REACT (Rapid Evaluation Areal Connection Tool)

User needs and data availability recommendations report

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Executive summary

Demands on the UK's electricity network are rising. According to a Climate Change Committee report, the UK's annual electricity consumption is set to double if net zero is to be delivered by 2050. Meanwhile, Transmission Owners (TOs) receive increasing requests to connect high-power-demand units (such as battery storage or, in the future, electrolytic hydrogen units) to the transmission network.

Transmission Owners face the challenge of how to develop comprehensive support and infrastructure solutions for high-power-demand unit developers. One potential solution is a geographical visualisation tool which allows stakeholders to easily establish the best locations for such units. Icebreaker One, alongside technology company Mapstand and energy data visualisation and application developer OIsights, are working with Transmission Owner SSEN Transmission (SSEN-T) on REACT (Rapid Evaluation Areal Connection Tool), a project to see whether such a tool can assist.

As part of the Discovery phase of this project, Icebreaker One researched and documented the current processes for connection applications, the data required, and the barriers in the process to make recommendations to reduce friction for data sharing and promote innovation.

This piece of work is focused around an increasing demand for electrolytic hydrogen connections in the north of Scotland. Electricity generation (much of which comes from renewable sources) currently outstrips local demand in this area, and there is high potential for electrolytic hydrogen plants to help address this imbalance.

This report by Icebreaker One lays out our analysis of research, process, discovery, results, and recommendations. The data required is outlined in this spreadsheet.

Connection process: where blockers exist

To connect to the grid, every high power demand and generation project needs to apply to the System Operator of the transmission network, National Grid Electricity System Operator (NGESO), which partners with the regional Transmission Owner of the network. However there are frictions in the application and consent process, including a lack of or poor access to relevant data, which can lead to wasted time and resources and sub-optimal outcomes. Key barriers identified by Icebreaker One's research include:

1. It's difficult for the Transmission Owner to determine future network capacity, as it is unsure which potential developments will connect to the network (and when).
2. Much of the data required for the application process is held in data silos within the Transmission Owner. Therefore, the Transmission Owner staff involved in the consent process must "hunt down" information, rather than easily accessing it.
3. Developers lack knowledge on the best locations for electrolytic hydrogen units.

Recommendations

These are our research-based recommendations to reduce friction in the existing application process, and to promote innovation.

Five recommendations to reduce friction

- The pre-application stage of the consent process between the developer, systems operator and Transmission Owner requires stakeholders to have access to more extensive and detailed relevant data in order to ensure projects succeed fast or fail fast.
- Key stakeholders must make data on planned projects available as early as possible, subject to commercial sensitivity restrictions, so that the energy industry has a clear picture of the future demands on the transmission network.
- Stakeholders must monitor and analyse the cumulative effect of power generation and demand developments on public opinion.
- NGESO and the Transmission Owner must decongest connection application backlogs, which could happen through a “use it or lose it” policy.
- The REACT project must align with SSEN-T’s existing data automation project, the Data Action Plan 2022-2026.

Five recommendations to promote innovation

- Stakeholders could make a reduction in constraint costs an organisational key performance indicator (KPI).
- Stakeholders must create a digital twin of the power system with existing data, rather than waiting for the perfect data to become available.
- A new information and visualisation tool should support decision making at a local community level.
- The Alpha stage of the REACT project should include engaging with NGESO and sectors outside of energy, who will be key in any electrolytic hydrogen project.
- Partners in the project must increase visibility and shareability of the datasets relevant to the project under appropriate open or shared licences.

Contents

Introduction

As demands on the UK's electricity supply increase at a rapid rate, Transmission Owners such as SSEN Transmission (SSEN-T) are receiving more requests for connections to the grid by developers of units of high supply and demand. The current consent process for these applications is in need of improvement, in order to:

- Minimise time and resources spent (and sometimes wasted) at pre-application stage and during applications
- Minimise the number of applications that fail to break ground due to unrealistic scoping/proposals and/or failure to consider alternative, potentially more suitable connection sites.

One potential solution is REACT, a geographical planning tool that can be used across the industry to provide a dynamic view of all future connection requests. The tool aims to utilise SSEN-T's power flow modelling data, which will approximate the grid impact of a connection prior to making an application, combined with using a spatial planning tool that will incorporate the current and future power and gas infrastructure to enable users to identify alternative grid connections.

This report is the output of Work Package 2 – User Needs and Data Availability – of the Discovery phase of REACT. The Discovery phase focuses on a use case around the grid connection requirements for an electrolytic hydrogen unit in the north of Scotland, understanding the user needs, requirements and data availability for the next phase of development.

Goals of REACT project

The overall goal of the REACT project is to make data available to potential developers of units of high power demand (and potentially generation) to make decisions on where to site their projects. This initiative should help Transmission Owners that see constraints on their networks:

- Identify where there is a need to build reinforcements to support new developments, or;
- Find ways to build fewer reinforcements by allowing new demand units, such as electrolytic hydrogen, to utilise the power supply at times of peak generation.

This compilation and visualisation of data, which is both internal to the transmission owner and external to the company, could also be useful for future developments of power generation units.

Discovery Phase Work Packages

SSEN-T - WP0: Project Management

WP0 will cover Project Management from start to finish. The SSEN-T Project Manager (PM) will ensure the Project is on track to meet all deadlines and will meet with partners on a weekly-basis to update on progress, risks, and insights. As part of the Alpha preparation, SSEN-T will document the benefits of the Project throughout the Discovery Phase.

MapStand - WP1: Literature Review

WP1 ensures REACT learns from best practices by producing a comprehensive literature review on hydrogen developments within GB and worldwide. This WP will map existing power transmission expansion scenarios and the impact on net zero goals.

Icebreaker One - WP2: User Needs and Data Availability

WP2 engages with stakeholders to determine user needs and investigate data availability and data governance of identified key data sets for REACT. This WP builds towards the Alpha phase, as it determines what may be possible with today's data and makes recommendations for reducing friction to promote future innovation.

OIsights - WP3: REACT Tool Planning

WP3 will analyse what is technically required to create the tool, investigate if SSEN-T modelling tools can be incorporated, and when connection studies need to be carried out.

Background and context

The responsibilities and obligations for the safe installation, operation and maintenance of our transmission network are split across two parties – the Transmission Owners (Transmission Owners) and National Grid Electricity System Operator (NGESO).[1]

There are four Transmission Owners in the UK, each of which are geographically allocated a region:

North Scotland: SSEN-T (Scottish and Southern Electricity Networks (SSEN) Transmission

[1] SSEN-T: Who's who in the connection process: https://www.ssen-transmission.co.uk/customer-connections/whos-who-in-the-connection-process2

South Scotland: SPEN (Scottish Power Energy Networks)

England and Wales: National Grid

Northern Ireland: Northern Ireland Electricity Networks

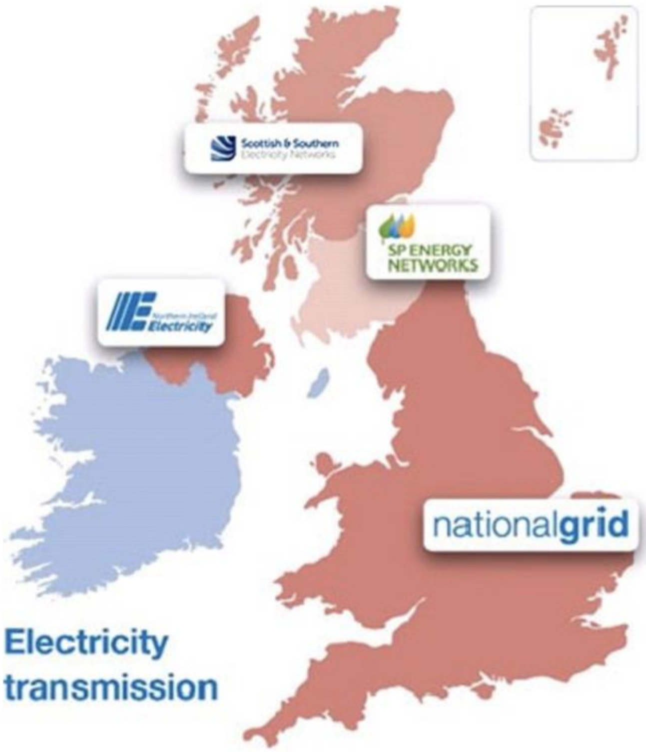

Image 1: SSEN-T, UK Transmission Owner Map (Source SSEN-T)

Across the UK, it is challenging for Transmission Owners to match up sources of electricity supply and demand with locations of capacity on the high voltage network. Different locations face different challenges, with some struggling with more demand than capacity, while others experience more generation than demand.

The north of Scotland continues to become a major hub of power generation, due to its vast potential for on and offshore wind. Due to the rapid increase in electricity generation, which often outstrips local demand, it is necessary to find a route for this power.

Potential routes include:

1. To store the power and reuse this locally when supply levels are low
2. To supply power to the rest of Great Britain or further abroad
3. To facilitate the construction of industrial units with high power demand close to the centres of power generation or transmission.

In the north of Scotland, all these options require further development and industrialisation, which puts further pressure on the power grid.

SSEN-T, which owns and maintains the high voltage transmission system for the north of Scotland, is responsible for reviewing connection requests to the grid for customers who supply and demand electricity in large volumes.

However the process of reviewing requests takes place in isolation, with little time to develop creative solutions on the best location to connect to the network while potentially helping to minimise electricity curtailment.

A significant number of sites for demand and generation in the initial stages of the connection process risk not becoming fully realised, as the current application process does not explore alternative connection locations.

One example of where this appears to be happening, and could happen in the future, is in developments of electrolytic hydrogen (green hydrogen, if the source of the power is renewables), which can make large demands on the network, and require significant investment in infrastructure, when at scale.

Therefore it is necessary to find a means by which realistic projects can break ground as soon as possible, and unrealistic projects do not become stuck within the system, potentially taking up space which could be used for a more viable project. It is also necessary to ensure there are no stranded assets, where Transmission Owners construct infrastructure to support a development that is not realised.

By identifying key barriers (or “problem statements”) inherent in the current consent process, this project determines the user needs of developers and the Transmission Owner in the application process for a grid connection for a large demand unit. It also identifies the datasets required to support those needs.

The research process

This piece of work focuses on a use case around the application process for an electrolytic hydrogen unit in the north of Scotland. In addition to extensive desk research, we identified and interviewed 20 different stakeholders within the system, including different departments within the Transmission Owner (SSEN-T), developers of hydrogen projects, the National Grid ESO (NGESO), and experts within the industry.

Our research enabled us to understand and document within this report:

- The background and context for energy supply and demand in the north of Scotland, and the potential for electrolytic hydrogen
- How the connection process currently works
- The data sources and datasets, internal to and external to SSEN-T, that would be required to support the use case – as well as their availability, accessibility and other systems barriers. This knowledge should assist in interoperability across various systems within the industry.

Through our research, we also identified 19 barriers, blockers and challenges which we listed as problem statements (found in Appendix 1). These covered issues relevant to both SSEN-T and to the developer making an application, and other stakeholders in the process, including the local authorities and the Systems Operator (NGESO).

On 4 May 2023 we brought together key stakeholders from different departments within SSEN-T, key figures in the energy sector and the project partners in a problem statement prioritisation workshop to help further develop the research.

We drew up a shortlist of problem statements, which we asked our workshop attendees to rank, so that we have an understanding of where the stakeholders believe the major issues within the use case lie.

Actors and stakeholders

The primary actors and stakeholders in this process are developers of high demand and high generation power units (over 10 MW installed capacity in the north of Scotland), the Transmission Owner (SSEN-T) and the Systems Operator (NGESO). Other stakeholders include land managers such as Crown Estate Scotland, local authorities, government innovation agencies, and business consultancies also carrying out similar projects. We spoke with over 20 stakeholders in the process, with a special emphasis on SSEN-T.

The potential for electrolytic hydrogen

Hydrogen is a useful chemical feedstock used for energy storage, in energy-intensive industries, and by heavy transport (including planes). It also has the potential to be used as a relatively more environmentally-friendly replacement for natural gas. However virtually all current hydrogen manufactured is so-called “grey” hydrogen, made from natural gas or other hydrocarbons, with carbon dioxide as a bi-product. This creates a relatively high carbon footprint.

Electrolytic hydrogen (called ‘green hydrogen’ when its feed-in power source is renewable energy) uses a unit called an electrolyser to split water into its two components, hydrogen and oxygen. Through this process, a facility can store electrical energy as chemical energy of the resulting hydrogen.

Water is an ideal source for producing hydrogen because it only releases oxygen, and excess water, as bi-products during processing (seawater also has a bi-product of sodium). This hydrogen can be utilised as a fuel or converted back to electricity when required.[2] If an electrolytic hydrogen unit uses renewable energy as its source of electricity, as opposed to conventional energy, the process of electrolysis results in fewer greenhouse gas emissions. However, it is worth noting that this is not a perfect process, and up to 30% of the energy can be lost in this conversion process which can make it an inefficient source of power.

Government support for green hydrogen

The UK government’s British Energy Security Strategy (April 2022) has set out an aim to double Britain’s carbon hydrogen production capacity to 10 GW by 2030, with at least half of this coming from green hydrogen.

The Scottish government has ambitious targets around the use of hydrogen. It stated in its 2022 Hydrogen Action Plan that: “Hydrogen, powered by renewable electricity, could present Scotland’s greatest industrial opportunity since oil and gas was discovered in the North Sea.”

Its priority is to leverage “as much renewable hydrogen into the energy system as quickly as possible” and to support the establishment of low-carbon hydrogen production at scale during the 2020s, linked to carbon capture and storage (CCS).

From a starting point today of zero, the plan is to develop 5 GW of installed renewable and low-carbon hydrogen production capacity by 2030 (equivalent to 15% of Scotland’s total energy demand) and 25 GW by 2045, for domestic use and export to the UK and Europe. It aims to export the first hydrogen by the mid-2020s, to mainland Europe.

2 https://www.mottmac.com/views/how-to-accelerate-green-hydrogen-for-the-race-to-net-zero

This is an "ambitious" target according to some stakeholders we interviewed, who cast scepticism on whether 5 GW can be achieved as no major project has broken ground yet.

According to its hydrogen plan, the Scottish government wants hydrogen to play a role in decarbonising industrial clusters, supporting the transition of the workforce away from high-carbon sectors (oil and gas) in the northeast of Scotland, and to "provide opportunities for our islands and rural communities to maximise the benefit of their vast access to renewable resources".

It appears the plan is for hydrogen to replace the oil and gas sector. The government supports growth of Regional Hydrogen Energy Hubs, and the first appears to be in Grangemouth, south Scotland.

The Scottish Hydrogen Assessment, published in 2020, noted in its most ambitious scenario that establishing Scotland as an exporter of green energy to Europe could result in a £25bn contribution to Gross Value Added (GVA) by 2045. This would be dependent on Scotland producing green hydrogen that is competitive in a European market. Supporting a domestic hydrogen market is likely to support anywhere between 70,000 to 175,000 jobs.

North of Scotland - an ideal location for green hydrogen generation

In much of the UK, demand for electricity risks outstripping supply, but in the north of Scotland, the volume of electricity generated (18.1 TWh) in 2020/21 was around three times the amount consumed (6.7 TWh).[3]

According to Scottish government energy statistics from 2022, across the whole of Scotland, net exports of electricity saw an increase in 2022 at 18.7 TWh, compared to 16.0 TWh in 2021.

Unconsumed power must be stored and used at different times to balance the network, exported or used by a local demand-hungry industrial facility.

As the chart below shows, as of 2021, more than half of the electricity generated in Scotland comes from renewable sources. These figures have been more or less stable for the last six years.

In terms of fossil fuels, there are no coal-fired power stations in Scotland. The north of Scotland has one gas-fired power station in Peterhead, with a 1.1 GW installed capacity.[4] In terms of nuclear power, Hunterston B power station near Glasgow was shut down

[3] Data from original REACT application (SSEN-T + partners) 2023 https://smarter.energynetworks.org/projects/ukri10058535/?alttemplate=sifr2projectpdf

[4] Peterhead's owner SSE Thermal is "currently exploring redevelopment opportunities for a decarbonised power station at Peterhead, using CCS or hydrogen solutions, to ensure the site can continue to provide essential flexible generation in a net-zero world" https://www.ssethermal.com/flexible-generation/operational/peterhead

last year. One nuclear power station, Torness, remains active in the south. Scotland will not open any more nuclear power stations.

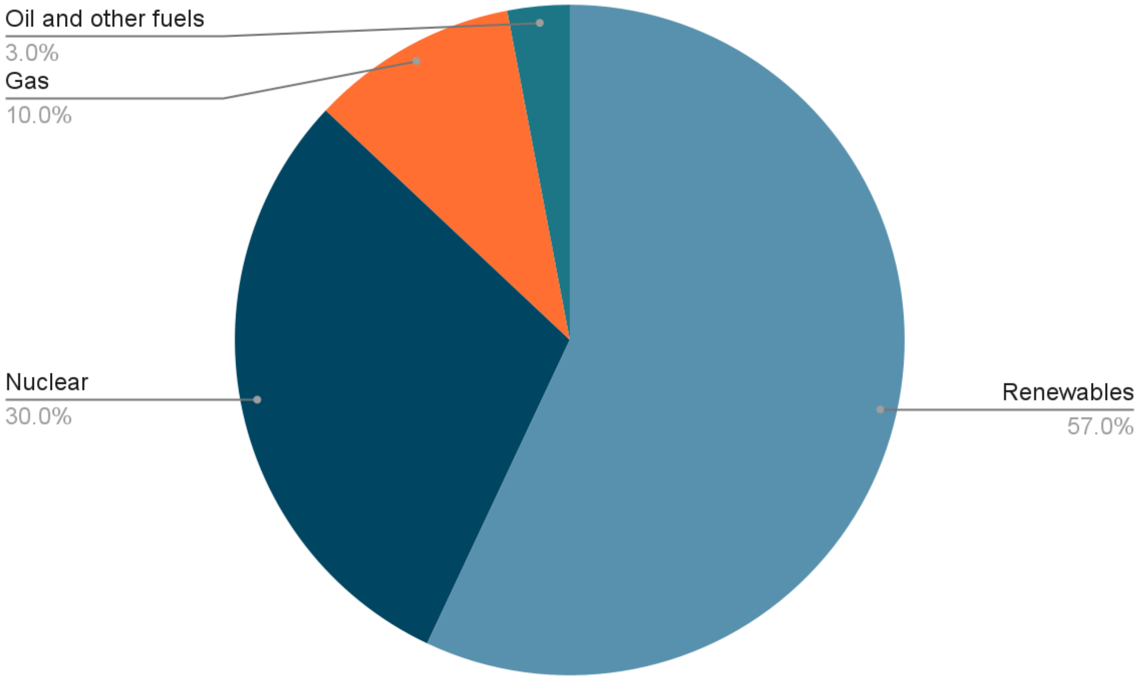

Image 2: Sources of energy in Scotland, Icebreaker One 2023, Data source BEIS 2021

The combination of a high generation versus consumption ratio, and the high proportion of renewable generation, makes Scotland an ideal potential location for green hydrogen technology. Indeed, one optimistically green scenario by SSEN-T in its Future Energy Scenarios for North Scotland sees hydrogen powering part of Scotland's rail network by 2035.

Renewable generation is likely to increase in Scotland. The latest figures for 2022 already show a sharp rise in wind power. The Scottish Government's ambition is to see the development of between 11 and 16 GW of renewable capacity up to 2032, which includes between 8 and 11 GW of offshore wind capacity by 2030.

SSEN-T's mildly optimistic green energy scenario of its Future Energy Scenarios sees growth in generation capacity for the north of Scotland, reaching 49 GW in 2050 from 8 GW in 2020. From 2030, this will be exclusively from renewable sources. By 2050, this strategy anticipates that energy generation in the north of Scotland will be made up as follows:

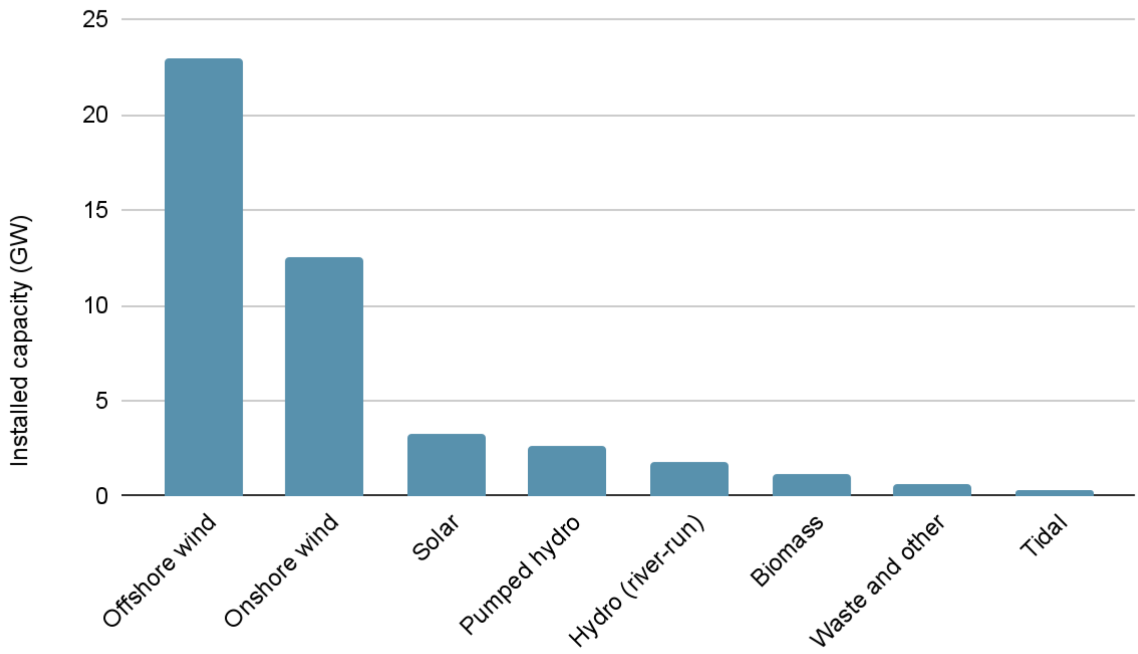

Image 3: Green Economy Energy Scenario 2050 for north Scotland, SSEN-T, 2022

With the exceptions of biomass, pumped hydro and waste generation, all these forms of renewable energy generation are reliant on factors outside of human control, therefore lacking flexibility. This means generation cannot be directly managed to match peak and low periods of energy demand. At some points, there may be more generation than demand, and vice versa.

However, if the UK is to move to a future where most or all of its energy is from renewables, it will be necessary to develop systems and processes to cope with this mismatch between supply and demand. For example, energy generated that outstrips local grid demand will need to be either:

- Transmitted through high-voltage direct current (HVDC) to areas of demand in the rest of the UK, such as SSEN-T's Eastern Link Project, currently in the early development process
- Used to power hydrogen electrolysers, which have different potential routes of the gas to market
- Stored for future local use, using pumped storage (hydro), or battery storage. Green hydrogen is also a good route for storing large quantities of power over long periods of time, although there are high energy losses at each conversion step. SSEN-T's Future Energy Scenarios report states storage "will be critical in balancing the supply and demand of electricity, especially with the intermittency of supply and reduced system stability associated with renewables".

Powering the creation of green hydrogen

A green hydrogen electrolyser can be powered in one of three ways, according to SSEN-T.

1. **Fully networked:** it draws all electricity from the grid
2. **Non-networked:** it draws all electricity directly from a power source that is independent of the grid, such as a wind farm
3. **Partially networked:** the majority of supply comes from independent power sources, but the electrolyser is able to draw electricity from the network when required – for example when wind resource is low at a linked wind farm.

According to its North of Scotland Future Energy Scenarios, SSEN-T believes the fully networked electrolysis case is "an unrealistic one, under current market arrangements, as electrolyser facilities will most likely obtain cheaper electricity prices by making direct contracts with wind farms or other generation sites."

The report highlights that the non-networked case could occur for units close to power generation sites, such as wind farms, where they can draw electricity and bypass the grid. This is the case with projects in the north of Scotland such as Dolphyn and Surf n' Turf. However, it anticipates that the partially networked electrolysis case would be used in most cases.

As part of our research, we spoke to a developer of green hydrogen technology who agreed with the need to be at least partially networked. They said: "We have to be networked. The problem of being non-networked is that a commercial developer is fully dependent on another commercial entity. Non-networked would work if the developer of the hydrogen was the same as the owner of the power generation unit."

If green hydrogen technology accelerates in the north of Scotland, developers will increasingly need to put in applications to connect their sites to the grid. However, the current application process is time-consuming and resource-heavy, and many applications fail.

Connecting large-scale generation or consumption sites to the grid

There are three main stakeholders in the application process for the development of large-scale generation or consumption units (such as green hydrogen plants) to the grid.

Developer: A major investor in a unit of power generation or demand (over 10 MW Installed capacity in the north of Scotland).

Transmission Owner: The transmission network in the UK is used for the transfer of large-scale electricity generation, particularly renewables, to the centres of demand.[5] Transmission Owner SSEN-T is responsible for the planning, design, construction and maintenance of the network (132 kV[6] and above) in the north of Scotland. This currently comprises 104 Grid Substations, 2,690 km of circuits and 11,012 pylons and structures (2016 statistics).

Systems Operator: National Grid ESO (NGESO) is the Systems Operator of the transmission network across the whole of Great Britain and ensures that electricity demand is matched by an equal volume of electricity generated by power stations.

In the north of Scotland, until recently most developers have focused on large-capacity requests to connect wind power and solar generation plants.

In the last two years, more developers have been asking about battery storage facilities, carbon capture and storage (CCS)[7] and hydrogen projects, which demand rather than supply electricity to the network. The process of the application for both demand and supply units is the same.

Consent process

Large-scale developers in the north of Scotland make an application for network connection directly to National Grid Electricity System Operator (NGESO), which then makes a contract with the Transmission Operator, SSEN-T.[8] The key stages in a developer's application process are summarised below; fuller details are in Appendix 2.

[5] Generation Connections, Guide 2016 (SSEN-T, formerly Scottish Hydro Electric) https://www.ssen-transmission.co.uk/globalassets/documents/connecting-to-the-transmission-network/4326-sse-transmission-connections-aw-screen2-2.pdf

[6] SSEN Transmission has 132 kV, 275 kV and 400 kV voltage levels. Approximate capabilities of transmission infrastructure at each of these voltage levels is: 132 kV = up to 200 MW (pole line), 300 MW (Tower line), 275kV up to 1,500 MW - 2,000 MW; 400 kV up to 3200 MW

[7] In the north of Scotland's process of decarbonisation, SSE Thermal's Peterhead gas unit in Aberdeenshire has plans for CCS, and joint venture Acorn (Storegga, Shell UK, Harbour Energy and North Sea Midstream Partners) has expressed interest in St Fergus gas terminals for use in CCS

[8] Related to this is a problem in the way the system is structured, with the developer dealing with NGESO, who then deals with the Transmission Owner. This adds an extra layer of meetings and bureaucracy. "It's quite hard to have conversations," says one developer. "To talk to someone, we have to get a date in that person's diary and that person's diary and that person's diary to align."

While the developer has a suite of contracts with NGESO and NGESO with the Transmission Owner, in practice there is regular direct communication between the developer and the Transmission Owner.

Step 1: Pre-application meeting

This meeting takes place between a developer, NGESO and the Transmission Owner. The developer presents their initial plan outlining the capacity they believe is needed, the planned location, and an ideal connection date. It gives the Transmission Owner the chance to highlight early any potential errors in the developer's information.

Some applications go no further than the pre-application meeting due to fundamental flaws in a developer's initial outline, which may be the result of limited access to important data to support their proposal.

Step 2: Application submission

The developer must then make an application to NGESO. It then makes an application to the Transmission Owner on the developer's behalf. The Transmission Owner must declare whether this connection request is viable or not, deemed "competent" or "non-competent". The feedback to the customer takes five days. If a project is deemed competent, the developer is advised of application fees payable to NGESO.

Step 3: Transmission Owner Connection Agreement (TOCA) drawn up

Upon receipt of the developer's approval and the developer's payment of the fee to NGESO, "Day 0" of the formal consent process begins. The consent process is designed to lead to a connection agreement between the relevant parties. If they consent to the outlines specified in this agreement, the Transmission Owner will then carry out necessary reinforcements on the network.

The Transmission Owner has 90 days to:

- Assess and analyse the developer's application, including any need for network reinforcements and the time required for these reinforcements.
- Discuss any scope amendments with the developer that would allow for an earlier connection date.
- Create a draft connection offer and issue it to NGESO to review and finalise before it is presented to the developer.
- Draw up the TOCA with National Grid ESO and issue this to the developer. The TOCA contains an identification of the connection, the infrastructure works required, costs, and a timeline from consent to completion.

Step 4: Developer accepts or rejects TOCA

The developer has 90 further days to accept or reject the TOCA. If they accept it, and pay necessary costs, reinforcement work can commence. If not, the project may go through further modifications within SSEN-T.

Data needed to support development of a green hydrogen unit

As part of data user needs, we examined what information a developer must consider before embarking on a green hydrogen project.

At present in the north of Scotland, there are small hydrogen unit developments, and a few plans for major projects at a larger scale of 3 GW.

Some stakeholders have stated "there is a lot of uncertainty as to scale and location" for green hydrogen projects and some developers do not yet have the comfort to properly pursue hydrogen.

From speaking with developers, this is some of the data they may need before embarking on a project outline.

Water supply data

Alongside electricity, the key resource for green hydrogen is water. A large green hydrogen project requires similarly large volumes of water, with a 3 GW facility needing 23,000m^3 of water per day (if at full capacity)[9]. Freshwater (from a river, for example) is optimal. If no freshwater is available, a unit could use seawater. But this is likely to need desalination plants. This is a further industrial project to take into account at a site. This will also require further permitting for infrastructure, such as an outfall pipe. Sodium then becomes a byproduct and brine discharge a potential pollutant to marine life.

Power connection data

A developer needs to know from the Transmission Owner of the network:

- The location of substations on the power network, at present and in the future
- The grid capacity, and reinforcements the Transmission Owner will need to make
- Locations on the network that are under most stress, at present and in the future. A developer states: "The whole system is constrained in Scotland, so the issue is where it is most useful to have somewhere to take it off the system."

Power consumption data

A developer needs to know information on local electricity consumption and future expected demand.[10] A list of high demand users may also be useful, especially large

[9] electrolysers require between 9 and 11 litres of water for every kg of hydrogen produced. https://watersmartsolutions.ca/wp-content/uploads/2020/12/Water-for-the-Hydrogen-Economy_WaterSMART-Whitepaper_November-2020.pdf. A 3 GW facility would require around 23,000 m3/day of water, according to a Wood Report (2022) [3.1 million m3/day per year for a 1 GW facility] https://www.evaluationsonline.org.uk/evaluations/Search.do?ui=basic&action=showPromoted&id=755

[10] There are various sources for this, including consumption data from the UK (past and predicted), and future scenarios from SSEN-T (Transmission Owner) and SSEN (DNO)

industrial units or customers who will need to switch from gas/fossil fuels to electricity or hydrogen as a means to decarbonise.[11]

Site location

A developer needs to know the ecological and environmental impact of the project. A 50 MW project would need two acres, a large-scale project of 3 GW would require around 110 acres (based on 0.015 ha/MW). A developer noted: "We are talking about a massive industrialisation of the landscape." Brownfield sites and former industrial units may be the best options. The location will require planning permission from local authorities, site owners and environmental bodies.

Gas infrastructure

A site will likely need a connection to the National Transmission System (NTS), which is the high pressure pipes of the gas network, if the project intends to put hydrogen directly into the gas network. It may also need underground storage capacity for gas, though this will depend on geological specification (Scotland, for example may not be suitable). Hydrogen could also be used in industry, such as ammonia or steel manufacture.

Power generation

A site needs to know the location and number of wind turbines (current and planned). It will also need to know how much wind is generated (and predicted) by these sites.

Price of electricity

A developer needs to know the past, current and predicted price of electricity by time of day.

Data on curtailment

When there are periods of high winds, and gas turbines are creating too much energy for the grid to handle, the National Grid ESO asks power generation owners to turn off certain wind turbines. To compensate the companies for these losses, the NGESO pays the companies "constraint costs". This process is known as "curtailment", and is an inefficient use of green power and public money. Green hydrogen units could take this excess and power and store it, reducing costs for consumers and not wasting renewable energy.[12]

Equipment supply data

Developers need information on the supply of electrolysers, their availability, and when

[11] One source for this data is industrial emissions, which can come from the UK's- National Atmospheric Emissions Inventory (NAEI)

[12] Elexon should have this data. Another broader source is here: https://www.ref.org.uk/ref-blog/371-constraint-payments-to-wind-power-in-2020-and-2021

these can be manufactured and delivered. This is key for a project. There are challenges, such as global supply chain pressures due to the pandemic, and sanctions on Russian metals. Meanwhile UK or Scottish electrolyser suppliers appear to be scarce. Supply issues could hold up projects. According to an ARUP analysis for ScotGov in 2022: “electrolyser manufacturers are already developing plans for their manufacturing out to 2030. The Scottish supply chain, as a result, needs development support now to allow it to integrate into this competitive market.

Hazardous site data

Developers must work with the Health and Safety Executive (HSE) to ensure their units comply with safety standards. One developer stated: “If there is any element of doubt, it would not be allowed to happen”. Potentially useful here is COMAH establishment data, and where locations are.

Barriers in the grid connection application process

Icebreaker One, with support from its partners in the project – SSEN-T, Mapstand and Olsights – looked into the user needs of a developer of a hydrogen electrolyser in the north of Scotland, and barriers and blockers that exist in the connection application and consent process. We focused particularly on issues around the availability of data developers require for a faster, more efficient and more realistic connection to the grid.

After undertaking interviews with stakeholders and studying and examining relevant material, we set out 19 problem statements (or focused "use cases"). The full list can be found in Appendix 1.

> ***What is a use case?***
>
> *We define a use case as outlining the tools (such as data) that a specific stakeholder (the primary actor) will need to achieve a specific, focused goal, and what needs to happen for the primary actor to achieve their goal. Each problem statement/use case is therefore expected to be fairly narrow in scope, though it may have applicability to other use cases.*

We then narrowed the original 19 down, based on the following criteria:

1. How much does it help to achieve net zero Targets of 2035 and 2050?
2. Is it relevant to the example of electrolytic hydrogen?
3. Can it help keep costs low for Transmission Owners, developers and GB consumers?
4. Does it Involve other stakeholders outside of the Transmission Owner?
5. Does it involve a policy change or regulatory change out of scope for this project?
6. Can it find a solution through the use of a tool proposed by the partners?

Use case shortlist

Following this rationalisation, we reached eight key use cases, as per the table below. You can find full details of each in Appendix 1.

#01	Developers face unexpected price hikes to their connection costs during the approval process, which can double the initial investment cost of the project.
#02	Time is sometimes wasted by both developers and Transmission Owners during in-person pre-application meetings due to unrealistic feasibility studies and business plans.

#03	The Transmission Owner receives far more electricity supply from generating companies than the regional demand in the north of Scotland. There is a risk energy produced goes to waste.
#04	It's difficult for the Transmission Owner to determine the future capacity of the network, as the Transmission Owner is unsure which potential developments will connect to network (and when)
#07	Developers lack knowledge on the best location for a hydrogen electrolysis development
#08	Much of the data required for the application process is held in data silos within the Transmission Owner. Thus staff involved in consent process must "hunt down" information, rather than access it easily
#11	A major reason for connection applications failing is due to developers (and Transmission Owner) not getting planning permission from local authorities, which could include approval from local communities
#20	Hydrogen use and transportation scenarios for the developments are not taken into account in the connection request process

Problem statement prioritisation workshop

Following a workshop prioritisation exercise with project stakeholders, the top-ranked problem statement was:

#04 It's difficult for the Transmission Owner to determine the future capacity of the network, as it is unsure which potential developments will connect to network (and when)

The next two highest-ranked problem statements were numbers #08 and #07.

Why is problem statement #04 so important?

We asked the stakeholders for feedback on the top-ranked problem statement. Many comments were supportive:

- **Transmission Owner: "**This is the essential challenge for network planning, as it shows there is uncertainty and volatility."
- **Transmission Owner: "**For net zero, knowing where the targets will be satisfied by technologies in locations would go some way to removing and reducing that uncertainty."
- **Transmission Owner:** "This could also show future requirements for capacity for the network."

However, some felt the problem statement was a lower priority than some others:

- **Energy company:** "This problem statement is important, but it loses sight of the end goal of what you are trying to achieve. This is to identify the location where it is best for a developer to connect."

General workshop feedback

In addition to commentary on the top-ranked problem statement, throughout the workshop participants made comments on the future of electrolytic hydrogen.

- **Innovation agency: "**electrolysers will be a key system balancing tool for running a zero gas system by 2035."
- **All parties** discussed that a key issue would be when electrolysers will start functioning at scale, and how they are being used will be a key issue, especially taking into account the role and the destination of the hydrogen.
- **Innovation agency: "**Hydrogen's first role in Scotland could be as a balancing mechanism to be used as an energy source at times of peak demand (especially in winter)."
- **Innovation agency:** "The gas networks' needs must also be taken into account, as some of these hydrogen projects will be supplying the gas networks."
- **Transmission Operator: "**Within SSEN-T, one of the biggest challenges is around data standards, interoperability and open data/data sharing around a diverse range of stakeholders and data owners (developers, consultants, statutory consultees, consenting units, NGESO, DNO, suppliers) which can hamper an assured and automated data transfer and insight."

As part of WP2, Icebreaker One has compiled a list of datasets that are necessary to address these problem statements, and which are relevant to the stakeholders in the application process.

Recommendations

Throughout the research process, two key themes stood out.

Firstly, from the example that we explored in the north of Scotland, there is a lack of a seamless data flow in the application and consent process, which can lead to wasted time and resources and sub-optimal outcomes. There are also other potential frictions during the approval process, both internal to the transmission owner, and external to the process.

Secondly, there is a need for innovative solutions to reduce friction and improve processes.

We've made recommendations to address these two key themes. These are recommendations that we made for the example of SSEN-T, which should also be relevant to other Transmission Owners, unless specified.

Recommendations to reduce friction between developers, Transmission Owner and National Grid ESO

- **The pre-application stage of the consent process between the developer, systems operator and transmission owner requires stakeholders to have access to more extensive, more detailed and relevant data in order to ensure projects succeed fast or fail fast**

At present, key connection applications for large demand units are often not passing the pre-application stage in a mature form. Some of these are unrealistic developments. However, in other cases the problem lies at least partially in developers lacking access to relevant data that could support and strengthen their application. Better access to data, alongside appropriate consultation with the Transmission Operator and Systems Operators, would often enable developers to shape their plans into viable and fully-costed projects.

The Transmission Owner must make as much data as possible available to developers, including power flow data and forecasts, and grid capacity data and forecasts in shareable formats. The data requirements for developers listed here must also be available. Information available at this stage should assist developers in finding a feasible site for their project that fits in with the transmission network, which is already facing constraints.

This information should be available in a format that is accessible and open to visualisation. This could be a geographical planning tool, such as REACT.

Depending on sensitivity, this data could have different access levels, where some information (such as transmission assets) is internal to the Transmission Owner.

This policy of “succeed fast and fail fast” at this early stage is necessary, so that SSEN-T does not have to process applications that it is aware might fail, or that will require a large number of modifications to proceed.

More detailed discussions may also be necessary, subject to regulatory requirements, between developers, transmission owners and system operators at a pre-application stage, so they can have a helicopter view on whether the site of their project is viable or not from a transmission network perspective.

Following this recommendation will help address the [three main problems statements identified by our workshop](#).

- **Key stakeholders (Transmission Owner, NGESO, developer) must make data on planned projects available as early as possible, subject to commercial sensitivity restrictions, so that the energy industry has a clear picture of the future demands on the transmission network**

Presently, data on proposed connections is available for projects where the developer has already opened a contract with NGESO. However, this is arguably too late. Data on these projects should be available to all developers at the pre-application stage, so that they are aware, for example:

- Which substations are currently crowded, or may become crowded in the future
- The volume of competitor projects.

Where data is commercially sensitive, it must be anonymised and restricted only to the details essential for effective planning and decision making. In the case of hydrogen, many projects are financed by local or national Government, which means there should be an obligation for some of the details of their project to be made public, as their projects include financing from taxpayers.

An alternative is for a dataset showing slated projects to be kept within the Transmission Owner or NGESO, which they can consult on when necessary.

- **Stakeholders must monitor and analyse the cumulative effect of power generation and demand developments, and their related infrastructure, on public opinion**

If a large number of industrial projects in power generation and demand are carried out at once, this will mean a large-scale industrialisation of the landscape. This will also necessitate power infrastructure to cross the land and sea to provide and receive electricity to and from the units. Privately, some stakeholders in Scotland are concerned about this impact, especially if Scotland chooses to become both a centre of power generation and demand, with a combination of units that generate, store, process and export power in one region.

To manage these concerns and ensure that projects are developed in a sustainable manner, it is essential that a holistic view is taken of the cumulative effect of such projects, rather than each one being developed in isolation, as is often the case currently.

Stakeholders in Scotland may benefit from reviewing the current situation in East Anglia, where public disapproval has grown towards towers (pylons) carrying electricity from offshore wind farms, and the location of substations. There is concern that hubs of development in Scotland, such as Peterhead, East Lothian and Angus could risk a backlash. There are some differences in Scotland: it has more space, a longer coastline, and a history of community acceptance of oil and gas infrastructure. However developers cannot take this for granted.

- **NGESO and the Transmission Owner must decongest connection application backlogs, which could happen through a "use it or lose it" policy**

Some developers who have completed the first stage of the consent process have not yet built their projects in the original timeframe they agreed upon with the NGESO and Transmission Owner. We understand in the case of SSEN-T there have been up to five of these. Instead, developers have used a loophole to modify their project on an annual basis. This means the developer continues to have a reservation on a bay (a portion of a substation to connect), which they are not using, and which could be useful for another developer, who is more willing and able to complete their project.

It could be necessary to empower National Grid ESO (NGESO) with the right to continue or terminate applications that are taking too long, and make way for next in queue. A scoring system could determine whether or not such developers keep their reserved spot. If they don't use it, they would have to return to the front of the queue and go through the entire application system from the beginning.

This "use it or lose it" policy change recommendation goes beyond the scope of this piece of work and report, but may need to be taken into account as an end result.

- **Specific to SSEN-T and this project, the REACT project must align with SSEN-T's existing data automation project, the Data Action Plan 2022-2026**

At present, there is a lack of automation and systemisation of data in SSEN-T. Currently, there are no datasets available in a shareable format that shows the capacity of the network as a whole, physical components, space available, circuit breakers available, and a connection point amenable to extension.

The Transmission Owner is going through a five-year programme to integrate its systems in a common network model, the Data Action Plan. However, the current lack of easy access to such datasets may be holding back the development of a project such as a geographical planning tool, (which could be a potential solution for Recommendation *the pre-application stage of the consent process between the developer, systems operator and transmission owner requires stakeholders to have access to more extensive, more detailed and relevant data in order to ensure projects succeed fast or fail fast* above).

A recommendation for the Alpha Phase would be a "deep dive" into how a project is steered through the application process, to see the different data touchpoints. This would enable stakeholders to see whether these datasets are available or shareable in formats that could inform both a geographical planning tool and the Data Action Plan. This is a form of sandboxing or user testing.

SSEN-T has expressed concerns that the two projects could overlap. To avoid duplication of effort, it will be important for the REACT project to align with, support and inform the current automation project, as well as acting as a critical friend in its data management and integration process.

Recommendations to promote further innovation between developers, Transmission Owner and National Grid ESO

- **Stakeholders could make a reduction in constraint costs an organisational key performance indicator (KPI)**

Constraint costs are the "canary in the mineshaft" that indicates the generation and demand system is not currently functioning. Therefore the ambition to bring these close to zero could be a useful target, as it shows that generation is equal to demand, and no renewable energy is going to waste.

One SSEN-T stakeholder noted the "win win" aspect of this approach, saying it: "benefits GB consumers in the most economic way. We get more wind power on the system, plus it makes sense from a GB consumer perspective."

This could be an indication of long-term success under the current system. However, it is important to be aware there are also potentially other solutions seeking to reduce constraint costs (such as locational marginal pricing).

- **Stakeholders must create a digital twin of the power system with existing data, rather than waiting for the perfect data to become available**

Many projects in the energy sector are looking to create a digital twin of the power systems, such as the Virtual Energy Systems project in the National Grid ESO.

One of the major blockers to digital twins in general is a conflict between the ambition of the stakeholders in the project, who want to make data freely available, and the limitations of the data owners, who frequently hold the information in non-machine readable formats, or in different locations, or in duplicated formats.

In this case the desire for perfection should not be the enemy of good enough. There will never be a time when all datasets needed are available and/or flawless.

Rather than holding back new concepts and innovation because the data is imperfect, stakeholders must work with the data available. As more data becomes available, this must be integrated into existing tools, and used to create new tools.

- **A new information and visualisation tool should support decision making at a local community level**

On a general level, planning permission is currently a major reason why projects fail, which could be due to either an unsuitable development project or a lack of data to inform a project. Therefore a solution is necessary to inform all stakeholders in the process about the impact of such projects, so that everyone is equally well-informed and the process is fully transparent. This could also emphasise not just the cold commercial reality of projects, but also how they benefit local communities.

As one stakeholder stated: "Transparency is good for communities, but they must see the benefits." This could include: using brownfield and derelict sites, and emphasising local job creation, upgrades to local power infrastructure and even compensation.

- **The Alpha stage of the REACT project should engaging with NGESO and sectors outside of energy, who will be key partners in any electrolytic hydrogen project**

An electrolytic hydrogen project requires joined-up thinking between a wide variety of stakeholders. In the Discovery phase, we have tried our best to engage with as many as we can, but we feel the Alpha phase will need to extend our reach.

Key to this must be stronger engagement with the Systems Operator (NGESO) as a key partner in the project, as it plays a key role in developers' network connection applications. Deeper engagement is also necessary with stakeholders outside of the energy sector, including environmental agencies, marine and river authorities, and the water industry.

A key recommendation at the Alpha stage would be further consultation with local authorities to find out why major projects could fail at the planning permission stage (see recommendation *A new information and visualisation tool should support decision making at a local community level* above).

- **Partners in the project must increase visibility and shareability of the datasets relevant to project under appropriate open or shared licences**

To enable the various parties involved in planning and developing this project to work more efficiently and collaboratively, the data and datasets required for doing so must be discoverable, open or shareable wherever possible. We also recommend that these datasets are indexed by platforms such as Open Energy, to maximise who is able to find and use the data.

Icebreaker One

Appendix 1: Full list of problem statements

Here is the full longlist of 19 problem statements, brief descriptions of the issues, and potential solutions. These are not numbered consecutively as each number is a "code" and some initial statements were dismissed or amalgamated at an early stage.

#01 COST OVERRUNS Developers face huge and unexpected pricing increases during the approval process, which can double the initial cost of a project. One energy insider stated: "A lack of visibility of potential cost increases can kill projects"
Key stakeholder Developer
Other stakeholders Transmission Owner, Systems Operator (ESO)
Brief description One developer with a large demand saw their project costs rise steeply during the approval process. In one case, the National Grid ESO had to make the system secure in case it lost this large demand customer. This included an increase in circuits to mitigate against part of the capacity falling off. However, this issue emerged partway through the process, not at the beginning. Therefore SSEN-T had to redo the offer, which almost doubled the cost (from £20m to £35m) for the developer. This could also be the case with big-ticket developments such as Carbon Capture and Storage (CCS), data centres, pump storage, and hydrogen. Up front, the quantity of reinforcements necessary are not always clear. This may result in cost overruns. Related to this is the cost of equipment used in reinforcement. SSEN-T states: "Inflationary pressures have increased costs incurred by developers, which has become an impediment."
Potential solutions • Such issues must be flagged as early as possible in the application process, preferably at the pre-application stage. • Government financing for projects should also be available for those projects in the later stages of development, which can face huge cost overhauls to make the grid ready, in certain cases
Relevant to all forms of power and demand (Including green hydrogen)

Yes
How can a solution keep costs low? Early identification of issues would help developers budget properly, while improved government financing would reduce costs for developers
How can a solution help reach net zero? Would help ensure net zero developments are realised faster

#02 APPROVAL PROCESS SLOW AND BUREAUCRATIC The approval process by the NGESO/SSEN-T for new power demand and generation units is slow and time consuming, placing an administrative burden on Transmission Owners and impacting how quickly they can issue approvals to developers
Key stakeholder Transmission Owner
Other stakeholders ESO, Developers
Brief description The approval process for a new unit to the grid can take three months from clock-start, and a further three months for the developer to respond. Less than 50% of applicants will realise the development of a proposed unit (there may be other factors than the time taken). One developer stated: "Any tools that cuts down on development time can be useful". Another developer stated: “The system is slow. Not fit for purpose. It is stuck in a layered, process-oriented system. A slow entity like ESO is talking to another slow entity like a Transmission Owner. Developers move faster than them and because they are slow, we are stuck. The system is rigid.”
Counterview The approval process “must not be rushed”, say some insiders. Another issue is that there are a large number of projects in north Scotland, so it's important not to put added pressure on staff. SSEN-T: "The time pressure of this process limits the ability to be strategic with new connections." Therefore efficiencies may be necessary.

Potential solution Speeding up the process may require a change in regulation outside of the scope of this project
Relevant to all forms of power and demand (Including green hydrogen) Yes
How can a solution keep costs low? This would reduce costs for developers
How can a solution help reach net zero? This would ensure realistic net zero developments are realised faster, and unrealistic ones fail to make the cut faster

#03 GENERATION NEEDS DEMAND SSEN-T receives far more electricity supply from generating companies than the regional demand in Scotland. There is opportunity for exporting it or utilising this imbalance to power new demand projects, such as hydrogen electrolysis plants
Key stakeholder Developer
Other stakeholders Transmission Owner, Systems Operator
Brief description SSEN-T stated: “The challenge we have on the network is generation, not demand, in north Scotland”. Over 100 power generation units (over 10 MW) are approved each year in north Scotland. This increased to 150 in 2022. "We export four and a half times the demand on the system". There are constraints in the transmission network meaning that it cannot operate at full capacity. If there is an over-supply of energy in north Scotland, power generating units in some cases must stand idle, and are paid constraint costs (curtailments) to not make energy by NGESO. This puts the energy system in a dilemma between the short term and long term needs: "Is it economic to reinforce the network further or continue paying constraint costs for outages?"

However, this problem is set to continue. "The potential time lag between the growth of wind generation in Scotland and network reinforcement is likely to lead to a significant volume of curtailed energy in the late 2020s"[13]
Potential solution There are different options for excess energy in north Scotland: 1. A HVDC Cable from north Scotland to the rest of UK to export energy (Eastern Link 2 proposal from Sandford Bay, at Peterhead, to Drax in England[14]). 2. A storage of energy to re-use domestically at peak times. This could be through green hydrogen plants. 3. Large demand users of energy located in north Scotland (such as green hydrogen plants, CCS, data centres, battery storage), close to power generation. This could reduce costs for power generation developers. This would reduce costs for NGESO and ensure no green energy goes to waste. "Generally, the frequency of curtailed energy is higher in northern Scotland due to additional network constraints, so electrolysers used for hydrogen storage located further north will have potentially higher load factors and a lower cost of hydrogen production, at least in the near-term. By the early 2030s, transmission-connected wind capacity is likely to significantly exceed off-peak electricity demand, meaning that curtailment will likely remain an ongoing feature of system operation."[15] SSEN-T view: "If there was a means of generating hydrogen instead of paying constraint costs it would make economic sense, and we could defer some of the reinforcements. It is a double headed sword that benefits GB consumer in the most economic way. We get more wind power on the system, it makes sense from a GB consumer perspective."
Relevant to all forms of power and demand (Including green hydrogen): Yes. Solution 3 relevant only to hydrogen
How can a solution keep costs low? This should ensure the most efficient use of power generated. Could reduce costs of Transmission Network Use of System (TNUoS) charges and constraint costs

[13] https://www.climatexchange.org.uk/media/5627/the-potential-for-hydrogen-to-reduce-curtailment-of-renewable-energy-in-scotland-jan-23.pdf

[14] https://www.ssen-transmission.co.uk/projects/project-map/eastern-green-link-2

[15] https://www.climatexchange.org.uk/media/5627/the-potential-for-hydrogen-to-reduce-curtailment-of-renewable-energy-in-scotland-jan-23.pdf

How can a solution help reach net zero?

This will improve efficacy of renewables and boost hydrogen tech and projects in GB

#04 LACK OF PREDICTABILITY ON SUCCESS AND FAILURE OF PROJECTS

It's difficult for Transmission Owners to determine the capacity of the network: which of the potential developments will and will not connect, and when they will connect. There is a lack of predictability

Key stakeholder

Transmission Owner

Other stakeholders

Systems Operator, Developer

Brief description

For a certain location, the Transmission Owner reserves capacity for developers at the scoping stage. As the application process draws on, developers form a queue at specific sites (on the network). If a new developer wants to locate at a site, there may be no space.

SSEN-T: "In the case where a new connection request triggers network reinforcements we might not know for certain whether these network reinforcements will go ahead, as they depend on the site which triggered the works actually following through with the connections process. As a result, we end up with several different potential network pathways, depending on which sites go on to connect and which do not. Part of the planning process at SSEN Transmission involves trying to consolidate these pathways and determine the likelihood of one happening over the other.

"So sites do not forever take up space in the queue, we have a deadline by which they have to accept an offer. But they can submit an application for modification and the process can keep going for months and months."

SSEN-T says it is "mapping uncertainty".

Potential solution

A developer stated: "More face-to-face collaboration is needed between developers and the grid. When I go to a local council, I can get a feel on what is possible in planning. With the grid, I can't have that conversation as someone is worried they will say the wrong thing."

Relevant to all forms of power and demand (Including green hydrogen)

Yes
How can a solution keep costs low? Efficiencies should ensure better projects break ground faster, which could save money
How can a solution help reach net zero? Should help accelerate projects that develop green economy

#05 CONSERVATIVE PROCESS The approval process for connections is risk-averse and unnecessarily conservative
Key stakeholder Transmission Owner
Other Stakeholders ESO, developer
Brief description The Security and Quality of Supply Standard (SQSS) sets out the criteria and methodology for planning and operating the National Electricity Transmission System. SSEN-T: "We make assessments for new connections with this in mind. Without evidence to the contrary, we make the assumption that [maximum energy supplies] could be exported at the same time." This may be more acute in SSEN-T because of the huge imbalance between power generation and power consumption. At present the SQSS has a "deterministic" policy to capacity (which is set at national level), although there may be a more "probabilistic" system in the future. Currently, it models much higher inputs than the figures that exist in reality. This lacks flexibility.
Potential solution A change in the SQSS to assess the network with a more pragmatic approach. However this approach may require a change in regulation which is outside of the scope of this project.
Relevant to all forms of power and demand (Including green hydrogen)

Yes
How can a solution keep costs low? Only indirectly by having a more flexible system
How can a solution help reach net zero? Only indirectly by having a more flexible system

#07 NO PUBLIC HOTLIST FOR UNITS Developers lack knowledge on the best location for a hydrogen electrolysis development
Key stakeholder Developer
Other stakeholders Transmission Owner, NGESO
Brief description One energy group insider stated: "We would bite off [SSEN-T]'s hand for a tool to offer the best location for an electrolyser". As far as we understand, there is no nationwide portal indicating prime locations for situating hydrogen (or power) generation.
Potential solution A heatmap which details the prime locations for a green hydrogen project based on • Geospatial data • Congestion hotspots on network • Locations available to build upon • Access to water • Access to transport • Land use details / ownership of land details • Port locations This could be offered to developers before they submit requests, offering alternative locations to site their project on the existing network with more capacity.
Counterview

If the heat map system was a "green, orange, red" for best to worst locations, such as indicating the ideal substation to position a green hydrogen project, this could risk a “rush” from developers to secure that spot. SSEN-T "We could see a huge influx for specific areas." However, a way of mitigating this is to maybe show anonymized data of the other applications slated for – or pending – for those locations.
Relevant to all forms of power and demand (Including green hydrogen) Yes, but very relevant to new tech such as green hydrogen
How can a solution keep costs low? This reduces costs for developers at the pre-application stage, and potentially reduces costs for Transmission Owners by creating more viable locations for projects
How can a solution help reach net zero? This creates planning efficiencies for green tech

#08 TRANSMISSION OWNER TIME AND RESOURCES STRETCHED Stakeholders involved in the connection approval process, who already have growing demands and workloads, currently lack the time and resources to collect and format the data necessary for a more automated process, which could be transformed into a heatmap in real time, or similar app
Key stakeholder Transmission Owner
Other stakeholders Systems Operator
Brief description Within SSEN-T, there needs to be a tool that brings datasets together. Some datasets exist in silos. "We need a tool that merges it all together". The time to do it is an issue. It is not a case of will. It is a case of prioritisation for the team, especially if this is not part of the regulated activities of the business, but an “add-on”.
Potential solution

The IT team within SSEN-T is working on a project as part of ED2 2022-2026 (part of the Digital Action Plan), which could help to automate the system and solve some of these issues.
Relevant to all forms of power and demand (Including green hydrogen) Yes
How can a solution keep costs low? Through greater efficiency
How can a solution help reach net zero? Through greater efficiency

#09 DISPARITY IN TIMELINES In the approval process, there are cases of connection applications failing to reach fruition due to failure to synchronise between Transmission Owner and developer. This happens after an offer has been made to a developer
Key stakeholder Transmission Owner
Other stakeholders Developer, NGESO
Brief description SSEN-T has made an offer to a developer, this offer has requested that the developer must connect on a particular date, or within a time period. However, the developer plans to connect at a different period of time "far in the future and not compatible with the business case". This disparity has caused projects to fall through. Conversely, projects also end because the developer has a preconceived connection date for the project, say 2028, and the Transmission Owner can only finished the reinforcements by 2034
Potential solution Can a tool help with this, or is this a communication issue? Greater predictability is necessary.
Relevant to all forms of power and demand (Including green hydrogen) Yes

How can a solution keep costs low? Through greater efficiency
How can a solution help reach net zero? Through greater efficiency

#10 UNREALISTIC DEVELOPMENT PLANS Developers and Transmission Operators sometimes waste time during in-person pre-application meetings, due to unrealistic feasibility studies and business plans.
Key stakeholder Developer
Other stakeholders Transmission Owner
Brief description At the pre-application stage, developers find out that the scope of work required for their desired connection is different from their plan. There are issues regarding access to the connection sites, such as substations.
Potential solution A tool to make some of these issues obvious to potential developers before any meeting takes place.
Relevant to all forms of power and demand (Including green hydrogen) Yes
How can a solution keep costs low? This could reduce burden of work on the planning department and reduce costs for developers
How can a solution help reach net zero? By helping green energy projects succeed fast and fail fast

#11 APPLICATIONS FAIL AT PLANNING PERMISSION STAGE A major reason for connection applications failing is due to developers not getting planning permission from authorities
Key stakeholder Developer
Other stakeholders Transmission Owner, local authorities, owners of land/property
Brief description Some developers face the challenge of getting planning permission and consent from the local authority to use the site they have identified for the development. "This is the most common reason for the termination of projects," said one SSEN-T manager. "Consenting is big for a substantial wind farm. It's a vast area of space – a lot comes down to visuals and whether the wider community is on board." SSEN-T also needs permission to build infrastructure such as cables and towers to sources of energy demand and generation, and to extend substations. This has a huge visual impact on the countryside. Scotland needs to be aware of the "cumulative effect" of projects. In themselves, power generation and demand projects may gain permission, and go ahead, but when these are mapped, they will show a large part of the country has now become industrialised, and could cause shock to local communities. This is only likely to become clear as more projects are developed.
Potential solutions ● Bringing the community on side at the beginning of the project. Explaining to them that the development must have a "community first" policy. ● Explaining to local authorities clear information about projects, as some seem to not be aware of full tech behind projects, and they have key role in allowing delivery of projects ● On a wide scale, people want to see the benefits in their pocket. Projects need to benefit locals first with electricity, and then be used as export ● Any permission on such a project has to come with improvements to community power infrastructure, not just reinforcements to and from the site. “Transparency is good for communities, but they must see benefits.” ● Brownfield locations need to be prioritised for sites, especially those which used to house heavy industry or for the oil and gas sector ● Locations next to centres of generation (the turbines) or demand (at the substations) need to be highlighted. Existing battery projects in north Scotland are close to substations, for example ● A project should emphasise local job creation ● A project should emphasise compensation for locals, where this is necessary

Relevant to all forms of power and demand (Including green hydrogen)
Yes
How can a solution keep costs low?
By helping projects succeed fast and fail fast
How can a solution help reach net zero?
By helping green energy projects succeed fast and fail fast

#12 PROJECTS GO NOWHERE
A significant amount of SSEN-T time and resources are spent (and arguably not used effectively) on processing applications for projects that fail to progress to fruition
Key stakeholder
Transmission Owner
Other stakeholders
Developers, NGESO
Brief description
SSEN-T spends time and effort on an application only for it to stall in mid-process. Some projects are doomed from the beginning, but SSEN must process application: “If a customers applies for an offer, we have to process this, even if we know [the network] is full”
Potential solution
A tool to assist in the pre-application stage where it can screen requests, identify ones that will likely not materialise, and help developers make better decisions that will increase the chances of the application's success.
Relevant to all forms of power and demand (Including green hydrogen)
Yes
How can a solution keep costs low?
Discouraging unrealistic projects at an earlier stage will save costs for Transmission Owners and developers

How can a solution help reach net zero?
Discouraging unrealistic projects at an earlier stage will ensure more realistic projects break ground sooner

#13 TRANSMISSION OWNER DATA IN SILOS Much of the data required for the application process is held in data silos within SSEN. Thus SSEN-T staff involved in the consent process must "hunt down" information, rather than access it freely. The process is manual rather than automated.
Key stakeholder Transmission Owner
Other stakeholders Developer, NGESO
Brief description Technical datasets are hosted on separate applications/tools that don't communicate with each other, such as PSSE in systems planning (which is being replaced by Powerfactory) and MAXIMO, which deals with assets. Sometimes information is duplicated. This same problem applies to commercial datasets which are hosted on ETHOS and other applications. SSEN-T states: "The sources we rely on are in spreadsheets... There is literally zero integration between systems...the picture of the network is not coherently available to a developer" and the picture of the network may not be currently available to SSEN-T. Those looking to grant connection requests have to hunt down information necessary for the approval process. The system is "manumatic", which involves "Scraping of spreadsheets and pdfs, opening docs, and downloading something off the internet.”
Potential solution SSEN-T's Digital Action Plan 2022-2026 with six value streams aims to remedy these issues. This includes future network modelling, in particular power flow modelling. They want to produce a “genuine live capacity view of network", which could result in a heat map. There are concerns that a lack of the best available data holding back the development of a project such as a heat map. Can this be achieved with imperfect data?
Relevant to all forms of power and demand (Including green hydrogen) Yes

How can a solution keep costs low? Indirectly, through creating efficiencies in the long term
How can a solution help reach net zero? Indirectly, through creating efficiencies in the long term

#14 TRANSMISSION OWNER LACKS MACHINE-READABLE DATASETS Existing datasets necessary for the application and consent process are not in a machine-readable format
Key stakeholder Transmission Owner
Other stakeholders **N/A**
Brief description Data necessary for the consent process are in PDF, Excel, and attachments to emails. SSEN-T says: "It is not that data does not exist. It is not in a system. Or, where it is in a system, then it doesn't have an API. It could be buried in an appendix of a Word document."
Potential solution SSEN-T's Digital Action Plan 2022-2026 with six value streams aims to remedy these issues.
Relevant to all forms of power and demand (Including green hydrogen) Yes
How can a solution keep costs low? Indirectly, through creating efficiencies in the long term
How can a solution help reach net zero? Indirectly, through creating efficiencies in the long term

#15 TRANSMISSION OWNER DATA TRUST ISSUES There are dataset trust issues regarding Transmission Owner information necessary for the consent process
Key stakeholder Transmission Owner
Other stakeholders Developer, NGESO
Brief description It is difficult to trust the sources of the dataset, and they are prone to varied human interference. There is duplication of information.
Potential solution SSEN-T's Digital Action Plan 2022-2026 with six value streams aims to remedy these issues.
Relevant to all forms of power and demand (Including green hydrogen) Yes
How can a solution keep costs low? Indirectly, through creating efficiencies in the long term
How can a solution help reach net zero? Indirectly, through creating efficiencies in the long term

#16 TRANSMISSION OWNER'S DATASETS ARE STATIC The SSEN-T datasets (in areas such as capacity and assets) are static and not dynamic
Key stakeholder Transmission Owner
Other stakeholders **N/A**

Brief description

The current system provides a static view of the potential network impact, states SSEN-T.

Data is not available in a format with high frequency (power flows, for example), and is not updated regularly. But the data itself is evolving all the time. This means there can be multiple variations of data. Data also changes each time a project is contracted, making it difficult to assess the long-term, cumulative impact each request has on the grid.

Potential solution

The IT department of SSEN-T has set out a digital action plan to be completed by the end of 2026 (ED2 period). This includes future network modelling, in particular power flow modelling. The team wants to produce a “genuine live capacity view of network”, which could result in a heat map, but this latter ambition has been delayed until 2024 or beyond.

Relevant to all forms of power and demand (Including green hydrogen)

Yes

How can a solution keep costs low?

Indirectly, through creating efficiencies in long term

How can a solution help reach net zero?

Indirectly, through creating efficiencies in long term

#17 REGIONAL COORDINATION NEEDED

Coordination between different regions within SSEN-T is not always happening in real time during the application process for connection to the network

Key stakeholder

Transmission Owner

Other stakeholders

N/A

Brief description

Information sharing between three different regions in north Scotland does not take place in real-time. The three different regions in SSEN-T might be working on different projects that will

have a similar impact on the grid. In the end, they have to step down a project for another to go forward
Potential solution Better communication between regions and the centre. The connections team has suggested monthly webinars, which could help.
Relevant to all forms of power and demand (Including green hydrogen) Yes
How can a solution keep costs low? Indirectly, through creating efficiencies in the long term
How can a solution help reach net zero? Indirectly, through creating efficiencies in the long term

#19 TIMESCALES TOO SHORT There is a lack of resources to complete the approval process within necessary timescales
Key stakeholder Transmission Owner
Other stakeholders NGESO
Brief description The timescales for the approval process for a large-scale unit are too short. This is currently 60 days for SSEN-T, and demands are high. There are 15/20 "simultaneous workflows" per month.
Potential solution These timescales are regulated, so would require regulatory change.
Relevant to all forms of power and demand (Including green hydrogen) Yes

How can a solution keep costs low? Indirectly, through creating efficiencies in the long term
How can a solution help reach net zero? Indirectly, through creating efficiencies in the long term

#20 WHERE DOES THE HYDROGEN GO? Hydrogen use and transportation scenarios are not taken into account in the connection request process
Key stakeholder Developer
Other stakeholders Transmission Owner, NGESO
Brief description It is important to know the destination of the hydrogen produced at the proposed site and whether the developer has a business plan. One of the concerns is the immaturity of the hydrogen regulation space, which could mean that commercial models and the business case framework are still in the early stages of development and that many of the use-cases proposed for hydrogen are still uncertain and not supported by evidence. Domestically, developers could use hydrogen as a form of storage for use of power at peak times. However they believe there will be an excess. There need to be export routes for the hydrogen. According to Climate Change, Scotland: "In the absence of a wider hydrogen network, hydrogen will need to be stored either by the supplier or the customer, to mitigate the temporal imbalances...The business case for using electrolysis for hydrogen storage will depend on the general growth of the hydrogen economy, transition of gas networks and broader market mechanisms that may be implemented across Great Britain's electricity and gas systems."[16]

[16] https://www.climatexchange.org.uk/media/5627/the-potential-for-hydrogen-to-reduce-curtailment-of-renewable-energy-in-scotland-jan-23.pdf

Potential solution Hydrogen is versatile. It can be used in heavy industry, such as steel industry, fertilisers and oil refineries, and in distilleries. It can be used to electrify the transport network, especially trains (an ambition of ScotGov) and as aeroplane fuel. Also it can be used for household heating. But potentiality does not mean practicality; there need to be clear routes to market.
Relevant to all forms of power and demand (Including green hydrogen): Just green hydrogen
How can a solution keep costs low? It creates a more solid business case
How can a solution help reach net zero? It creates a more solid business case for green energy

#21 POWER SQUATTERS Customers are hogging capacity and not developing projects
Key stakeholder Transmission Owner
Other stakeholders NGESO, developer
Brief description Access to a bay (a power line in a substation which connects a circuit to a busbar) is hot real estate. SSEN-T states: “[Some] customers are hogging capacity and reserving a bay five or six years up from starting a project. It is uncertain whether the project will happen, and they don’t terminate the scheme. Through the modification process, they spend £10,000 to push the project back by 12 months. They can use the modification process to keep revising the project and go back and forth. There are “four or five cases of this”. This can give the impression the network is full, when in fact projects are squatting in the substations on paper, without breaking ground.

Potential solution SSEN-T wants developers to reach milestones and offer evidence as to whether a project is realistic or not. This would give NGESO the right to continue or terminate applications, and make way for next in queue. This is a “use it or lose it” policy change needed beyond the scope of this project. A scoring system could determine whether or not they keep their spot. If they don't use it, they may have to return to the front of the queue and go through the entire application system from the beginning.
Relevant to all forms of power and demand (Including green hydrogen) Yes
How can a solution keep costs low? Decongests queue system of projects
How can a solution help reach net zero? Helps realistic green energy projects reach fruition faster

Appendix 2: Grid connection consent process

Please note: a graphic summarising the steps in the consent process can be found on the ESO website.

Pre-application meeting

This meeting takes place between a developer, Systems Operator and the Transmission Owner to have an initial discussion about how to connect a facility to the transmission network.

It is an opportunity for the developer to present a plan outlining the capacity they believe is needed, the planned location of the substation with a six digit grid reference, and the ideal date to connect to the network. It gives the Transmission Owner the chance to highlight early any potential errors in the developer's information.

The key question for most developers at this point is whether when they will be able to connect, alongside likely costs and how much capacity they can get.

Some applications go no further than the pre-application meeting due to fundamental flaws in a developer's initial outline.

Application submission

Assuming that the pre-application meeting has not thrown a developer's plan out entirely, the developer must then make an application to the National Grid ESO.

National Grid ESO (NGESO) makes an application to a Transmission Owner on the developer's behalf, asking the Transmission Owner to specify "the most economic and efficient design for this development and provide costs for the completion of necessary work."[17] Guidelines regarding the relationship between these two operators are in the Systems Operator Transmission Owner Code (STC), which is administered by NGESO.

Fees and technical competency

The Transmission Owner must declare whether this connection request is viable or not, dubbed "competent" or "non-competent". The feedback to the customer takes five days.

If a project is deemed competent, the developer is advised of the application fee payable to NGESO. This is determined by factors such as network area and the capacity of the development in Megawatts.

While the developer has a suite of contracts with NGESO and NGESO with the Transmission Owner, in practice there is regular direct communication between the developer and the Transmission Owner. The developer needs to follow a set of rules set

[17] Connecting to the transmission network (information for customers) https://www.ssen-transmission.co.uk/customer-connections/connecting-to-the-transmission-network

out for planning and connection in the Grid Code (managed by NGESO). These are checked by the Transmission Owner and NGESO for technical verification.

Upon receipt of the developer's approval and the developer's payment of the fee to NGESO, "Day 0" of the formal consent process begins. The consent process is designed to lead to a connection agreement between the relevant parties. If they consent to the outlines specified in this agreement, the Transmission Owner will then carry out necessary reinforcements on the network.

Consent process: timeline

Day 0	A Connections Offer Manager within SSEN-T is assigned to a project. The project goes to the System Planning and Development team in SSEN-T for analysis. This is based on the size and rating of application, and what the technology is – wind, hydro, power flow studies etc. The analysis: • Assesses whether the existing network has sufficient capacity without needing reinforcement or, if not, what reinforcements may be required. • Checks (potential) contributions to fault levels, short circuits on the network, the flow of the current, and if the system can safely handle this. The Connections team communicates with the developer: "We chat through what we are proposing, advise customers of any scope for what they can tweak to get earlier connection date, such as reducing the installed capacity from 500 to 350 MW as this would give them a date of 2029 as opposed to 2033, or they could have a phased connection, and add additional MW when the additional reinforcement comes on board." Costings go into a "technical report" and "commercial report" . The management signs off on these, and the information is transferred into Transmission Owner offer under The Connection and Use of System Code (CUSC)[18].
Day 40	By this date, a Planning Engineer contacts the developer (the client) to confirm and discuss the technical design proposal.
Day 74	Around this date, the Connection Offer Manager completes the draft connection offer and issues it to the NGESO to review and finalise

[18] The CUSC Is the contractual framework for connecting to and using the National Electricity Transmission System (NETS) (the code administrator is NGESO).

	before it is presented to the developer.
Day 90	SSEN-T's connections manager draws up a Transmission Owner Connection Agreement (TOCA) with National Grid ESO, which contains: an identification of ● The connection, and ● The infrastructure works required (design), their costs, and a timeline of how long this will take from consent to completion. The manager meets with the developer to confirm the TOCA. In turn, National Grid ESO has a suite of contracts with the developer, including a BCA (Bilateral Connection Agreement), which deals with compliance issues, and a CONSAG (Construction and Use of System Code Construction Agreement), which details design costs and any other industry requirements. This will include the costs the developer must pay for construction of infrastructure works and connection.[19]
Between day 90 and day 180	The developer has 90 further days to accept or reject the TOCA. If they accept the TOCA, the relationship is passed to SSEN-T's Customer Relationship team. If the project needs modifying, it comes back to the Connections Team.

[19] Infrastructure works are paid for via Transmission Network Use of System (TNUoS Charges). A developer pays all charges levied to National Grid ESO, which pays SSEN-T under established regulatory mechanisms.
The developer will pay ongoing connection charges in advance or over the lifetime of the development, which is typically 25 years.