northern Ireland (SONI)	Transmission System Operator in Northern Ireland.
Transmission Impact Assessment	The process by which NESO assesses the impacts that a project seeking to connect to the distribution network will have on the transmission network, to identify whether reinforcement work is required.
Transmission Network	The high-voltage part of the electricity system that transports electricity over long distances from large power stations to regional distribution networks or large industrial users.

¹ UK Government (2024) Clean Power 2030 Action Plan: A new era of clean electricity. Available at: <https://assets.publishing.service.gov.uk/media/677bc80399c93b7286a396d6/clean-power-2030-action-plan-main-report.pdf>

² NESO (2025) Clean Power 2030: Our Next Steps. Available at: <https://www.neso.energy/document/362956/download> (Accessed: 20 October 2025)

1. Introduction and context

The UK electricity system has been transformed over the past three decades; moving from a system primarily fuelled by centralised fossil fuels, to one where an increasing amount of decentralised renewable electricity is fed into the system. With net zero targets, and Clean Power 2030, the government, and society, are pushing for continued transformation to a system in which;

“In a typical weather year, the 2030 power system will see clean sources produce at least as much power as Great Britain consumes in total over the whole year, and at least 95% of Great Britain’s generation...”³

One of the biggest obstacles facing new renewable electricity projects is the availability of capacity on the electricity network and the difficulty in obtaining feasible grid connection offers from the network operators. Although this is highly dependent on the area, new projects are often given connection dates well into the 2030s or offered heavily curtailed grid connection offers where they may be unable to export in times of generation. The network in many areas is still highly constrained and will require significant reinforcement to provide more capacity for additional projects to connect.

The connections process depends on the size of the project, and grid connection feasibility can be an issue across all project sizes. Very large-scale projects (typically >100MW) connect directly to the transmission network. In Great Britain these apply to the National Energy System Operator (NESO) for a grid connection offer, and in Northern Ireland they apply to the System Operator for Northern Ireland (SONI Limited). Smaller projects that connect to the distribution network apply to their regional Distribution Network Operator (DNO).

Up until recently the applications process in Great Britain for grid connections was ‘first come first served’, where even highly speculative projects could apply for grid connection and be added to the queue of those waiting to connect, effectively keeping aside that grid capacity even if the project didn’t go ahead for many years. This has resulted in a queue of 771GW of projects (as of March 2025), far beyond the total amount of new capacity currently required for GB to meet net zero⁴.

For Clean Power 2030 to be achieved an overhaul of the connections process is required so that the projects most needed can go ahead. NESO have implemented Connection Reform measures covering the network in Great Britain to try and address this; moving the system from ‘first come, first served’ to ‘first ready and needed, first connected’. This will re-order the existing queue based on strict readiness criteria for the project and by which projects are most needed on a regional basis according to NESO’s modelling. It is hoped that this will free up about 500GW of capacity, meaning more potential to connect new projects more quickly in some areas (although this will still be highly area dependent as some regions might be oversubscribed for certain technology types and others might be undersubscribed).

³UK Government (2024) Clean Power 2030 Action Plan: A new era of clean electricity. Available at: <https://assets.publishing.service.gov.uk/media/677bc80399c93b7286a396d6/clean-power-2030-action-plan-main-report.pdf>

⁴Energy Networks Association, ENA (2025) Joint Transmission and Distribution Connections Dashboard. Available at: <https://www.energynetworks.org/industry/connecting-to-the-networks/connections-data>

This new process only applies to new projects connecting to the transmission network or those connecting to the distribution network but above a certain MW threshold, which triggers the need for a Transmission Impact Assessment (TIA). The MW threshold for TIA varies in different parts of Great Britain, as summarised in table 1. Smaller scale local energy projects (including locally owned and community projects), connecting at distribution level, are a key part of the UK Government’s plan to achieve the Clean Power 2030 goals. The Local Power Plan launched by GB Energy has an ambition of 8GW of new local power by 2030. To increase the speed of connection for new smaller-scale projects (including local energy projects), Ofgem approved proposals to increase the lower threshold for evaluation of TIA in England and Wales from 1MW to 5MW (on the condition there is appropriate fault level headroom at the GSP) in May 2025⁵, with the threshold in Scotland’s mainland increasing from 50kW to 200kW in 2024⁶.

As such, any projects exceeding the thresholds in table 1 will need to follow the new connections process, with smaller projects avoiding a TIA and continuing to follow a ‘first come, first served’ process.

In Northern Ireland, for projects less than 5MW in capacity there is no requirement for a TIA, there is just a requirement for sufficient capacity at the relevant Bulk Supply Point⁷. For generators with a capacity greater than 5MW, System Operator for Northern Ireland (SONI) will complete a Firm Access Quantity (FAQ) analysis at the appropriate time⁷.

Area of Great Britain	Threshold
England and Wales	5MW
Scottish mainland	200kW
Scottish islands	50kW

Table 1: Transmission impact assessment thresholds in Great Britain

Whilst the TIA threshold provides an opportunity for smaller projects to connect more quickly, constraints on the distribution network mean that a lot of these smaller projects may still face long timescales and high costs. These timescales and costs arise from the need for reinforcement works to the electricity network to address the constraints and facilitate the connection. Reinforcement works can be significant, and costs quoted for sub 5MW projects have been known to run into millions of pounds.

This document provides guidance to developers of these smaller embedded generation assets (sub-TIA MW size) to support them to design and develop projects that avoid potential connection delays and accelerate implementation to support local net zero ambitions.

⁵ Ofgem (2025) Ofgem Decision to approve CMP446: ‘Increasing the lower threshold in England and Wales for Evaluation of Transmission Impact Assessment’. https://www.ofgem.gov.uk/decision/decision-approve-cmp446-increasing-lower-threshold-england-and-wales-evaluation-transmission-impact-assessment?utm_source=linkedin&utm_medium=ofgem&utm_term=&utm_content=&utm_campaign=

⁶ SSEN (2024) SSEN Transmission takes important step to speed up new connections in the north of Scotland - SSEN Transmission. <https://www.ssen-transmission.co.uk/news/news-views/2024/8/ssen-transmission-takes-important-step-to-speed-up-new-connections-in-the-north-of-scotland/>

⁷ Northern Ireland Electricity Networks (2023) Distribution Generation Application and Offer Process Statement. Available at: <https://www.nienetworks.co.uk/getattachment/86e81498-a206-4d3c-b9ae-3398864b94df/Distribution-Generation-Application-Offer-Process-Statement-Nov-23.pdf>

Six potential options for navigating grid constraints are introduced:

1. Exploring alternative connection points on to the distribution network.
2. Reducing the project's overall generation capacity or integrating a phased build-out of the project.
3. Directly consuming the electricity generated and limiting the amount of electricity exported on to the distribution network.
4. Pursuing an alternative connection offer with non-firm network access.
5. Integrating battery storage.
6. Using the electricity to generate green hydrogen.

What are constraints?

The electricity network has been built to facilitate the flow of electricity from generators to consumers. The individual components/equipment forming the electricity network allow for a certain level of electricity to flow through them. Where electricity is restricted in its potential to flow between two points of the electricity network, this is referred to as a constraint⁸.

Constraints:

- can be actively managed by the transmission system operator or distribution system operator (e.g. through actively altering supply/demand of electricity at certain locations on the network); or
- may lead to network operators preventing new generation/demand connecting to the network in a certain location until the necessary infrastructure is upgraded and can facilitate the additional flow of electricity.

In addition to constraints which limit the flow of electricity at certain points of the electricity network, insufficient fault level headroom on specific parts of the electricity network can prevent the connection of additional electricity generation. When generators connect to an electricity network they increase the maximum energy released when a fault occurs on the network. The network equipment has a safe fault level design limit which cannot be exceeded⁹. The difference between the fault level design limit and the existing fault level (based on the generators already connected or contracted to connect) of a specific area of the network is called the fault level headroom. New connections may not be possible where fault level headroom is insufficient to allow it to safely connect.

⁸ National Grid (no date) Constraint management service. Available at: <https://www.nationalgrid.com/sites/default/files/documents/Constraint%20Management%20Services%20v1.0.pdf>

⁹ SP Energy Networks (2021) Fault level monitoring and management. Available at: <https://www.spenergynetworks.co.uk/userfiles/file/ED2-LRE-SPEN-001-CV3-EJP%20-%20Fault%20Level%20Monitoring%20and%20Management%20-%20Issue%202.pdf>

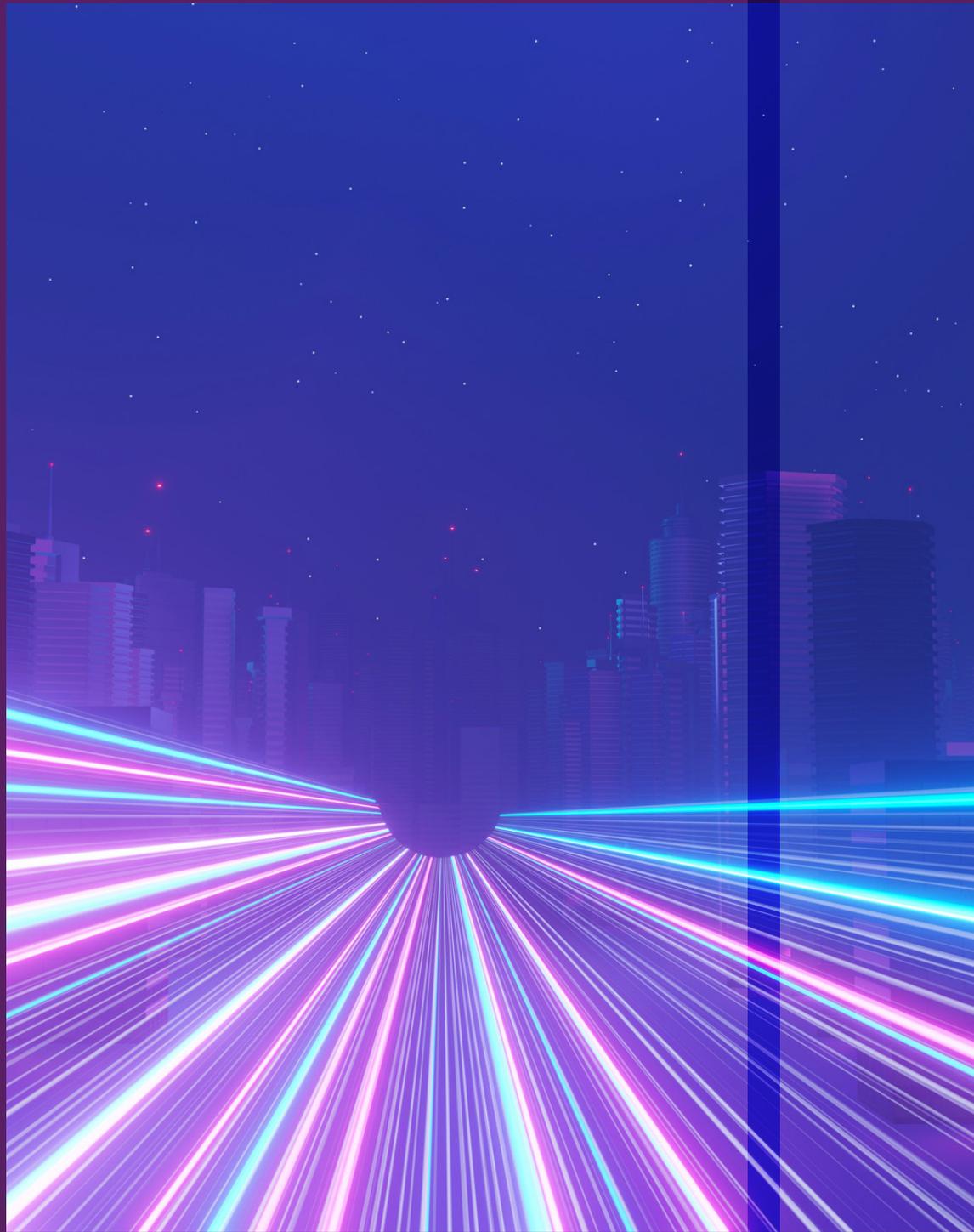
How are grid connection costs calculated?

In 2022, the decision on the 'Access and Forward-Looking Charges Significant Code Review'¹⁰ looked to reduce the overall connection charge incurred by those connecting to the distribution network, whilst retaining and strengthening protections for bill payers associated with the most expensive types of distribution connections. It did this by:

- Requiring DNOs to offer connecting customers a non-firm access connection (see section 3.4), where this presents a network benefit and the customer wishes to opt for this, and include within these offers, clear curtailment limits and an end-date when the connection can convert to a firm connection.
- Altering the way the cost of connecting a distribution asset is calculated, as follows:
 - For network connection extension works that solely benefit the connecting generator, the connecting generator is liable for 100% of the costs
 - For wider network reinforcement works at the voltage of connection the connecting generator pays a proportion of the cost up to a High Cost Cap;
 - For wider network reinforcement works at voltages above the voltage of connection the DNO covers the costs of the works up to a High Cost Cap (previously the customer had to contribute to reinforcement costs one voltage level above the voltage of connection);
 - The High Cost Cap is a £/kW value above which the connecting customer is required to pay in full for any reinforcement costs, with the cap currently set at £200/kW.

Whilst the changes made by this decision have reduced potential connection costs faced by connecting generators, costs can still be significant and present a barrier to deployment. Additionally, any reinforcement works to facilitate a firm connection are still required, meaning connection timescales can still be long.

¹⁰ Ofgem (2022) Access and Forward-Looking Charges Significant Code Review: Final Decision. Available at: <https://www.ofgem.gov.uk/sites/default/files/2022-05/Access%20SCR%20-%20Final%20Decision.pdf>



2. Understanding your project's likely connection status

Before formally applying for a grid connection offer there are ways to check how likely it is your project will be able to connect in the near future:

1. Identify your District Network Operator (DNO)

If you are unsure about who your DNO is, enter your site's postcode into the Energy Network Association's (ENA's) online tool¹¹. Figure 1 identifies the DNOs across the UK and Ireland.

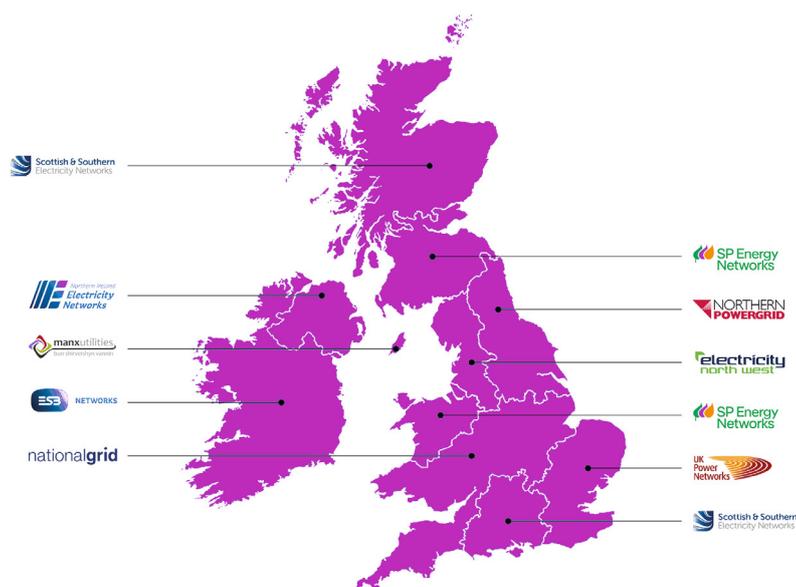


Figure 1: DNOs across UK and Ireland¹¹

2. Engage with the DNO's support information

All UK DNOs provide a suite of online tools and data to help customers understand the status of the network for new connections and any grid capacity constraints. These resources range from interactive capacity maps and data portals to connection advisory services. They enable demand and supply customers to:

- assess network headroom and understand the geographic spread of constraints
- view DNO plans for planned network upgrades
- show zones where the DNO is actively seeking flexible services due to constraints
- navigate the connections process.

The level of information provided varies between operators. The ENA provide a [list](#)¹² of details available for each DNO, with web links on their website. Details of typical resources are provided in table 2.

¹¹ ENA (2025) Who's my electricity network operator? Available at: <https://www.energynetworks.org/customers/find-my-network-operator>

¹² ENA (2025) Connections data. Available at: <https://www.energynetworks.org/work/industry/connecting-to-the-networks/connections-data>

Table 2: Resources and services provided by DNOs to support developers with grid connections

Resource	Purpose	DNO links
Capacity Heat Maps / Network Capacity and Constraints Maps	Visual representation of available headroom at substations or circuits for new load or generation to support identification of potentially feasible locations for new connections.	ENWL , NGED , NIEN , NPG , SSEN , SPEN , UKPN
Embedded Capacity Registers (ECR)	Detailed information on existing and accepted generation and storage connections.	ENWL , NGED , NPG , SPEN , SSEN , UKPN
Long-Term Development Statements (LTDS)	Provide technical data on network assets and planned reinforcements to support early-stage assessments.	ENWL , NGED , NPG , SSEN , SPEN , UKPN
Open Data Portals	Datasets (e.g. asset ratings, load data) for technical self-assessment and analysis.	ENWL , NGED , NPG , SSEN , SPEN , UKPN
Flexibility Services Maps	Shows zones where DNOs are actively seeking flexible services due to constraints.	Piclo Flex (covers ENWL , SPEN and NPG), NGED , NIEN , SSEN , UKPN
Connection Support Services e.g. connection surgeries and application portals	Allow customers to discuss project scope, constraints, and connection options directly with DNO engineers before committing to a formal application and incurring associated costs.	ENWL , NGED , NPG , UKPN , SPEN , SSEN
Budget Estimate Tools	Provide free indicative cost estimates for new connections without a formal application.	ENWL , NIEN , NPG , SSEN , SPEN , NGED
Cluster maps	In Northern Ireland, cluster connections are used as a way of minimising the visual and environmental impact of network infrastructure by combining this for several projects planned in the same area. Individual projects (usually onshore wind farms) connect to one hub substation via shorter 33kV lines. NIEN publish cluster maps of existing and planned clusters; joining an existing or planned cluster may allow a project to connect earlier. Although these are primarily used for larger projects, smaller scale projects planned in the vicinity of a cluster may also be encouraged to connect into the cluster ¹³ .	NIEN
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¹³ NIEN (2025) Clusters. Available at: <https://www.nienetworks.co.uk/connections/generation-connections/small-large-scale/clusters>

3. Contact the DNO to discuss your project

Where possible arrange to meet with an engineer from your DNO to discuss your project early-on and prior to formal grid application. They can provide real-time insights into the constraints experienced at your location on the electricity network and advise how best to design your project to ensure it can be connected in a suitable manner. Most of the DNOs provide "connections surgeries" (see table 2). For those that do not provide formal connections surgeries, still reach out via their website contact details to see if you can arrange a meeting and receive feedback on your proposed project.

What to ask when talking to the DNO?

- Provide details of your proposed project (geographic location, technology type, indicative point of connection etc.) and likely maximum export capacity (regardless of any potential onsite/private wire consumption).
- Enquire as to the likely complexity of this connection and likelihood of requirement for significant works or reinforcement to facilitate connection.
- If it is indicated the connection would be subject to significant delays or costs, enquire as to whether there is a lower export capacity that would not trigger such works (see section 3.2).
- If the project has potential for onsite consumption or consumption via a private wire, enquire as to whether the maximum development capacity could be connected with export limited to a lesser capacity (based on the amount likely to be consumed onsite/ via a private wire).
- Ask if an approximate cost and timescale for connection can be provided (this may need to be requested via a budget estimate).



3. Six ways for projects to navigate high grid costs / long connection timescales

3.1 Explore an alternative connection point

One potential solution to long connection timescales is to explore an alternative connection point. This may cause an increase in capital costs due to longer cabling requirements but can provide a net financial or timescale benefit for the proposed renewable energy scheme if grid reinforcement requirements are avoided. DNOs provide infrastructure maps (Capacity Heat Maps/Network Capacity and Constraints Maps, see table 2) which contain the locations of all primary, bulk supply point (BSP) and grid supply point (GSP) substations. These maps also hold additional information on the import and export capacities of each substation and general connection viability (typically depicted using a red/amber/green scale) and can therefore be used to identify alternative connection points with more favourable import/export capacities.

A proposed connection point will be provided by the DNO following the submission of a budget estimate or formal grid application. When discussing a formal offer or budget estimate response with the DNO, challenge the proposed connection point to understand if an alternative connection point would be more beneficial, in terms of timescales and costs. When discussing an earlier stage project with the DNO, discuss all options, and confirm if the information in the infrastructure maps is up to date or likely to change in the near future due to planned or ongoing works.

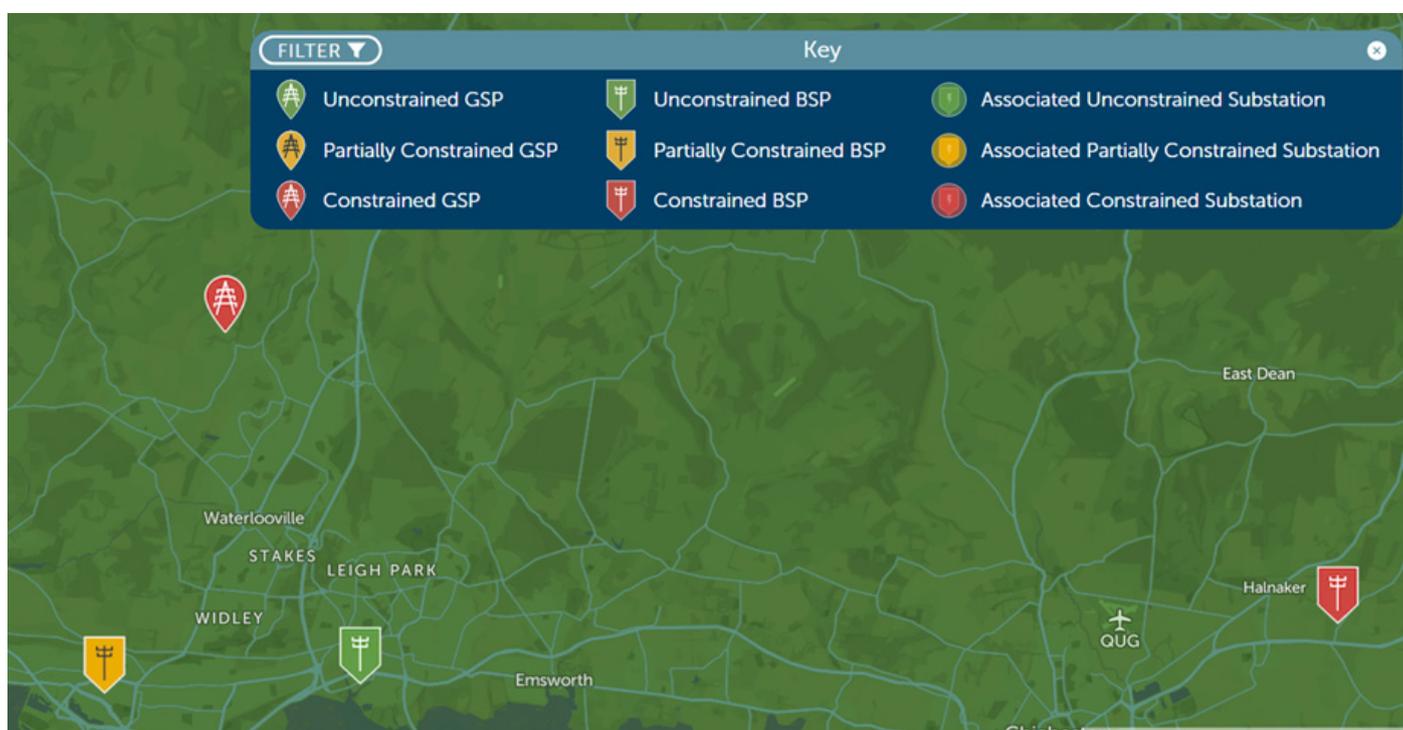


Figure 2: Snapshot of SSEN network capacity map, depicting substation locations and constraint status¹⁴

Technology suitability:

- Most suitable for larger solar and wind farms.
- Unlikely to be suitable for roof-top solar or micro hydro projects.

¹⁴ SSEN (2025) Network Maps. Available at: <https://network-maps.ssen.co.uk/>

COED ELY SOLAR FARM

The Coed Ely solar farm is a ~6MW solar farm near Tonyrefail (south Wales), which was developed and is now owned and operated by Rhondda Cynon Taf County Borough Council (RCTCBC). The solar farm exports 5MW of electricity to the electricity network, and 1MW to the local Royal Glamorgan Hospital. The solar farm was first identified in 2018, at that time there was not a viable grid connection available on the electricity network. The council, supported by the Welsh Government Energy Service, explored private wire arrangements as an alternative route to market, but at that time none were found to be viable. The council kept in touch with the Distribution Network Operator about a number of different renewable energy projects and through a face to face meeting between RCTCBC, the Welsh Government Energy Service, and Western Power, network constraints maps were reviewed and a new electricity line was identified, which had been built for a nearby wind farm, as a viable export solution enabling the 5MW export connection to be secured. This allowed project development to be initiated. At a later date, by taking advantage of works underway on the road that links the solar farm to the hospital, the council were able to lay ducting for the private wire and enable the export connection to the hospital.

This example:

- illustrates that grid connection status is not static, and
- exemplifies the benefit of keeping in touch with distribution network operators and regularly reviewing network constraints maps.



(Image source: Welsh Government Energy Service Impact Report 2024 to 2025¹⁵)

¹⁵ Welsh Government (2025) Welsh Government Energy Service Impact Report 2024 to 2025. Available at: <https://www.gov.wales/energy-service-impact-report-2024-2025.html>

3.2 Reduce the overall generation capacity or integrate a phased build out

The DNO may be able to advise on a reduced generation capacity that would be able to export its full capacity to the grid and avoid the need for costly and lengthy grid connection works. A small reduction in the planned overall generation capacity may be possible while maintaining project financial feasibility.

Alternatively, a phased build-out of the project could be adopted. Under this scenario, phase 1 of the project build-out could meet the current network capacity with a later phase being built at a later date when network reinforcement works have been completed enabling the full project capacity to be built and connected.

Technology suitability:

- Most suitable for solar PV which can easily be built out in distinct segments.

3.3 Direct consumption and export limitation

Direct consumption of generated electricity, either by you, as the organisation developing the generation asset, or by a third-party organisation connected to the project via a private wire, may enable a reduction in export capacity required without reducing the overall generation capacity. This scenario requires an export limitation scheme to be incorporated into the project.

Export limitation schemes allow generation or storage installations to connect to the grid by capping export to agreed capacity levels (in some cases to zero). These schemes measure power at the grid connection point and automatically restrict generation (or increase demand) to avoid overloading network assets. The ENA provides technical and operational requirements for such schemes, called Engineering Recommendation G100.¹⁶

To comply with G100, installers must use approved control hardware/software capable of rapidly reducing exports below the agreed limit, with built-in fail-safe mechanisms. Installations must also adhere to ENA's technical standards and undergo DNO-supervised commissioning. The total generation capacity and export capacity that can be installed under an export limitation scheme will depend on the network's thermal limits, voltages, and fault levels at the point of connection. The design capacities are set to ensure safe operation of the grid during times of occasional excursions from normal operation, in which current flow exceeds the export limits for a short period of time (less than 15 seconds). Information from the DNO and specialist electrical engineering advice will be required to inform a suitable project and export limitation scheme design. In some locations an export limitation scheme will not be possible, e.g. where there is no fault level headroom available.

¹⁶ ENA (2023) EREC G100 Issue 2 Amendment 2 – Technical Requirements Customer Export and Import Limitation Schemes. Available at: <https://www.energynetworks.org/publications/ena-erec-g100-issue-2-amendment-2-technical-requirements-customer-export-and-import-limitation-schemes>

To apply for a grid connection with an export limitation scheme, applicants must submit a G100 application form alongside their main generation application to the DNO. The DNO reviews this and, if approved, the installer proceeds with installation and commissioning. A separate commissioning form must be submitted within 28 days of commissioning.¹⁷

In addition to potentially enabling faster, lower cost grid connections, other benefits arising from direct consumption of the generated electricity include:

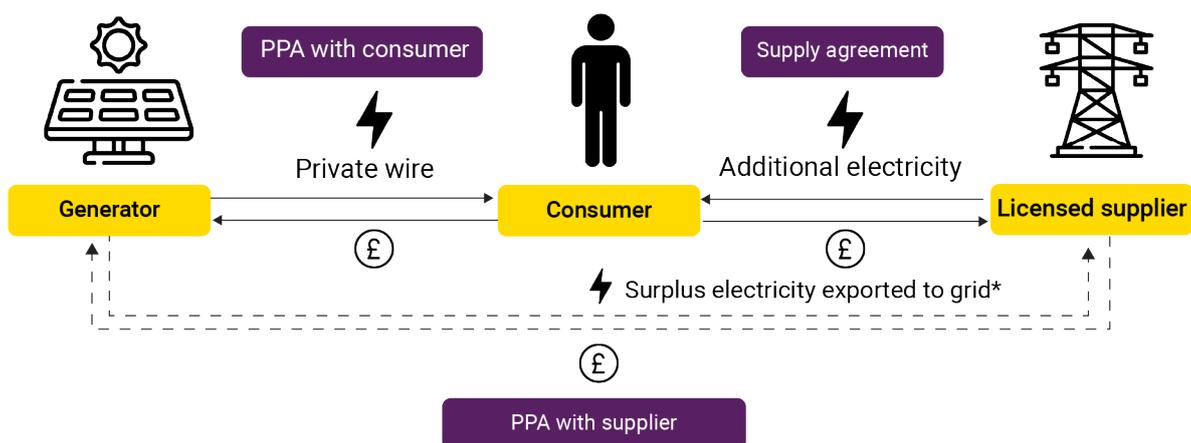
- Supporting organisational net zero targets and potential for scope 2 emissions reduction through direct consumption of renewable electricity generation; and
- Financial benefits of self-consumption/sales to a third party, by offsetting higher cost electricity imported from the grid or achieving a more favourable private wire Power Purchase Agreement (PPA) tariff.

Where power is purchased by a local third-party consumer ('offtaker') e.g., a local business with significant electricity demand, a Power Purchase Agreement (PPA) will need to be agreed to fix the terms of the electricity sale. The structure of private wire PPAs is shown in figure 4. You, as the generator, enter into an agreement with the consumer for sale of a certain volume of electricity produced by the renewable energy asset at a mutually agreeable price. This could be the entire electricity output or a certain agreed minimum amount. As the electricity demand of the consumer will fluctuate and it is unlikely that the renewable energy generation will provide all of their needs at all hours of the day, the consumer will still require a supply agreement with a licensed supplier to purchase the remainder of their electricity needs. If the PPA is only for sale of a proportion of the generation, then you can sell surplus electricity to the grid which will be governed by a separate PPA with a licensed electricity supplier or other relevant offtaker. There is also the potential for an arrangement with multiple offtakers via a microgrid, however it should be noted that this increases the technical and legal complexity of the project, and associated costs.

Private wire PPA arrangements are generally mutually beneficial to both you, as the generator, and the third-party consumer. Typically, the generator can secure higher electricity sale prices than the grid export price, and the consumer will pay less for the electricity than their retail import electricity price and can hedge against further electricity price increases in the future. When implementing a PPA, it is important to ensure suitable legal advice is gained to advise on the agreement terms as well as supply license exemptions.

¹⁷ NGED (2025) Export Limitation Schemes: Customer Applications. Available at: <https://connections.nationalgrid.co.uk/customer-export-limitation-schemes/>

Figure 3: Structure of a private wire PPA



Direct private wire connections incur costs, which can be substantial for projects involving private wires covering considerable distances. It is important to conduct financial analysis to determine whether the cost of the private wire can be sustained. If the site is located directly next to the consumer or on the same premises then this is very likely to be favourable, however the further away the generator is from the consumer the more expensive the private wire is likely to become. It also depends on the route the cabling will need to take; with the type of ground being crossed (agricultural land/greenspace versus hard surfaces) and any infrastructure obstacles (e.g. railway lines, bridges) along the route affecting the cost. Land ownership and permissions is another key consideration; if the cabling crosses the land of third-party landowners wayleaves or easement will need to be agreed, and this could greatly add to the legal complexity and potentially add costs and delays to the project. Typically, the larger the project, the greater the distance the generation asset can be from the offtaker and still be financially viable. Whilst financial viability is highly project specific, and sensitive to the agreed electricity sale price, table 3 suggests some typical distance thresholds to consider when initially identifying potential offtakers.

Table 3: Approximate distances within which to explore a possible private wire offtaker(s)

Technology	Indicative installed capacity	Approximate distance within which to initially explore a possible private wire offtaker(s)
Solar PV	< 200kW	Onsite/adjacent to site (e.g. solar car ports)
Solar PV	1MW	Up to ~2.5km
Solar PV	5MW	Up to ~5km
Onshore wind	1MW+	Up to ~5km

If you, as the generator, are supplying your own electricity demand these distances could also be increased due to the higher value associated with the electricity. The greater the distance, the more complicated the private wire will be to arrange, and therefore the private wire should be factored into the development from an early stage.

When identifying a potential direct consumer of electricity, it is important you understand the potential for the generation profile to match the consumer's demand profile. Half-hourly metering data of electricity consumption can be analysed against electricity generation simulations to understand the potential profile match and determine the most appropriate project capacity size for the consumption profile and export capacity available. The closer the profiles match, the more likely the project is to be viable. It is also worth considering potential future changes to demand, e.g. increased demand through electrification of heat and transport. It is additionally important to consider the longevity of the consumer, particularly where there is limited opportunity to export electricity to the grid. You need to be confident that the consumer will require your direct supply for a sufficient time period to warrant progressing with the project.

Technology suitability:

- Suitable for any project in close enough proximity to a suitable electricity load.

Aberystwyth University Penglais Campus

Aberystwyth University developed, owns, and operates a 2.5MW solar farm on a site near to its Penglais campus. The solar farm directly supplies the campus with electricity via a 1.5km private wire. The solar farm is located in a grid constrained area and has a zero export connection with the local electricity network, preventing it from exporting electricity onto the distribution network. Due to this, the solar farm was designed to maximise direct consumption of the electricity generation potential. Energy modelling during development provided the University with the confidence that a large percentage of the potential electricity generation would be consumed by the campus and that the solar farm would contribute significantly to meeting the campus' electricity demand. In the first year of operation, the solar farm provided 21% of the campus' electricity demand and reduced emissions by 481tCO₂e. Cost savings from unpurchased electricity, resulting from the project, provide strong financial value to the university and mean the project has a forecast payback period of under 8 years.

This example:

- illustrates that projects can be successful without a grid export connection, and
- exemplifies the multiple benefits of self-consumption of renewable energy projects.



3.4 Pursue an alternative connection offer with non-firm network access

A standard grid connection is assumed to have firm network access. Generators with grid connections with firm network access are able to export their full export capacity at all times (excepting outages). Alternative connections providing non-firm access can have their export level reduced at times of network constraint. These alternative connections are used by UK DNOs to enable connections in areas of the electricity network that are already constrained or close to capacity. Rather than delaying projects until network reinforcements are complete, these mechanisms allow generation customers to connect earlier under these non-firm arrangements, accepting the possibility that their output may be curtailed under certain conditions.¹⁸

Alternative connection offers include:

- **Timed** connections, which limit **export during certain periods of the day, week, month or year;**
- **Soft-intertrip connections**, which can be used where there is one specific constraint point that is monitored and leads to the generator being curtailed to a specified level when the constraint is detected.¹⁹
- **Active Network Management (ANM) or Distributed Energy Resources Management System (DERMS) connections**, which provide a real-time, automated system that monitors the load and generation across the network and **dynamically curtails** connected users when operational limits (such as thermal ratings or voltage thresholds) are approached. These systems are typically implemented at 11kV and above (therefore only for larger scale projects), though lower voltage trials are underway, e.g. in Northern Ireland.²⁰

The contract conditions for alternative connection offers are subject for review. This means that you may see changes over time, for example, the curtailment conditions may be relaxed or removed following a network upgrade or may evolve as new customers connect.²¹

It is important to understand that alternative offers carry a risk of curtailment, that is being instructed to reduce output or consumption at certain times, which affects the consistency of your revenue generation. To help assess the impact of this risk, DNOs typically provide curtailment assessments or reports at the offer stage or upon request. These are often informed by historical network data, seasonal forecasts, and load flow modelling, and they estimate the expected frequency and duration of curtailment.

¹⁸ UKPN (no date) Connections Products – ANM and Timed Offers. Available at:

<https://www.ukpowernetworks.co.uk/low-carbon-technology-commercial/connections-products>

¹⁹ NGED (no date) Flexible Connection Offers. Available at: <https://www.nationalgrid.co.uk/downloads-view-reciteme/540250>

²⁰ NIEN (2025) LV Active Network Management. Available at: <https://www.nienetworks.co.uk/future-networks/innovation-projects/our-innovation-projects>

²¹ SPEN (2024) Guidance to Technical Limits Curtailment Assessment. Available at: https://www.spenergynetworks.co.uk/userfiles/file/Guidance_to_Technical_Limits_Curtailment_Assessment_Apr24.pdf

If you consider opting for such a connection, it is important to assess the viability of the connection by assessing the potential economic impact of curtailment. Key considerations include project size, technology type (e.g. solar vs. wind), revenue models (e.g. fixed PPA), local demand profiles and curtailment mitigation strategies, such as battery storage. A high level of predicted curtailment may render a project financially unviable. Therefore, it is recommended that you:

- engage with your DNO early on;
- review curtailment estimates; and
- factor these risks into your financial modelling.

While non-firm offers can significantly reduce connection lead times and costs, they require a careful evaluation of long-term financial performance under curtailment risk.

Technology suitability:

Relevance to any technology will be dependent on the extent of the constraint, i.e. the level of export limitation applied, how often, and when. The DNO should be able to provide estimates based on past generation/demand patterns.

Timed connections:

- Depending on timing of limitation, this option could be used with all technologies.
- If deployed with solar PV, battery storage or behind the meter consumption during times of constraint is likely to be required to support the business case.

Soft-intertrip connections:

- Could be used with all technologies but the likely frequency of intertripping needs to be understood to determine the impact on the business case.

Active network management:

- Relevant to larger solar and wind projects, although based on trials in Northern Ireland may become more relevant to smaller projects like roof top solar PV.

Orkney Isles

The Orkney Isles has abundant renewable energy resources (particularly wind and marine energy) and as such received a lot of early interest from renewable energy developers. Due to the relatively low electricity demand on the islands and distribution network infrastructure servicing this demand, the network was one of the first areas of the UK to reach its theoretical capacity and encounter constraints. To allow projects to progress in advance of any costly or time-consuming network reinforcement, Active Network Management (ANM) was trialled on the islands in 2006 and then officially introduced in 2009. It was the first place in the UK to introduce this system which has now been replicated across the country. Projects were offered a non-firm connection offer with projects needing to accept curtailment at times of high generation and/or low electricity demand.

As a result of the ANM system, 21.8MW of new connections were made possible (on top of the existing 47MW²²) despite the constrained network. The ANM itself reached its limits by 2012 and was closed to new applicants (other than very small connections under 3.68kW), reopening in 2020 with limited additional headroom²³.

This example:

- illustrates how non-firm connection offers can allow more projects to connect, but
- also shows that on a heavily constrained network there are limitations to what can be achieved with ANM.

²² Scottish and Southern Electricity Networks (2010) Orkney Active Distribution Network Management. Available at: https://smarterenergynetworks.org/projects/prj_1012

²³ SSEN (May 2023) Orkney Connection Options. Available at: <https://www.ssen.co.uk/globalassets/anm/orkney-connection-options--anm.pdf>



3.5 Integration of battery storage

One option for supporting a reduction in electricity export or reducing the impact of potential curtailment on your grid constrained project could be to integrate battery storage, behind the meter. This could be used to store excess electricity at times of high generation and insufficient export capacity, and would be particularly useful for projects with a timed export limitation (e.g. if a solar project has a timed export limitation during the middle of the day, excess generated solar electricity can be stored at this time and then exported in the evening when demand is higher and the export limit is removed). The stored electricity can then be exported to the grid when capacity becomes available at times of lower generation. If the renewable energy asset has a direct offtaker (either via self-consumption or a third-party), integration with a battery storage system can improve the demand/generation matching. This is known as load-shifting and means that more of the offtaker's demand is met directly by the renewable energy asset, allowing for an increase in carbon savings and cost savings/revenue (if the costs of the battery can be met by the increase in electricity consumed).

Additional revenue streams associated with batteries:

In addition to shifting the time of electricity export/use, battery storage integration may allow you to tap into additional revenue sources, such as energy arbitrage or grid balancing/flexibility services. Generally, these revenue sources either rely on charging the battery when prices are low (either via the grid or your onsite generation asset) and discharging when prices are high (energy arbitrage), or by supporting network operators to ensure security of supply or relieve constraints on the electricity network. The potential to access these additional revenue sources will in itself depend on the nature of the electricity network (and any potential constraints) at your point of connection. Specialist site specific advice should be sought regarding the likely revenues associated with the addition of battery storage at your site.

When considering the potential for battery storage at your site, it is important to discuss this potential with your DNO and assess your export constraint and behind the meter electricity load to determine whether a battery will help to address the constraint. You also need to ensure that a range of other technical considerations for co-locating battery storage with your renewable generation asset can be met at the site, including:

- sufficient space availability;
- ground stability/load bearing requirements (particularly relevant at landfill sites);
- site access for construction; and
- additional safety measures.

Technology suitability:

- Suitable for any technology, but particularly useful with timed connections, or projects with direct electricity loads.

3.6 Hydrogen generation

Whilst working with local authorities on renewable electricity generation projects, many have expressed an interest in exploring the potential for hydrogen production. Electricity generated by a solar farm or wind farm has the potential to be used by electrolyzers to produce green hydrogen gas. This is achieved by splitting water into hydrogen and oxygen through a process called electrolysis using electricity generated by the renewable asset.

Integration of hydrogen electrolyzers with renewable energy assets has the potential to generate additional low-carbon energy, yield additional revenue, and could be implemented in sites where there is limited export availability to the grid. However, a viable project requires an offtaker for the hydrogen, for which there is still limited demand in the current market.

Integration of hydrogen generation also adds significant complexity to a project, and there are many challenges that would need to be met if hydrogen generation were to be integrated into a project. These include but are not limited to:

- space requirements
- ground stability/load bearing requirements
- site access for construction, operation and transport of the hydrogen
- additional safety measures (hydrogen is extremely flammable)
- local water source and its reliability, ease of access, cost, quality and requirement for purification; around 20-30 litres of water per kg of hydrogen production are required²⁴
- additional capital investment and maintenance costs
- route to market and revenue stream certainty

These challenges should not be underestimated. The integration of hydrogen electrolyzers with intermittent renewable generators also requires battery storage and/or additional back-up energy sources to ensure that electrolysis is not hindered during periods of low/no generation. To ensure that the hydrogen produced is considered to be green hydrogen, any back-up energy sources will need to come from low carbon sources. As hydrogen generation is still a nascent technology, there are also challenges associated with a lack of regulatory guidance, both at the national and local level.

²⁴ RMI (2023) Hydrogen Reality Check: Distilling Green Hydrogen's Water Consumption. Available at: <https://rmi.org/hydrogen-reality-check-distilling-green-hydrogens-water-consumption/>

To support the business model development, you will need to identify who will consume the hydrogen produced. If there is no onsite demand, the hydrogen will need to be sold to a third party, which will require additional legal, financial and commercial considerations, alongside the technical considerations related with transporting the hydrogen to the third party. Currently the demand for hydrogen is limited. To strengthen revenue values and certainty the government has introduced a hydrogen support scheme; the Hydrogen Production Business Model²⁵. This provides hydrogen producers with revenue support for a 15-year period. A hydrogen strike price will be agreed with the government, and if this strike price is not met by the sale of the hydrogen, the government will make up the difference (via a wholly owned government company). Where the price received by the hydrogen project exceeds the strike price the hydrogen producer will pay back the difference to the government. Strike prices under the Hydrogen Production Business Model are allocated through auction rounds. The first round was held in 2022 and saw an average strike price of £241/MW agreed²⁶. There are rules and processes governing the Hydrogen Production Business Model, which will need to be adhered to, to be eligible for any payments²⁷. Given the complexity of hydrogen generation, and currently limited demand, whilst hydrogen production is theoretically an option for use of renewable electricity in grid constrained areas, it is considered that its application by local authorities will be very limited at the current time.

Technology suitability:

- Limited applicability but relevant to larger renewable energy projects.

²⁵ DESNZ (2025) Hydrogen production business model. Available at: <https://www.gov.uk/government/publications/hydrogen-production-business-model#:~:text=The%20business%20model%20will%20provide,Agreement%20includes%20the%20following%20documents:>

²⁶ DESNZ (2023) Hydrogen Production Business Model/Net zero Hydrogen Fund: HAR1 successful projects. Available at: <https://www.gov.uk/government/publications/hydrogen-production-business-model-net-zero-hydrogen-fund-shortlisted-projects/hydrogen-production-business-model-net-zero-hydrogen-fund-har1-successful-projects>

²⁷ DESNZ (2025) Hydrogen Production Business Model. Available at: <https://www.gov.uk/government/publications/hydrogen-production-business-model>

Aberdeen Hydrogen Hub

The Aberdeen Hydrogen Hub is a joint venture between bp and Aberdeen City Council to produce green hydrogen through electrolysis using renewable electricity supplied by local renewable energy installations. The project was initiated by Aberdeen City Council with bp appointed as their development partner via a competitive tendering process²⁸. The first phase, targeted for initial production in 2026²⁹, involves producing hydrogen for bus and truck refuelling from an 8MW solar farm built on an ex-landfill site³⁰. It is expected that this first phase of development will produce approximately 300 tonnes of green hydrogen per annum and fuel 25 buses and a similar number of other fleet vehicles per day²⁹. The initial phase 1 project has both a grid export connection (from the solar farm) to export excess power when required and an import connection to produce hydrogen in times of low production from the solar farm. Future phases of the project are expected to be delivered in response to an anticipated growth in hydrogen demand for transport and heat as well as an increase in local renewable energy generation.³¹

This project is an example of how:

- renewable energy projects can reduce the requirement for grid connection through hydrogen production and use, and
- local authorities can partner with larger energy organisations to deliver complex and innovative hydrogen projects.

²⁸ bp (2021) bp selected as preferred bidder for Aberdeen City Council Hydrogen Hub partnership. Available at: https://www.bp.com/en_gb/united-kingdom/home/news/press-releases/bp-selected-as-preferred-bidder-for-aberdeen-city-council-hydrog.html

²⁹ Aberdeen City Council (2024) Green light for Hydrogen Hub. Available at: <https://www.aberdeencity.gov.uk/news/green-light-hydrogen-hub>

³⁰ Aecom (2023) Planning statement – Aberdeen Hydrogen Hub. Available at: https://publicaccess.aberdeencity.gov.uk/online-applications/files/D9E923B2FC7A85AF83B0450CE74BD4F3/pdf/230299_DPP-Planning_Statement-2227263.pdf

³¹ Bp (2022) Aberdeen City Council and bp sign joint venture agreement to develop city hydrogen hub. Available at: https://www.bp.com/en_gb/united-kingdom/home/news/press-releases/aberdeen-city-council-and-bp-sign-joint-venture-agreement-to-dev.html





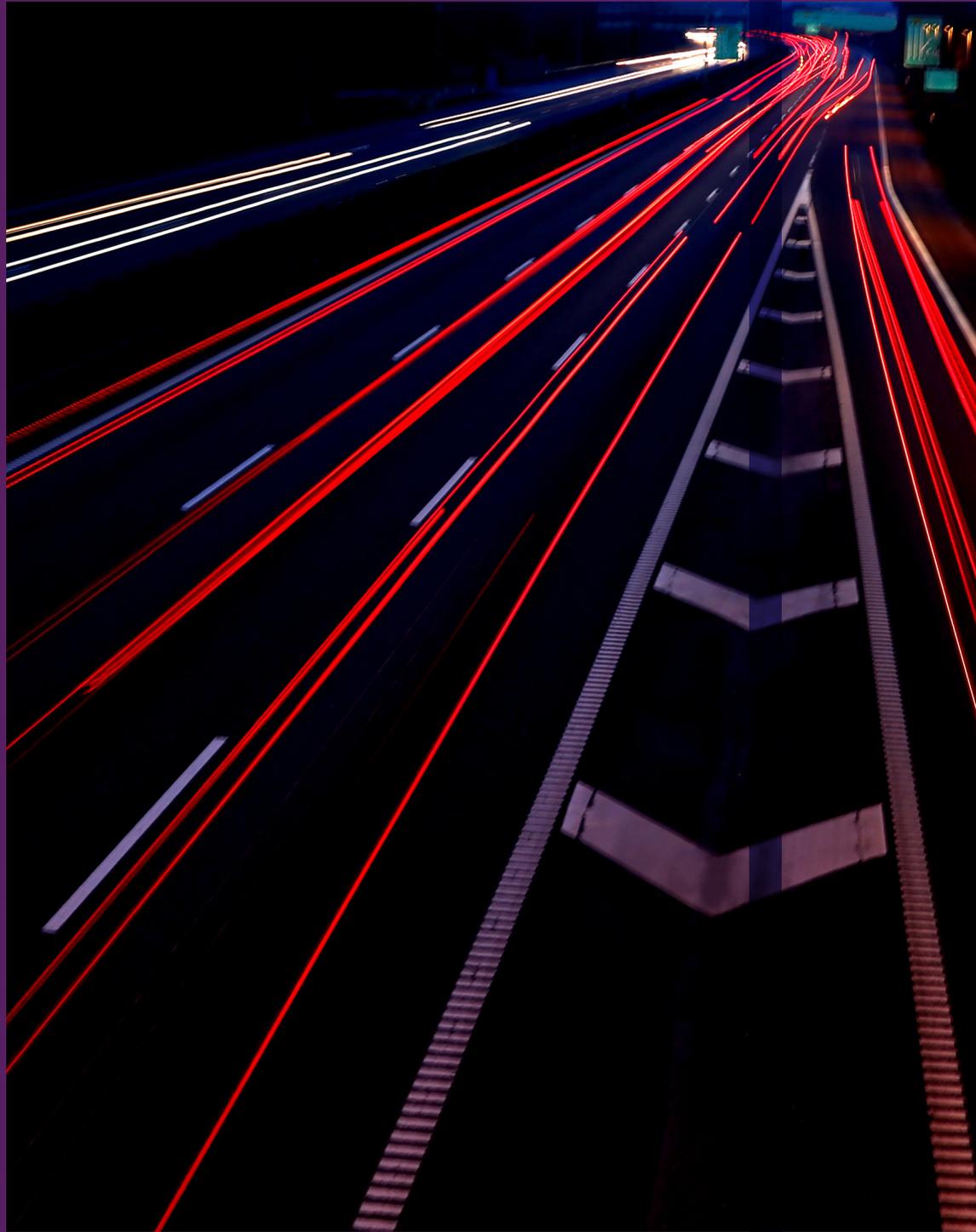
4. When you are ready to connect, what type of connection will you need?

4. When you are ready to connect, what type of connection will you need?

Once you have designed your project and determined your export capacity and arrangements, a formal grid connection application needs to be completed. There are different connection types dependent on the size and nature of your generation asset:

- G98: applies to small-scale, fully type tested micro-generators, typically rooftop solar PV, small wind turbines, or battery storage. The rated output must be under 16A per phase (equivalent to 3.68kW per phase or ~11kW on three-phase systems). Click [here](#) for more details.
- G99 (Standard): applies to generation installations in excess of 16A (3.68kW) per phase (above G98 threshold), typically covering commercial and industrial generators up to 50MW, and includes more rigorous application and compliance requirements than G98. Click [here](#) for more details.
- G99 (Fast Track): the fast track route is a streamlined option introduced by many DNOs to accelerate connections for small-scale generation that exceeds G98 limits but poses low risk to the network. Fast track is typically offered to pre-approved, low-voltage systems, often up to 32 A (7.36kW) per phase, and the Aggregate Registered Capacity for all power generating modules is 60 A or less. Click [here](#) for more details.
- G100: defines the technical requirements for export-limitation schemes, enabling generators to connect under controlled output restrictions when full capacity isn't available. See section 3.3 for more detail.

All grid connection application forms are available on the Energy Networks Association [document catalogue](#), or from your specific DNO.



5. Conclusions

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There is an opportunity for smaller renewable energy projects to avoid the long grid connection queues associated with larger projects. However, smaller projects can still be affected by long and costly grid connections associated with constraints on the distribution network.

By identifying issues early on, you can prioritise projects accordingly, and design projects in constrained areas to account for the constraints so that they can still progress in a timely and viable manner, where possible. Early discussion with Distribution Network Operators is key to success.

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