

## Grid Connection Module

This toolkit builds on the work completed for the Scottish Government's Community and Renewable Energy Scheme (CARES) by Local Energy Scotland and Ricardo Energy & Environment.

### Module Structure

The Grid Connection Module is designed to cover all sizes of project and to assist community groups of all kinds. Information specific to scale is flagged as appropriate. The module is divided into the following sections:

#### **The UK Electricity System**

A brief overview of the electricity distribution system, designed to support discussions that will be required during the connection process.

#### **The Connection Process**

An overview of the connection process for different sizes of generation.

#### **The Cost of Connection**

An overview of the components of and issues around connection charges.

#### **Securing a Connection**

Information about the content of connection offers, and the timescales around receiving and accepting them.

#### **Alternative Network Connections**

The cost of connection can make a project unviable. There are alternatives to the standard grid connection which can provide projects with additional revenue or allow connections to be made under otherwise constrained conditions.

#### **Further Information**

Appropriate links to find more information.

## The UK Electricity System

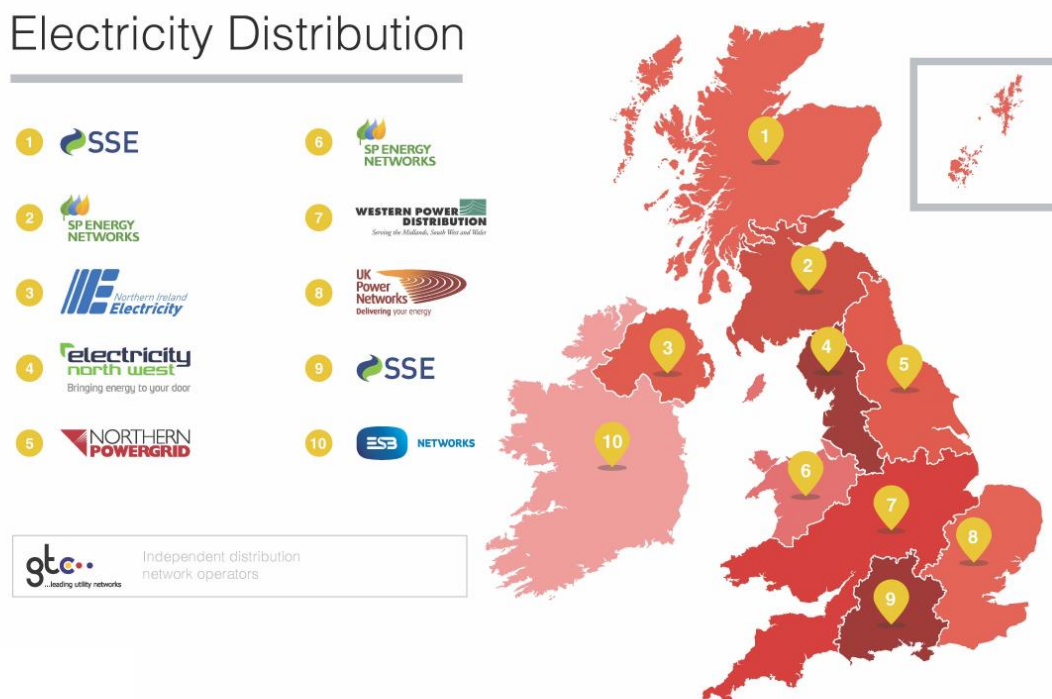
Electricity supply comprises two linked systems – transmission and distribution.

**Electricity transmission** transports electricity over long distances across the country. Electricity is transported at a high voltage to reduce losses. In Wales, the transmission network includes network at 400kV and 275kV, and is owned and operated by National Grid.

**Electricity distribution** takes power from the transmission network and distributes it to consumers. The voltage is reduced to the correct supply voltage for the loads. In England and Wales, these networks operate at 132kV and lower. Most residential customers are supplied at 230V. These networks are owned and operated by licenced Distribution Network Operators (DNOs) who are each responsible for the network within a geographic area.

The DNO in Northern Wales is SP Energy Networks, and in Southern Wales is Western Power Distribution (see Figure 1).

**Figure 1: Electricity Distribution Network Operators (Source: Copyright to Electricity Network Association (ENA) and kindly supplied. Should not be reproduced unless given permission by ENA)**



**Independent Distribution Network Operators (IDNOs)** also exist and operate small areas of network. These are often associated with major developments like business parks and industrial sites where the developer has chosen to maintain control of their network.

The operation of electricity networks is a separate business from electricity supply. Suppliers are responsible for buying electricity from generators, and selling it to consumers, and carry out activities such as metering, billing, and customer services. While customers can choose and change their electricity supplier, this is obviously not possible for DNOs.

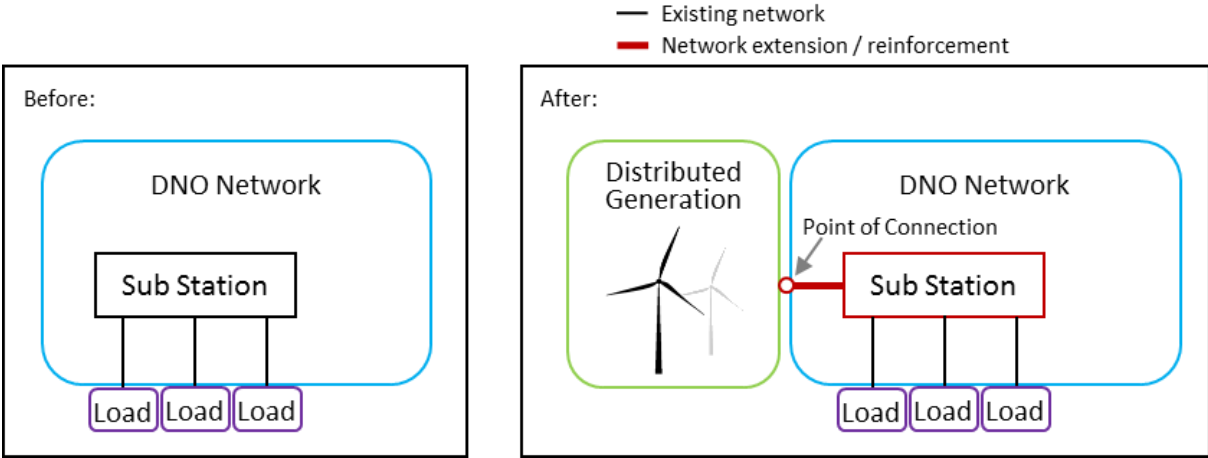
In a traditional power system, large power stations feed into the transmission network and the electricity is then transported to the distribution Networks. The distribution networks carry the electricity to consumers, such as homes and businesses. The transmission and distribution networks are also called transmission and distribution systems.

However, an increasing number of small electricity generators are being developed, often connected to distribution networks. Generation connected to the distribution network is called Distributed Generation (or Embedded Generation). Distributed Generation can result in electricity flows both from the distribution network to customers and from customers with Distributed Generation back into the distribution network. The system is no longer a “waterfall” system, with electricity flowing from the large power stations in one direction towards customers. Instead, electricity flows are more unpredictable.

This Guide is aimed at community renewable energy schemes to be connected to the distribution network. Therefore it will be your DNO who is your main point of contact for connection. However, there can also be constraints at the transmission network level which can affect the operation of embedded generation projects.

In the diagram below, the generation is connected to the DNO network via a network extension, and the local substation also needs to be reinforced (for example with a larger transformer). Note that in some cases, equipment further up the network may also need to be reinforced.

**Figure 2: An example of a typical generation connection**



**The Connection Process – Embedded Generation**

A number of technical standards are in place to govern the requirements for grid connection. These standards serve several purposes, including:

- to ensure that the generator will be able to operate safely on the network, and will not cause any issues with network protection or power quality (such as voltage level and frequency); and
- to protect the generator from any faults that may occur on the distribution network.

The processes used for connection of embedded generation depend on the size of electricity generator, and falls under two sets of Engineering Recommendations (EREC); G83 and G59.

Engineering Requirements	Criteria	Examples
G83 Single Premises	<p>Applies to ‘Small Scale Embedded Generation’, defined as generation up to:</p> <ul style="list-style-type: none"> <li>• 3.68kW on a single-phase supply,</li> <li>• 7.36kW on a two-phase supply, or</li> <li>• 11.04kW on a three-phase supply.</li> </ul> <p>This limit applies to the aggregate capacity of the installation on one supply point.</p> <p>The generation equipment must also be tested and approved according to the G83 requirements (known as ‘type tested’ equipment).</p>	<ul style="list-style-type: none"> <li>• Solar panels on a roof (domestic scale or small commercial scale)</li> <li>• Small single wind turbines</li> <li>• Very small single hydro power turbines</li> </ul>
G83 Multiple Premises	<p>If a developer is installing G83 compliant generators to more than one premises (e.g. with separate supply connection points) in a ‘Close Geographic Region’, then they have to follow a slightly more complex process.</p> <p>The DNOs will be able to give advice on this, but a general rule is that if the sites are within 500 meters of each other, or if the post codes are the same at least up until the last two letters, then they are likely to be within a close geographic region.</p>	<ul style="list-style-type: none"> <li>• Solar panels installed on multiple roofs within one community</li> </ul>
G59	<p>Applies to all other generation, including those that are too large to fall under G83, and those that are not type-tested.</p>	<ul style="list-style-type: none"> <li>• Solar farms</li> <li>• Wind farms</li> <li>• Hydro turbines</li> </ul>

The process of connecting generating equipment that falls under G59 and G83 (single and multiple installations) is summarised in the sections below.

## Connection under Standard G83 – Single Premises

In most cases, the installation of Small Embedded Generation into a single premises will have very little effect on the network. Therefore the connection process is relatively simple, and can be summarised as “fit and inform”. The key tasks are needed to connect G83 compliant generation to the network are listed below. There is no charge or delay for connection of embedded generation under G83. Hence, some schemes are carefully sized to fall within the maximum limits of G83.

Design, Construction and Commissioning	Find a competent installer to install and commission generation and connection equipment. A competent installer will be aware of the technical requirements of G83 and ensure that construction and commissioning is in line with these.
Inform the DNO	There is a legal obligation for anyone wishing to install this type of generation to notify the DNO of their proposal within 28 days following the date of commissioning. An installer will often offer to submit the notification as part of its scope of work.
Ongoing Responsibilities	The equipment needs to be maintained throughout its lifetime to ensure that it is in good working order and continues to meet the requirements of G83.

## Connection under Standard G83 – Multiple Premises

Where customers, developers or installers wish to install more than one G83 unit within a close geographic region, there is a much greater chance that the connected generation will have an impact on the local network. DNOs may have to upgrade existing equipment, or install new equipment, to ensure that the network can maintain proper operation when the generation comes online. Therefore an agreement must be made with the DNO before the connection is made, and the generation developer will be required to pay a connection charge to the DNO to cover the costs incurred.

The list below presents the key actions that you have to complete to connect multiple to the electricity distribution network. This is alongside the other elements of the project such as design and construction of the installation itself and any commercial arrangements to sell the electricity that the system will produce.

Review Information and Discuss with the DNO	<p>DNOs provide information to support generation developers on their websites, such as maps that show the existing spare network capacity. Many also hold dedicated generation ‘surgeries’ or ‘drop in’ sessions to discuss projects.</p> <p>Early engagement with the DNOs is important to identify any potential grid connection barriers to the project. This is important to ensure grid connection timelines and costs are commensurate with project ambitions. See the Further Information section for links to the DNO websites.</p>
Formal Application and Connection Offer	<p>Before the connection to the network is constructed, a formal connection offer must be agreed with the DNO. To do this, an application form must be submitted in the format given in <a href="#">Appendix 2 of EREC G83</a>, which is available on the Energy Network Association’s website. The form is often submitted by the installer.</p> <p>Once the DNO has reviewed the form and conducted any assessments, they will produce a connection offer. This will specify the conditions for the connection and any connection charges that apply. You should ensure that you fully understand this offer before accepting it, and can discuss questions with your DNO if you are unsure.</p>
Construction and Commissioning	<p>The DNO may need to carry out some work to prepare for the connection, for example to increase the capacity of the local network to ensure that your generation can connect safely. Close communication with the DNO throughout this process will allow coordinated planning of construction and connection.</p> <p>Again, a competent installer should be aware of the technical requirements of G83 and ensure that construction and commissioning is in line with these.</p>
Inform the DNO	<p>Once the installation is complete, the DNO needs to be made aware of your generating unit(s) and the technical detail of the installation. An installation commissioning confirmation form must be submitted for each installation within 28 days of commissioning. This is usually completed by the installer.</p>
Ongoing Responsibilities	<p>The equipment needs to be maintained throughout its lifetime to ensure that it is in good working order and continues to meet the requirements of G83. The DNO must be informed if any change is made to the generation or connection equipment, and when the equipment is decommissioned.</p>

## Connection under Standard G59

The tasks for connecting generation equipment under G59 are similar to those to connect multiple generators under G83, in that there needs to be a connection agreement with the DNO before the connection is made. However, the process is potentially more complex and the cost of connection could be significantly higher if the infrastructure and planning required to make the connection is much greater. The list below presents the key actions that you have to complete to connect multiple generators to the electricity distribution network.

<p>Review Information and Discuss with the DNO</p>	<p>Use the information provided by the DNOs during the design of your project. For example, their Long Term Development Statements which will lay out the plans that they have to develop their networks in the future, and network capacity information including capacity heat maps. Many also hold dedicated generation ‘surgeries’ or ‘drop in’ sessions to discuss projects.</p> <p>Early engagement with the DNOs is important to identify any potential grid connection barriers to the project. This is important to ensure grid connection timelines and costs are commensurate with project ambitions.</p>
<p>Gain Information and Plan Provision of Connection</p>	<p>Seek initial meetings with the DNO to discuss the proposed generation project, discuss the process of connection, and clarify the contestable and non-contestable work required for the connection.</p> <p><b>Non-Contestable Work:</b> The tasks that DNOs must do themselves, so that they can maintain co-ordination and control of their networks. Generally this includes reinforcing existing network equipment.</p> <p><b>Contestable Work:</b> The work that is open to competition it is called Contestable work, and can be conducted by the DNO or Independent Connections Providers (ICPs). This will be an individual project decision. Often, this work includes installation of new infrastructure, such as cables, transformers etc., that do not yet exist on the network.</p>
<p>Formal Application and Agreements</p>	<p><b>Connection Application:</b> All DNOs use the same common application form for G59 connection applications, and the DNO will specify what information they need. There is also a simplified form specifically for smaller generation projects (50kW or less three phase, or 17kW or less single phase), which is type tested under G59 or G83. This form may be submitted by the developer, installer, or the ICP.</p> <p><b>Connection Agreement:</b> Once the DNO has reviewed the form and conducted any assessments, they will produce a connection offer. This will specify the conditions for the connection and any connection charges that apply. You should ensure that you fully understand this offer before accepting it, and can discuss questions with your DNO if you are unsure.</p> <p><b>Adoption Agreement:</b> Where an ICP has been used to construct some of the connection infrastructure, an Adoption Agreement may be necessary to lay out the terms under which the DNO will take ownership of these connection assets.</p> <p><b>Site Responsibility Schedule:</b> (sometimes called a Joint Operational Agreement) In some cases it will be necessary to have a formal agreement for the operation of the connection interface between the generation project and the distribution network.</p>

Construction	<p>Clear communication is essential between the developer, the DNO and the ICP (where applicable) in order to coordinate construction of the generation equipment itself and the construction of the connection infrastructure.</p> <p>Once the equipment is constructed, the final generation equipment parameters will need to be submitted to the DNO. Where this is different to those supplied before the connection offer, then the DNO may need to review the offer.</p>
Commissioning	<p>Clear communication is also required during planning and carrying out the commissioning and connection, as both the generation unit and the connection equipment will need to be ready for the connection to be made.</p> <p>The generation equipment will need to be commissioned according to the requirements of G59, and the DNO may need to witness this. You must inform the DNO of the proposed commissioning schedule at least 15 working days before the intended date.</p> <p>After commissioning, a Commissioning Form will need to be submitted to the DNO. This must be within 30 days of commissioning.</p>
Ongoing Responsibilities	<p>The equipment needs to be maintained throughout its lifetime to ensure that it is in good working order and continues to meet the requirements of G59. The DNO must be informed if any change is made to the generation or connection equipment, and when the equipment is decommissioned.</p>

## Generation Embedded within a Building's Electrical System

If the proposed installation is to be connected to the system after the fuse protecting the DNO electricity supply and there is no intention to export electricity to the grid, then a connection agreement is not required. Under these circumstances, you must put the appropriate technology in place to prevent overspill of electricity on to the grid. Again, all work should be carried out to the necessary health and safety requirements and wiring regulations. Such detailed evaluation of the electrical systems should be completed by a qualified electrical engineer and is likely to form part of the technology supply agreements.

## The Cost of Connection

The cost of connection charged by a DNO will include a number of elements. The most obvious element is the cost of the infrastructure to connect the generation unit. This is made up of:

- Network Extension – the cost of any new infrastructure built to connect the generation project to the network will be charged to the developer through the connection charge.
- Network Reinforcement – a proportion of any infrastructure associated with reinforcement of existing network will be charged to the developer through the connection charge.

The connection charge will also include other elements, such as the cost of any investigations and studies carried out in order to deliver the connection offer, site visits and administration.

DNOs publish information on how they determine connection charges (often called ‘charging methodologies’), and these can be used to gain an idea of the likely charges that will be included before the formal offer is made. This information will be on the DNOs’ websites.

Budget or indicative estimates for connection charges may be gained by a DNO or third party consultants, though these should be interpreted carefully as they may not be accurate. While DNOs cannot charge when giving formal quotes, some may charge to give estimates.

In some cases, the planned generation will impact the transmission network, and additional studies will need to be carried out by the Transmission System Operator, National Grid. This is known as the Statement of Works process, and is more likely where the generation is larger, though it may apply to even smaller generation under certain circumstances. The DNO will interface with National Grid to carry out this process, but it may have a significant impact on the cost of connection.

Grid connection costs can range from £100,000/MW to £1,700,000/MW. In addition, it should be noted that the initial cost of connection identified at the feasibility stage can vary significantly from the final cost of the connection. See Further Information for more examples of connection costs.

## Securing a Connection

Available capacity and connection capability on the network is a limited resource, and is sometimes in high demand from developers. Therefore, if you are developing projects under G59 or G83 Multiple Premises, then it is a good idea to secure an agreement quickly.

## Accepting Connection Offers

The DNO must provide the Connection Offer within certain timescales after submission of the connection application. These timescales are different depending on whether the DNO is completing just non-contestable work, or if they will also be carrying out contestable work, and they also depend on the voltage level within the distribution network that the generation is connecting to. The maximum timescales are given in the table below:

Maximum timescale for DNOs to provide a connection offer (From date of application submission)

Voltage Level	Where DNOs are completing non-contestable work	Where DNOs are completing contestable and non-contestable work
Low Voltage: Less than 1kV In practice, this is 400/230V	30 working days	45 working days
High Voltage: 1kV – 22kV In practice, this is 6.6kV, 11kV or 20kV	30 working days	65 working days
Extra High Voltage: Above 22kV In practice, this is 33kV, 66kV or 132kV	3 month	65 working days



Though DNOs are obligated to provide connection offers, it is possible that the date at which the connection can be made is a significant time, as much as several years, in the future. This is generally in areas where the local network requires significant upgrade in order to make the connection, and is more likely if the generation to be connected is larger. Uncertainty over the future level of FIT payments may increase the risk of developing community projects in this area. However, deposits may not be requested in these cases, and it may prove valuable to secure a place in the queue as circumstances may change, for example if other planned projects do not go ahead, or if changes in regulations or technology allow more generators to connect.

### Constrained Connection Agreements

In most cases, to provide a connection offer, the DNO has to take into account all of the worst-case conditions that could occur, and will design the connection so that the generation can output at full capacity under all normal network circumstances. This can lead to high costs of connection.

It may also be possible for generators in areas of grid capacity constraint to enter into connection agreements that are constrained according to a specific set of circumstances. This is sometimes called a 'non-firm' connection agreement. A connection may be possible, in return for agreement that the DNO may need to restrict or switch off the generator. Such agreements can be useful to allow generators to connect to heavily congested networks without needing to pay very large connection charges, but the conditions will introduce additional risk and uncertainty in predicting revenue.

It should be noted that even with a standard connection agreement, in very rare cases the DNO may need to curtail generation in order to ensure safe operation of the network or to maintain power quality.

### Accepting a Connection Offer

Once the offer is issued by the DNO, you have a limited time in which to respond, generally between 30 and 90 days. Once this time is over, then there is no guarantee that the offer can be made in the same terms again, for example if the conditions on the network have changed, or the available capacity has been assigned to another application.

Since obtaining a grid connection is required to pre-accredit for the Feed-in Tariff (FIT) and to secure financial close, the connection application must usually be made at risk, in advance of funding being available. This makes it essential to identify a source of any deposit prior to deciding to secure a connection. The deposit can be as much as 25% of the cost of the non-contestable works and can sometimes be negotiable with the DNO.

In some cases it will be possible for multiple connection applications to affect each other, for example if they are connecting to the same area of network with limited available capacity. These applications are generally classed as 'interactive' and can be subject to a set process. In this process, the applications are considered in the order that they were received, and parties are each given an opportunity to accept the offer. Therefore, if you think your project may become interactive, it is important to submit your connection application as soon as you can. The DNO will inform all parties if their connection offer is, or becomes, interactive, and will explain their place in the queue and the process of accepting interactive offers.

It should be noted that connection offers can be withdrawn if the project is not progressing with reasonable pace. This is so that the network capacity is not set aside for projects that are not going ahead, and to allow other projects to use that capacity. The DNO may specify milestones in their connection offer that the project must meet in order to keep the agreement.

## Wayleaves and Consents

Where possible, the DNO will design any infrastructure routes so that they lie either within the boundary of your land, or on land that they have control over, avoiding the need for third-party agreement. If this is not possible, then an agreement will need to be reached with all land owners along the proposed connection route.

DNOs will require the consent of the landowner prior to beginning any work – consent is normally granted via a wayleave or servitude. This can affect the quotation offer and lead times required to complete the work. Early engagement with all parties is essential to identify any potential barriers to grid connection.

You will have to take the following into consideration when planning your project:

- Timescales associated with obtaining third-party agreement can affect your project's delivery timetable;
- DNOs do not seek such consents until you have accepted their quotation;
- The charges given on quotations are given subject to all consents being agreed;
- Where consents are refused, a new design and quotation will be required; and
- DNOs cannot undertake any works on third-party land until all consents have been agreed.

Legal advice on securing consent from other landowners is recommended.

## Preparing for Financial Close

All information relating to the grid connection should be held securely in a central location. Potential lenders will want to see this information. Securing a grid connection is a key requirement before lenders will fund a project. Showing progress in securing the grid connection is important in the early stages of engaging with a lender.

## Alternative network connections

The standard process for connecting generation equipment to the local electricity network outlined above has been designed to preserve the safety and security of the supply, while allowing generation to connect.

While the DNO cannot refuse connection to their network, it is possible that the connection offer issued will give very high connection cost values, or may not allow connection for a number of years. It is therefore not uncommon for projects to be made unviable based on these restrictions. Because of this, it is sometimes necessary to seek alternative technical models to build a successful project.

### Non-Traditional Network Connections

As discussed above, where a connection offer contains high connection costs and a long lead time, this is generally as a result of reinforcement required to the network, which is needed to accommodate the new generation on the network.

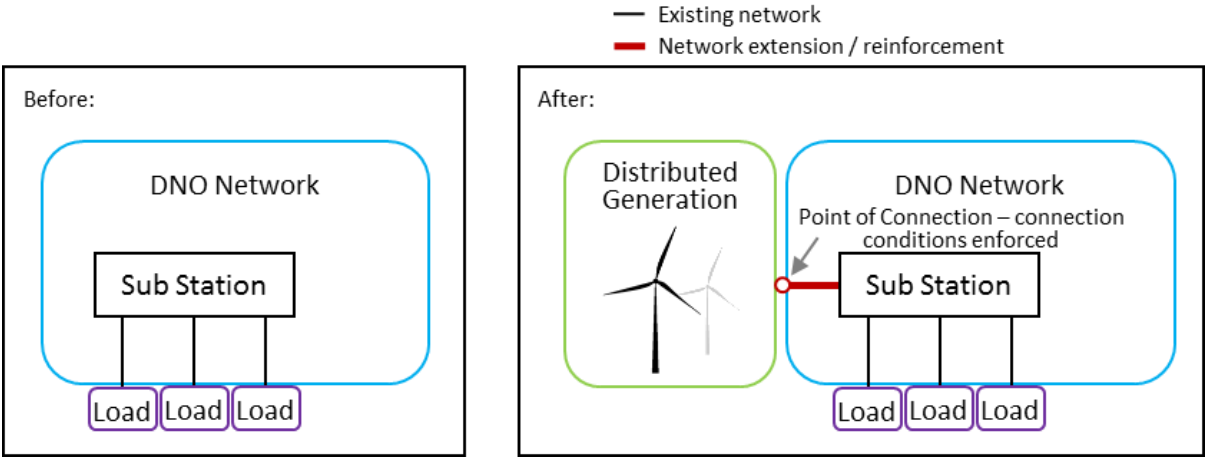
Depending on the particular issue, a possible alternative to reinforcement is to enter into a non-traditional connection agreement with the DNO. A Flexible Connection Offer may be issued, for example, where the DNO sets a maximum level for export, or restricts generation export under certain network conditions. This could involve entering into a specific commercial arrangement with the DNO where these conditions are enforced. It should be noted that constraining the output from the generating units can affect the economics of a project and a lender will want certainty around the amount of electricity that can be exported.

Another approach is an Active Network Management (ANM) scheme. ANM schemes are starting to be offered as part of Business As Usual connection offers by some DNOs. They use control systems to manage certain aspects of generation, such as their power output or power factor, so that they do not cause network capacity limits to be exceeded. Note that ANM connections may only be available in selected parts of the network. The Energy Network Association (ENA) have developed a guide called 'Active Network Management Good Practice guide', which is available on the ENA website (see Further Information).

Export limiting devices are also coming into use. These devices allow a limit to be set above which the generation will not export. This may allow generation to have a constrained connection, to reduce the need for reinforcement. If you want to explore the use of these devices, seek guidance from your DNO.

In the diagram below, the generation is connected to the DNO network via a network extension, but instead of costly and lengthy reinforcement of the substation, the DNO has imposed connection conditions upon the connection. There may be ongoing management of these aspects, and a specific commercial agreement with the DNO.

Figure 3: An example of a generation connection with a non-traditional connection agreement

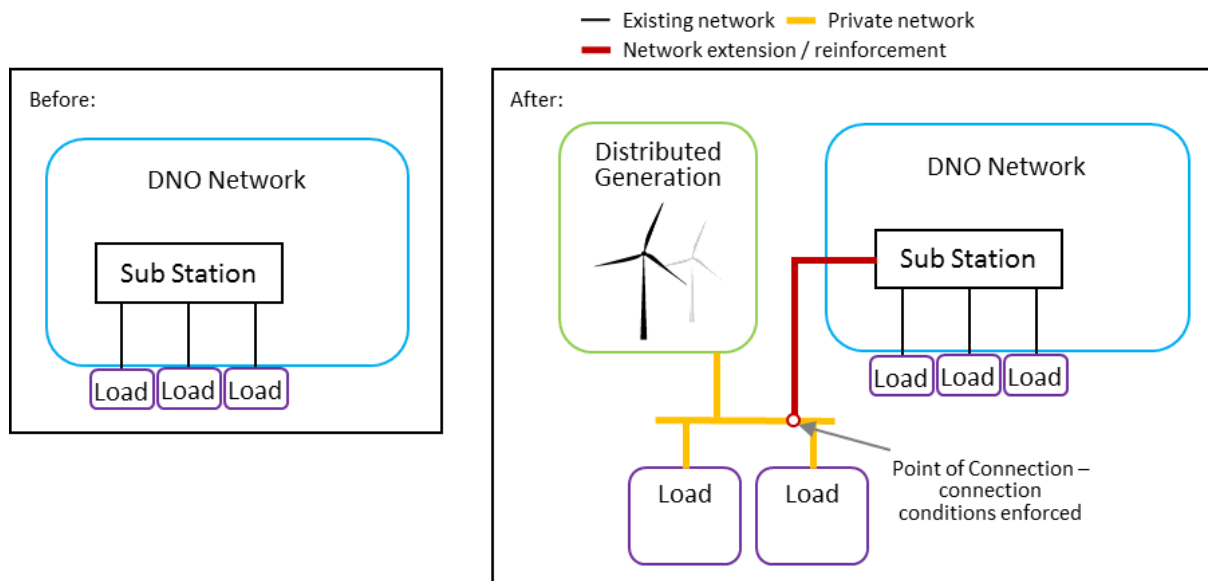


## Private Network

A private network is a network owned and operated privately, but is connected to the wider national electricity system through one or more network supply points.

In the diagram below, a private network is installed, connecting the generation with some nearby loads. Energy can be traded directly between generation and loads, and the system can be managed using control systems. The system is also connected to the DNO network, which provides excess energy or load when needed.

Figure 4: An example of a private network generation connection



This can bring the following benefits over the typical renewable energy business model described previously:

- Enable direct commercial arrangement between loads and generators which are connected to the private network, allowing them negotiate more beneficial commercial arrangement than is possible through a Power Purchase Agreement with a supplier.
- Enable a certain amount of increased autonomy from the wider electricity system, for example in network design, operation and modification. Note that this will not enable complete autonomy, for example, the local network operator will impose conditions on the private network owner at the network supply points, including the amount and quality of power transferred. Planned generation will still need to be discussed and agreed with the connecting network operator and will need to comply with all relevant standards of power quality and performance.
- May help mitigate certain connection issues, for example if the design of the private network can enable the connection point of generation to be flexible.

Though this type of system may have many of the same elements as the Islanded system described below (generation, loads, network, storage, and control systems), the connection to the wider network means that the operational control required to run the system is greatly reduced. For example, electricity generation and load within the system do not need to match, as the wider electricity system can supply excess load, or transport excess generation. Supply agreements will need to be arranged for this.

Whatever the design or arrangement, a private network is likely to need expert design and implementation, to ensure that it is safe and is capable of meeting the requirements of the individual parties. There is a wide range of potential control strategies that can be adopted, and this will need to be considered in the design of the system. The practical and cost implications of designing, implementing and managing this system will need to be identified and considered. A private wire solution is often implemented by local authorities via an Energy Services Company (ESCO).

Below are some examples of private networks:

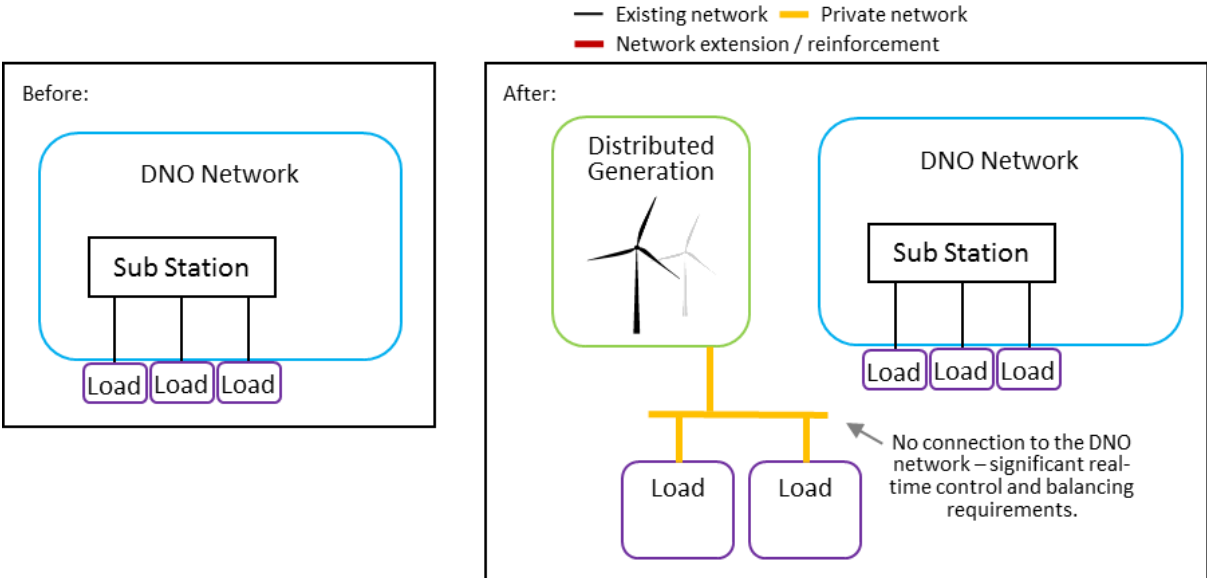
- Electricity networks on private land, for example many university campuses are examples of this; and
- Networks connecting generation and load in order to enable easier direct trading between the two, for example, Woking private network.

### Island Systems

An Islanded system is a grid system with network, generation, and load, which is not connected in any way to the wider, national electricity supply system. A simple example of this is a single cable or small number of cables connecting a generator to nearby loads, which will use all the electricity generated.

In the diagram below, an islanded network is developed, connecting the generation with some nearby loads. Energy can be traded directly between generation and loads, and the system can be managed using control systems. Not having a connection to the DNO network has significant implications, for example on the real time control requirements.

Figure 5: An example of an islanded system



This can bring the following benefits over the typical renewable energy grid connection described above:

- Enable the development of a renewable energy scheme in locations where there would otherwise be restrictions due to the capability of the existing distribution network, including prohibitive costs or delays in connection.
- Enable direct commercial arrangement between load and generator, which allows generators to sell electricity directly to consumers if they are both connected to the island network, and so potentially benefit from a higher generation tariff than selling through a Power Purchase Agreement with a supplier.
- Enable autonomy from the wider electricity system and its restrictions.

The key disadvantage of this kind of system is that it cannot rely on a wider grid to supply excess load that is not covered by generation, or to take excess generation that is not used by the loads. The impact of this is that there is a need to develop and operate a much more complex system, involving generation, network, loads, and control systems. There are a number of key aspects that will need to be considered when deciding if this is the best option for a particular project, including:

- **Location of Generation and Load** – What is the location of the loads to be supplied compared to the generation site? The closer the two are together, the shorter the network routes are likely to be.
- **Ownership and Accessibility of Route** – Negotiating access and use of land for routing networks (wayleaves) can be complex, particularly if the route crosses many different land ownership boundaries, or if it needs to cross or run near to public roads.
- **Matching the size of Generation and Load** – In a system that is not connected to the wider electricity system, the energy generation and energy requirements of the load will need to be closely matched.
- **Power Profiles** – The amount of power required by the load may vary over time, and this varying power profile will need to be supplied by the system. It is possible that the generation output will be sufficiently controllable to supply this power profile. However, where the output of the generation is not sufficiently controllable (for example solar or wind generation) then additional equipment may be needed, for example energy storage.
- **Power Quality** – Electricity supplied from distribution networks from the national grid is controlled to ensure that certain aspects are suitable for use in connected appliances. These aspects include frequency and voltage. In an islanded system, there is no such guarantee of power quality. It is important that the actual power quality requirements of the loads are identified so that the system can be designed to meet them.

Whatever the design or arrangement, an islanded system is likely to need a significant amount of expert design and operation, to ensure that it is safe and is capable of meeting the requirements of the individual parties. Control systems will be required to ensure that the power demand of the loads is matched by the power output by generation and/or storage. The practical and cost implications of designing and operating this system will need to be identified and considered.

Generally, island electricity systems are used to provide an electricity supply to an area that cannot be supplied (either practically or economically) with a larger electricity system. For example:

- Geographical islands, for example Fair Isle and the Isle of Rùm in Scotland;
- Extremely remote locations; and
- Rural or remote electrification in developing countries, which is used where a country's electricity system is not developed enough to cover the whole population.

Island systems are not often a suitable solution for small scale renewable generation development, due to the significant technical and logistical requirements to successfully design, implement and operate them, and the costs associated with this.

## Microgrids

True Microgrids are networks that connect generation and load, and are capable of being run both connected to, or isolated from, the wider electricity system. This brings the advantages of being connected to the wider system, which provides excess energy or load as it is needed, but it also has the capability of improving security of supply – when problems occur in the main grid, the microgrid can disconnect and continue to operate.

However, the technical requirements of such a system are even more comprehensive than those for an island system. This is because as well as being able to run islanded, the microgrid must be able to make the connection with the wider system, which requires specialist equipment and design.

Examples of a microgrid system are:

- Tohoku Fukushi University (Japan), developed for security of supply; and
- Santa Rita Jail (USA), developed to provide a more economical energy trading opportunity, and also for security of supply.

As with island systems, true microgrid systems are not often a suitable solution for small scale renewable generation development, due to the significant technical and logistical requirements to successfully design, implement and operate them, and the costs associated with this.

A user guide to the issues and value of microgrids has been made available by Highlands and Islands Enterprise (HIE) and Scottish Government. The aim is to assist in the understanding of microgrids, their issues and value. The scope is to provide sufficient context as to what constitutes a microgrid, set out key issues and identify the advantages and disadvantages of microgrids. See 'Further Information' for further information.

## Business model comparison

The table below compares the four business models described above.

	<b>Description</b>	<b>Pros</b>	<b>Cons</b>
Typical Generation Connection	A standard connection application form is sent to the DNO, and they respond with a connection offer.	Standard procedure that is well developed.	The need to reinforce the network may bring significant costs and time delays. Energy cannot be easily traded between small scale generation and load unless you have a supply licence.
Non-Traditional Network Connection	The generator and the DNO enter into an agreement for a flexible connection. A proportion of the reinforcement cost is avoided by the connection being constrained within certain operating conditions.	A proportion of reinforcement costs and time delays may be avoided.	Connection restrictions may negatively impact the business case of the project. Energy cannot be easily traded between small scale generation and load unless you have a supply licence.
Private Networks	A private network is installed, for example connecting generation with nearby loads. This network is connected to the wider DNO network, which will provide additional energy or load when needed.	Energy can be more easily traded between generation and loads connected to the private network. A proportion of reinforcement costs and time delays may be avoided through careful design.	Connection to the DNO network will impose restrictions in the connection point, which may impact the business case for the project. Reinforcement may still be necessary, with the associated costs and time implications. There is likely to be an increased cost implication of a private network when compared to a typical connection.
Islanded System	An island network is installed, for example connecting generation with nearby loads. This network is not connected to the wider DNO network. This means that generation and demand will need to be balanced in real time on the network, and the power quality will need to be managed.	Energy can be more easily traded between generation and loads connected to the private network. No DNO network reinforcement costs will be incurred. Autonomy from the wider network means that certain restrictions, e.g. on power quality, may not have to be met.	There are significant control implications associated with this solution, with the associated cost and logistical arrangements. Safety and power quality will need to be managed. There is likely to be a significant cost associated with the setup of an island network when compared to a typical connection.



# Supporting Technologies

## Smart grid technologies

'Smart grid' is a term used a lot in the energy industry, and is generally used to describe a grid and system with the capability to monitor, operate, and control system elements in such a way as to optimise operation. It may include elements such as smart meters, smart appliances, renewable energy resources, energy efficiency technologies and communications between devices.

Though smart grids are often talked about as part of the wider electricity network, they can be used on a smaller scale as well. For example, islanded systems and private networks may use them as an essential way of operating the network efficiently and effectively.

Some of the most relevant Smart Grid strategies include:

- **Real Time Monitoring and Control** – A key element of Smart Grids is the capability to understand what is happening within the network in real time, and to make an impact on its operation. This is vital in an Islanded system, which will need to be controlled and balanced in real time. This necessitates components such as sensors to capture data, analysis capability, and some controllable element within the network, for example to control the settings of assets such as transformers and switches. In many cases, particularly for larger networks, this may be partly or completely automated, and will be controlled by an automated control system.
- **Demand Side Management** – It is vital that generation and load are balanced in real time. Traditionally, this is done by controlling the generation to match demand, which has been possible due to the fact that most of the generation is highly controllable. However, in an islanded system, the generation source may not be controllable (for example, where the generation relies on uncontrollable renewable energy sources such as solar and wind), or there may be certain restrictions such as peak output. Demand Side Management enables the demand to be varied to match the generation. This is carried out using smart appliances and controllable loads, which are responding to the requirements of the network. In practice, balancing may be achieved through a mixture of generation output control and Demand Side Management.

## Storage

The key advantage of incorporating energy storage into a network is to enable excess generation to be stored for future use by the load. This means that there is more flexibility in the timing of generation profiles and load profiles. The integration of storage technologies with renewable generation is still an innovative approach to the design of renewable systems, so will be considered as such by any potential lenders, potentially requiring additional technical due diligence before any finance would be provided.

Electricity storage can take many forms, including:

- Electrochemical storage in batteries, which are generally built using three basic components – anode, cathode and electrolyte. Batteries are capable of multiple

charge and discharge cycles and are modular which means that they can be readily combined to create large scale battery storage systems if required. The main advantages are that they are a low capital cost solution (in comparison with other storage) and have high power and energy density, which means that they do not take up a large footprint. Additionally, batteries can store electricity over a long duration but can only typically discharge for up to a matter of hours at a time.

- Flywheels, which are a form of mechanical storage which use the rotation of a mass to store energy. Flywheels can store energy from both electrical or mechanical sources, making them flexible as energy storage devices. They typically operate in a vacuum, which means the storage duration is very long. The benefits of flywheels are their rapid response and high efficiency, but they can only deliver energy over a short duration.
- Hydrogen (created through electrolysis using excess electricity). Hydrogen has the highest energy to weight ratio of all conventional fuels, almost double that of natural gas and gasoline. However, it has a low energy to volume ratio. Some of the major benefits of hydrogen are that it can be combusted to produce heat and steam or it can produce electricity when combined with oxygen in a fuel cell. In this way, hydrogen has applications in the electricity, heating and transportation sectors. However, hydrogen is difficult to store due to its nature and as such storage is a large cost barrier for this technology if it cannot be used imminently. Using excess electricity to generate hydrogen through electrolysis is relatively immature, but there are a number of pilot projects which are investigating the feasibility and costs of this solution.
- Ammonia; Ammonia is a compound of hydrogen and nitrogen which is a colourless gas that has a characteristic sharp smell. As a result of its chemical composition, it contains more hydrogen than pressurised or liquefied pure hydrogen and is therefore a good candidate for a hydrogen carrier and fuel. As such, it can be used in much the same way as described for hydrogen above with the added benefit that storage of ammonia is much less costly than hydrogen as it is easily liquefied and stored in inexpensive and low pressure containers.
- Electricity can also be stored as heat in what is termed Pumped Heat Electrical Storage (PHES), where the electricity is used to drive a heat pump connected to two large thermal stores. The system operates by pumping heat from a 'cold store' to a 'hot store', in much the same way as a fridge, to store electricity. The heat pump can be reversed to become a heat engine to generate electricity via a generator. This solution is low cost however it is still in its infancy. If combined with a heat network excess electricity can also be stored as hot water.

## Further information

The first port of call for information to do with capacity and plans on the local network, and the process of applying for and gaining network connection should be the DNO websites:

DNO	Regions Covered	Main Website
SP Energy Networks	Northern Wales	<a href="http://www.spenergynetworks.com">www.spenergynetworks.com</a>
Western Power Distribution	Southern Wales	<a href="http://www.westernpower.co.uk">www.westernpower.co.uk</a>

The Energy Networks Association have produced a set of Guides to support developers and owners through the process of connecting Embedded Generation under G59 and G83: [www.energynetworks.org/electricity/engineering/distributed-generation/distributed-generation.html](http://www.energynetworks.org/electricity/engineering/distributed-generation/distributed-generation.html)

Information on connections costs and connection times that other community groups have faced can be found online. For example, see: [www.uk.coop/sites/storage/public/downloads/cornwall\\_energy\\_report\\_overcoming\\_grid\\_connection\\_issues\\_for\\_community\\_energy.pdf](http://www.uk.coop/sites/storage/public/downloads/cornwall_energy_report_overcoming_grid_connection_issues_for_community_energy.pdf))

If there is a dispute about the terms in the connection offer, then the first step is to follow the complaints procedure of the individual DNO. If disputes cannot be resolved, the matter can be referred to the Energy Ombudsman, and then Ofgem.

The Energy Networks Association has produced a guide on Active Network Management which can be found here: [http://www.energynetworks.org/modx/assets/files/news/publications/1500205\\_ENA\\_ANM\\_report\\_AW\\_online.pdf](http://www.energynetworks.org/modx/assets/files/news/publications/1500205_ENA_ANM_report_AW_online.pdf)

The user guide for microgrids can be found here: <http://www.hie.co.uk/community-support/community-energy/low-carbon-infrastructure-transition-fund--lcitp.html>

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