# REACT (Rapid Evaluation Areal Connection Tool)

## Data accessibility and interoperability report

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# Executive summary

The rapid decarbonisation of the UK's electricity grid is a Net-Zero transition success story. Since 2008, when 80% of the UK's electricity was generated from fossil fuels, "the UK has cleaned up its electricity mix faster than any other major world economy."[1]

Delays in the connection process for green energy developers, however, are slowing the Net Zero transition and increasing costs for consumers,[2] with network companies struggling to roll out the much-needed major transmission infrastructure quickly enough.[3] If we are to meet Net-Zero targets, there is also an urgent need to tackle 'hard-to-abate' sectors involving complex risk, such as steelmaking, construction and chemical production.[4]

To achieve Net Zero by 2050, there is a requirement for tools and processes that model and mitigate complex risk, reduce delays in the grid connection process and improve strategic planning for Transmission Owners – so they can deliver targeted infrastructure upgrades faster. There are also significant cost savings to be made through tools and processes that reduce constraint costs. It is the goal of REACT to provide such a tool by addressing these areas simultaneously.

> **REACT must ensure the *power of data* flows freely to key decision-makers, where it's most needed**

For REACT to succeed, it must ensure the *power of data* flows freely to key decision-makers, where it's most needed. It must use data from a diverse range of sectors to model and mitigate complex risk, gathering data across 'information silos' often hidden from view. REACT must overcome powerful barriers – cultural, technical, legal and commercial – that stop data from being shared once it has been located.

This report, produced by Icebreaker One, analyses the current state of the data ecosystem as it relates to the REACT project, looking specifically at data accessibility and interoperability. Based on this analysis, Icebreaker One makes **five recommendations**

[1] Evans et al., 2019.

[2] Energy Systems Catapult, 2023.

[3] "With very few new transmission lines built in the last 30 years and a dramatic increase needed through to 2050 to achieve Net Zero targets, Mr Winser said even these long timescales may be challenging to meet if we fail to streamline the process." ibid.

[4] de Chammard, A.-L., 2022.

on how to transform the data network so data flows freely to where it's most needed, in order to solve complex, multi-stakeholder problems.

## Recommendations

1. **Embracing market-scale solutions**: To ensure REACT's solution has the widest possible applicability across the market, REACT's Advisory Groups **must** work closely with Open Energy's Steering Group to promote accessibility, agree common rules, processes and legal compliance and encourage a common rights-based approach to data access.[5]
2. **Reducing friction**: To improve data assurance, reduce friction across data silos and provide forward compatibility with the Virtual Energy System, the REACT project **must** embrace a 'Trust Framework' methodology throughout its work.[6]
3. **Improving data accessibility**: To improve the discoverability of datasets and encourage process innovation, Transmission Owners **should** publish internal process diagrams that describe the workings of complicated internal processes - such as the Network Connection Request process.[7]
4. **Improving prediction**: To improve long-term planning for Transmission Owners and for other stakeholders, a statistical model of projects **should** be embraced that tracks a project's estimated probability of success according to the best available data.[8]
5. **Embracing innovation**: To radically embrace innovation around processes, such as the Network Connection Request process, virtual 'sandbox' representations of these processes with representative data **should** be created. This will enable innovators to safely experiment with innovative solutions without affecting Business as Usual.[9]

[5] See Data accessibility and interoperability during Alpha - Interoperability.

[6] See Data accessibility and interoperability during Alpha - Trust Frameworks.

[7] See Data accessibility and interoperability during Alpha - Discoverability.

[8] See Appendix B: Deep analysis of problem statement - How to embrace a holistic approach to planning.

[9] See Appendix C: Deep analysis of primary use case - Phase 2: Network connection request process.

## Report structure

The content of this report is structured as follows:

**Introduction to REACT** provides an overview of the project and why REACT is essential to achieving Net Zero. A short summary of the Discovery Phase and Alpha Phase work is also included. A description of the report's recommendations is provided with links to the more detailed discussions that informed these recommendations.

**Data accessibility and interoperability - addressing the challenge** provides an explanation of why data accessibility and interoperability are important to REACT. A more detailed exploration of the data accessibility and interoperability work carried out during Alpha is also provided.

**Broadening REACT - future challenges** explores possible use cases that should be considered in the future development of the REACT project. Data accessibility and interoperability issues that might arise from scaling up REACT are also considered.

**Appendices A - G** offer a more detailed discussion of specific technical aspects of the project, including deep analysis of the problem statement and primary use case, a practical guide to use case analysis and reflections on research limitations and further research.

## Project deliverables

| Deliverable | Section covered |
|---|---|
| Organise advisory group, which will include network data analytics and IT team members | • Data accessibility and interoperability during Alpha<br>• How to broaden REACT - other use cases |
| Data sensitivity testing with key users | • Data accessibility and interoperability during Alpha |
| Provide data-sharing recommendations and guidance for use-case analysis | • Data accessibility and interoperability - addressing the challenge<br>• How to broaden REACT<br>• Appendix F: Use case analysis |

| | |
|---|---|
| Provide recommendations on how open and relevant data sets can be accessed in an efficient way and guidelines for retooling for different assets | • Data accessibility and interoperability - addressing the challenge<br>• How to broaden REACT |
| Lead the data accessibility and interoperability work, which is essential to ensure that data sharing does not restrict the use and users of the tool as it heads towards Business as Usual. | • Data accessibility and interoperability during Alpha |

## Engagement and impact

| Section | Description | Metrics |
|---|---|---|
| Engagement | *Number of people engaged and the degree to which they were meaningfully engaged.* | • Initial outreach to 75 potential Advisory Group candidates.<br>• Follow-up calls with 15 candidates.<br>• Convened three Advisory Groups involving 28 separate stakeholders.<br>• Contacted 20 hydrogen developers and interviewed four hydrogen developers.<br>• Contacted 32 Scottish councils. |
| Impact | *What has actually been done in terms of tangible impact?* | • Project partners created an Alpha version of the REACT tool and presented it to 49 stakeholders, including hydrogen developers, water companies, environmental agencies and local councils.<br>• Project partners created 94 user testing accounts leading to 19 users of the REACT tool. |

# Contents

# Introduction to REACT

## *Why REACT is critical to Net Zero*

For the UK to reach the government target of Net Zero by 2050,[10] it must decarbonise the electricity system across Great Britain (England, Scotland and Wales) by 2035.[11] Delays in the connection process for green energy developers, however, are slowing the Net Zero transition and increasing costs:

> *"The UK has been successful in stimulating investment in generation from renewables in recent decades, but this has not been matched with investment in electricity transmission networks… Renewable energy developers and other connection customers are currently receiving connection offers for the 2030s, slowing the clean energy transition. While annual constraint costs – paid to generators to switch off when supply outstrips demand – could rise from around £0.5-1 billion per year in 2022 to a peak of £2-4 billion per year around 2030 if all current investment is delivered on time."* Energy Systems Catapult, 2023.

So, to achieve Net Zero by 2050, there is an urgent need for tools and processes that reduce delays in the connection process and improve strategic planning for Transmission Owners - so they can deliver targeted infrastructure upgrades faster. There are also significant cost savings to be made through tools and processes that reduce constraint costs. The goal of REACT is to provide a tool that addresses these areas simultaneously.

For REACT to succeed, it must use data from a diverse range of sectors, gathering data across 'information silos' often hidden from view. Powerful barriers – cultural, technical, legal and commercial – often stop data from being shared once it has been located, a further obstacle for REACT to overcome.

The focus of Icebreaker One during the Discovery and Alpha Phases of REACT has been to improve access to such diverse data - both in terms of making that data more discoverable and finding efficient ways to share it at scale once located. Data is key to good decision-making for reaching Net Zero and Icebreaker One's goal is to make it easy to find, access and trust the data we need to reach Net Zero.

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[10] Department for Energy Security & Net Zero, 2023a, p. 4.

[11] Department for Business, Energy & Industrial Strategy, 2021.


**Screenshot of REACT tool**

## Project background

The REACT project is funded by energy network users and consumers through the Strategic Innovation Fund (SIF), a programme from the UK's independent energy regulator Ofgem, managed in partnership with Innovate UK. The project's partners are Scottish and Southern Electricity Networks (SSEN) Transmission, National Grid Electricity Transmission, SGN,[12] OIsights, MapStand and Icebreaker One.

The 'Discovery Phase' of REACT ended in May 2023 and the '**Alpha Phase**' ran from October 2023 to March 2024. The Discovery, Alpha and Beta Phase approaches to project development are part of SIF's three-phase approach to supporting innovative projects:

[12] Formerly known as Scotia Gas Networks.

*Figure 1: SIF three phase approach*

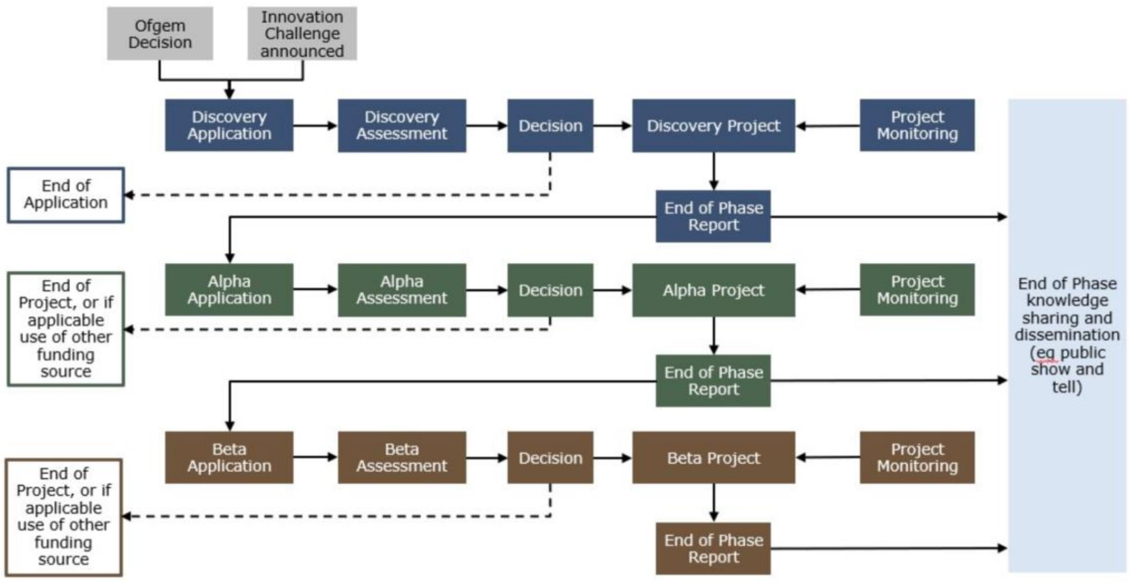



*Image source: Ofgem, 2021, p. 7*

During the Alpha Phase of REACT, Icebreaker One focused on improving data accessibility and interoperability for the project. This report summarises Icebreaker One's work on this aspect of the project during Alpha and includes recommendations on how to improve data accessibility and interoperability for the project.

## Discovery Phase - overview

During the Discovery Phase of REACT, the problem statement, the proposed solution and the primary use case for the project were decided in consultation with key stakeholders:[13]

### Problem statement

The REACT project selected the following problem statement to guide future work during Alpha:

> *"Currently, the process for reviewing connection requests is carried out in isolation, i.e., other potential developments are not considered, so there is little time to explore solutions that are optimal for the network.*
>
> *"The current system only provides a static view of the potential network impact a connection will have; however, this view changes each time a new project is*

[13] See REACT Discovery Report, Bird et al., 2023.

*contracted, making it difficult to assess the long-term cumulative impact each request has on the grid.*

*"The existing connections process is complicated, with large numbers of, sometimes unrealistic, requests clogging the system, undermining the strategic aims."* (Problem statement as articulated by SSEN Transmission).

## Proposed solution

The REACT project aims to create a geographical planning tool, providing users with the ability to view electricity grid connection requests in real-time using an interactive visualisation map. By incorporating a more holistic view of other connection projects within the tool, it is possible to explore optimal solutions for the electricity network.

REACT's visual planning tool brings together a diverse range of datasets to better inform critical decision-making for a wide range of users - from Transmission Owners trying to plan future infrastructure upgrades and project developers trying to select optimal locations for projects to local authorities wanting to fast-track future Net-Zero projects in their area.

## Primary use case

To understand how the problem statement can best be solved, a primary use case of 'green' electrolytic hydrogen in the north of Scotland was selected by stakeholders during the Discovery Phase. Green hydrogen is hydrogen produced by electrolysing water using renewable electricity, as opposed to other forms of hydrogen production, which use different source chemicals or energy sources.[14]

This primary use case was designed to make the problem specific and tangible, allowing for the selection of relevant datasets and more targeted research to better address the core problem statement.

The selection of electrolytic hydrogen in the north of Scotland was a powerful use case for the following reasons:

- In the north of Scotland, the electricity grid is severely constrained and there is an urgent need for localised high-demand electricity projects, such as electrolytic hydrogen, to use up an oversupply of electricity from renewables.
- In contrast to more mature and low-risk sectors, such as wind and solar renewables, the electrolytic hydrogen sector is relatively immature and high-risk, with unpredictable[15] demand for its end product. There is, therefore, a pressing

[14] National Grid Group, 2023a.

[15] For example, at the time of writing, it is unclear the extent to which green hydrogen will be used to heat UK homes (by supplementing or replacing natural gas) in the future.

need for innovative solutions that improve risk modelling and mitigation in this area.
- Electrolytic hydrogen projects are critically dependent on a diverse set of stakeholders to succeed - from Transmission Owners, gas and water companies to environmental agencies, local/national government and communities.

## Following Discovery

Since the end of the Discovery Phase in May 2023, a number of events occurred in the wider electricity industry that were relevant to REACT:

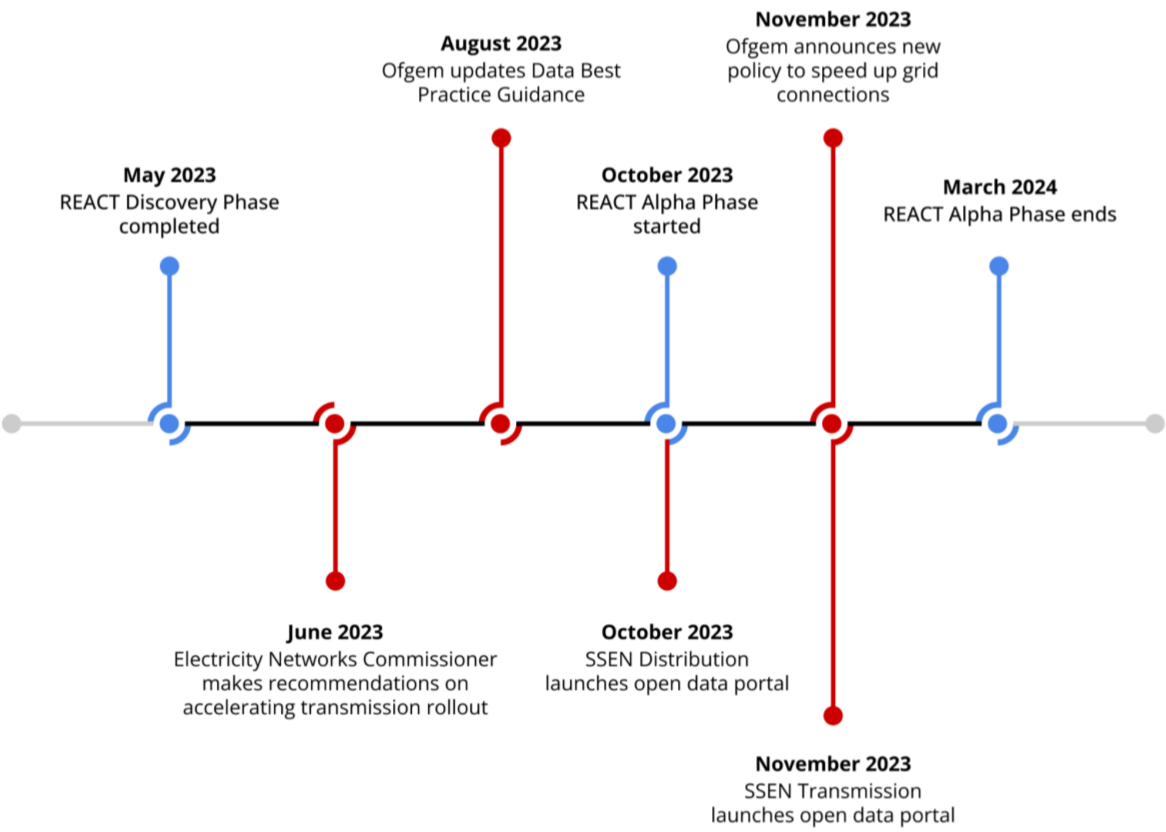



*Image source: Icebreaker One, 2024*

- **June 2023**: The [UK's Electricity Networks Commissioner makes recommendations on how to accelerate deployment of transmission infrastructure]
  In response to the Secretary of State for Energy Security and Net Zero's challenge to speed up transmission rollout, the Electricity Networks Commissioner made a number of recommendations. These included creating a 'Future System

Operator' and a 'Strategic Spatial Energy Plan' and finding ways to better engage communities affected by new infrastructure.

- **August 2023**: Ofgem updates Data Best Practice Guidance
  Ofgem's updated guidance provides clear 'open data triage' processes for network data managers to follow to assess the data sensitivity of datasets prior to publishing them as open or shared data.
- **October 2023**: SSEN Distribution launches its open-data portal with Icebreaker One data sensitivity/assurance classifications
  SSEN Distribution's new data portal is the first open-data portal to include Icebreaker One's data sensitivity/assurance classifications alongside datasets as a way of improving trust in data.
- **November 2023**: Ofgem announces new policy to speed up electricity grid connections
  Ofgem's new policy addresses one of REACT's key Discovery recommendations (see Appendix A: Discovery Phase recommendations).
- **November 2023**: SSEN Transmission launches open-data portal
  SSEN Transmission's new data portal provides many datasets directly relevant to REACT. The portal also provides access to the 'open data triage' process documents used to assess data sensitivity before publishing datasets.

## Alpha Phase - overview

### Purpose

The Alpha Phase of the project began in October 2023. The main aims of the Alpha Phase were twofold:

**To deepen analysis of the Discovery Phase work** – to better understand the core problem and the primary use case (green hydrogen in the north of Scotland). The ultimate goal of this aspect of Alpha was to produce practical recommendations that address the core problem statement and the primary use case.

**To anticipate possible future development of the REACT project** – so it can be easily extended to other use cases, which may include very different stakeholders, with the minimum friction and the maximum impact.

The Alpha Phase also reviewed the final report recommendations of the Discovery Phase. This review can be found in Appendix A: Discovery Phase recommendations.

## Research - deepening analysis and future developments

At the start of Alpha, the core problem statement was examined in detail. This analysis concluded that a probabilistic/statistical model of the likely success of any project is needed to fully take into consideration all projects in future planning (see Appendix B: Deep analysis of problem statement). To adequately address the core problem statement, therefore, Icebreaker One makes the following recommendation in this report:

**Recommendation - Improving prediction**

To improve long-term planning for Transmission Owners and for other stakeholders, a statistical model of projects **should** be embraced that tracks a project's estimated probability of success according to the best available data.[16]

To understand the key components of risk that affect a project's probability of success, further analysis was carried out on the green hydrogen primary use case (see Appendix C: Deep analysis of primary use case). This prompted a further recommendation:

**Recommendation - Embracing innovation**

To radically embrace innovation around processes, such as the Network Connection Request process, virtual 'sandbox' representations of these processes with representative data **should** be created. This will enable innovators to safely experiment with innovative solutions without affecting Business as Usual.[17]

Further work on data accessibility and interoperability during Alpha highlighted the crucial role of data governance and market-scale collaboration in improving data accessibility and interoperability. Alpha research consistently supported the finding that the problem statement cannot be addressed using technology alone (see Data accessibility and interoperability during Alpha).

This finding leads to two recommendations with a data governance focus:

**Recommendation - Embracing market-scale solutions**

[16] See Appendix B: Deep analysis of problem statement - How to embrace a holistic approach to planning.

[17] See Appendix C: Deep analysis of primary use case - Phase 2: Network connection request process.

To ensure REACT's solution has the widest possible applicability across the market, REACT's Advisory Groups **must** work closely with Open Energy's Steering Group to promote accessibility, agree common rules, processes and legal compliance and encourage a common rights-based approach to data access.[18]

[18] See Data accessibility and interoperability during Alpha - Interoperability.

**Recommendation - Reducing friction**

To improve data assurance, reduce friction across data silos and provide forward compatibility with the Virtual Energy System, the REACT project **must** embrace a 'Trust Framework' methodology throughout its work.[19]

Finally, the complicated nature of the network connection request process within Transmission Owners highlighted the crucial role of publishing process schematics *about* datasets, in addition to datasets themselves, to improve 'discoverability' and accessibility:

**Recommendation - Improving data accessibility**

To improve the discoverability of datasets and encourage process innovation, Transmission Owners **should** publish internal process diagrams that describe the workings of complicated internal processes - such as the Network Connection Request process.[20]

[19] See Data accessibility and interoperability during Alpha - Trust Frameworks.

[20] See Data accessibility and interoperability during Alpha - Discoverability.

# Data accessibility and interoperability - addressing the challenge

## Why data accessibility and interoperability matter

*Data analysts must use large numbers of datasets to model complex risk, but they are faced with a range of practical challenges when trying to do this at scale. To address these challenges requires improved data accessibility and interoperability.*

To model complex real-world systems effectively, risk-modelling and risk-mitigation tools rely on a wide range of datasets to capture key data points. Even with relatively linear[21] systems, e.g., planning policy, there can be a large range of datasets involved; REACT's Alpha research highlighted over 70 planning-related datasets that are potentially crucial to modelling risk in UK planning.[22]

A data analyst wishing to model or mitigate risk must, therefore, bring a wide range of datasets to bear to build a solution. This presents the first challenge:

> **Discoverability challenge:** How to find relevant datasets that can help model and/or mitigate risk?

To solve this challenge, datasets must be easy to 'discover' to begin with - so an analyst knows a relevant dataset exists *in principle*. The analyst can then formulate a solution, confident in the knowledge there is data available that could potentially help solve their problem.

Once an analyst has discovered the existence of relevant datasets, further details about the dataset will be needed: when it was last updated and how regularly; the quality of the data and trustworthiness of the data provider; and, whether it's openly published or not, i.e., typically, can it be freely downloaded. This presents a second challenge:

> **Metadata challenge**: Does the necessary information *about* the dataset, i.e., its 'metadata', exist so the analyst can make an informed decision on whether or not to use the dataset?

Whether or not a dataset is openly published is typically the most important consideration at this point, as it affects how easily the dataset can subsequently be accessed. This information is closely related to the 'data sensitivity' of the underlying core data, i.e., whether it contains personal, commercial or safety-critical information

[21] 'Linear' here is in contrast to complex nonlinear systems, such as weather systems or stock markets.

[22] Icebreaker One, 2023a.

requiring limits on publication. Metadata information describing the extent to which a dataset is openly published is, therefore, provided by the dataset's 'data sensitivity class'.[23]

Closely related to this metadata challenge is finding clear and unambiguous information about *how* the dataset may be used legally, for example, whether it can be reused in a commercial product or can only be used in internal research. This presents a third challenge:

> **Data-licensing challenge**: What are the legal restrictions governing how the dataset may be used? Are these restrictions clearly and unambiguously stated in a widely used data licence? Or are additional legal resources required to interpret how the dataset may legitimately be used?

A dataset's 'data licence' should ideally provide clear and unambiguous information about how the dataset can be legally employed. Using a widely recognised data licence, e.g., Creative Commons, helps ensure minimal additional legal resources are required before the dataset can be used.

Regardless of the data analyst's position - whether academic researcher or public- or private-sector employee - it is vital they understand the legal implications of using the intended dataset before deciding on whether or not to still use it. Assuming the analyst still wants to employ the dataset in their project, they are presented with a fourth and final challenge:

> **Data-access challenge:** How easily can the dataset be accessed in order to start using it? If a dataset is not freely available - perhaps for security or commercial reasons - what processes are in place to efficiently enable access?

Improving **data accessibility** is about improving the discoverability of datasets, publishing clear and reliable metadata around the datasets, providing clear and unambiguous data licences and enabling effective access to these datasets, whether they are openly published or not. Improving data accessibility maximises the scope for data solutions providers to create innovative risk-modelling or risk-mitigation solutions that depend on a large number of datasets.

In addition, improving **data interoperability** helps streamline the data pipeline for data analysts and increases the potential impact of innovative solutions. This is especially true as solutions are scaled up geographically.

[23] Data sensitivity classes broadly range from 'open' (*IB1-O*) and 'shared' (*IB1-SA*, *IB1-SB*, *IB1-SP*) to 'closed' (*IB1-C*). See Icebreaker One, 2023b.

A data analyst modelling risk, for example, may spend considerable time and effort implementing data pipelines for a large number of datasets for a specific region. As the geographical coverage of the solution is extended, additional time will be needed to deal with the lack of data interoperability across organisations in different geographical areas - whether the different countries of the United Kingdom or the different licence areas of Transmission Owners or Distribution Network Operators.

Improving data interoperability across organisations in different geographical areas, therefore, reduces friction in data processing as solutions are scaled up, maximising the potential impact of effective risk-modelling or risk-mitigating solutions.

Similarly, improving data interoperability across organisations in *different sectors* maximises the potential for applying a solution to radically different use cases or stakeholders. Improving the data interoperability of the outputs of a risk-modelling/mitigation solution also makes it easier to integrate the solution into existing processes and tools, thus increasing the scope for market-scale application and collaboration.

## Data accessibility and interoperability during Alpha

*During Alpha, Icebreaker One researched and attempted to address the different aspects of data accessibility and interoperability relating to REACT. This led to a number of recommendations, including the use of a 'Trust Framework' approach.*

During REACT's Alpha Phase, Icebreaker One improved data accessibility and interoperability for the project in the following ways:

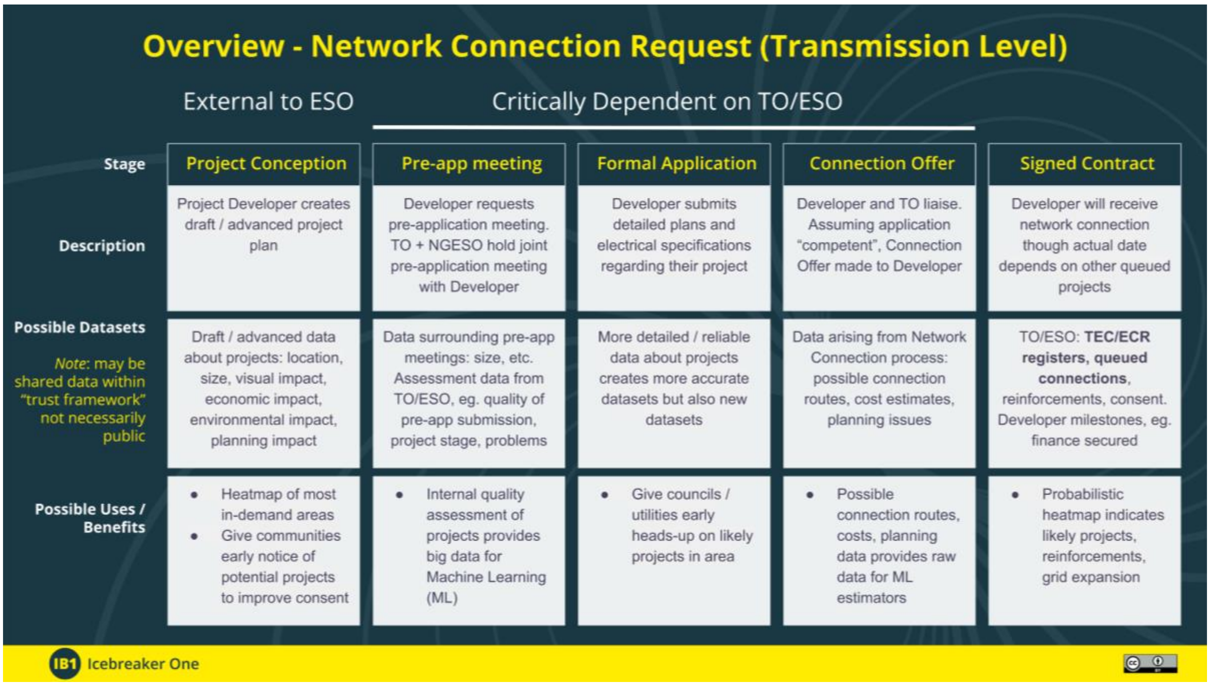
### Discoverability

**Open-data catalogue**: To improve the discoverability of data sources used in the project, all open-data sources used in the tool were added to Icebreaker One's OpenNetZero open-data catalogue (see REACT-tagged OpenNetZero.org datasets). This catalogue contains over 50,000 global datasets from 400+ organisations and provides an open-standards CKAN/DCAT data catalogue that can be easily integrated with open-standards geographical visualisation tools, such as QGIS.[24]

**Connection request datasets**: Icebreaker One obtained detailed internal diagrams from SSEN Transmission describing the complex range of datasets involved in the network connection request process. An overview of these connection process datasets

[24] e.g., https://extensions.ckan.org/extension/qgis-ckan-browser/

was presented to stakeholders (see image below) during a REACT Advisory Group meeting[25] as a way of proactively promoting dataset discoverability and encouraging innovative thinking around possible applications of datasets.




**Network Connection Request process diagram presented during REACT Advisory Group**
Shows possible datasets created prior to and during the Network Connection Request pipeline of a Transmission Owner; created using information from ESO Connections Offers Process
*Image source: Icebreaker One, 2024*

The complicated nature of the network connection process and the datasets involved in it, however, presents a challenge: how can data analysts make data requests if internal processes are so complicated it is unclear which *kind* of datasets exist in the first place?

To improve the discoverability of datasets, internal process schematics of complicated internal processes should be published to help developers understand the range of datasets involved in these processes. The need to improve the discoverability of datasets involved in complex processes informs the following recommendation:

**Recommendation - Improving data accessibility**

To improve the discoverability of datasets and encourage process innovation, Transmission Owners **should** publish internal process diagrams that describe the

[25] Icebreaker One, 2024a; all Advisory Group minutes are published on Icebreaker One's website, subject to the Chatham House rule.

workings of complicated internal processes - such as the Network Connection Request process.

In addition, as mentioned above (see Alpha Phase - overview and also Appendix C: Deep analysis of primary use case - Phase 2: Network connection request process), this report also recommends that virtual 'sandboxes' of complicated processes, like the network connection request process, be created. Using representative, rather than live data, these would give innovators maximum scope to explore and test out innovative solutions; the use of non-sensitive, representative data helps circumvent data sensitivity issues and avoids interrupting Business as Usual.

## Metadata and data licensing

**Data sensitivity classes**: A dataset's 'data sensitivity class' metadata field describes how sensitive the data in the dataset is, e.g., whether it contains personally or commercially sensitive information.[26] This will, in turn, determine how widely the dataset can be shared with others without violating legal, statutory or other obligations.

Before publishing any data, whether openly or through an access-controlled system, organisations must follow an 'open data triage' process to determine the data sensitivity class of the dataset.

During the Alpha Phase of REACT, Icebreaker One reviewed Ofgem's latest data best practice guidance,[27] which outlines guidance on how to conduct an open data triage process. Icebreaker One also analysed the number of energy companies implementing Ofgem's guidance, including publishing their processes and results as open data. We found at least four organisations - including project partner SSEN Transmission - who openly publish their open data triage process for many datasets.[28]

To encourage best practice around data sensitivity classes, Icebreaker One gave a presentation on data sensitivity classes to stakeholders during REACT's inaugural Advisory Group meeting.[29] Icebreaker One also supported SSEN Transmission in testing the open data triage process on two REACT-specific datasets: a substation-capacity dataset and a selection of internal process diagrams relating to the network connection request process. This process highlighted the need for granular distinctions within

[26] For a simple diagram of the data 'spectrum' of energy data, see Icebreaker One, 2020.

[27] Ofgem, 2023b.

[28] Icebreaker One, 2024b.

[29] Icebreaker One, 2023c.

'shared' data, which is reflected in Icebreaker One's different 'shared' data sensitivity classes (IB1-SA, IB1-SB or IB1-SP - see Icebreaker One, 2023b).

It should be noted, that while much of the data used in the REACT tool during Alpha was open data, there are safety-critical datasets, such as SGN data relating to underground pipe infrastructure, that are of potential benefit to the project. While these datasets are unlikely to receive an 'open' (IB1-O) or 'public' (equivalent to IB1-SA) data sensitivity classification, they could still receive a 'shared' (IB1-SB or IB1-SP) classification allowing them to be used in the project.

During Alpha, therefore, Icebreaker One supported SGN in applying the open data triage process to a network infrastructure dataset of potential relevance to REACT. This process concluded that the data sensitivity class for the dataset was 'shared' (most likely IB1-SB or IB1-SP), rather than 'open' (IB1-O). 'Trust Frameworks', described below, provide an efficient way of enabling access to such non-open shared data.

**Data Assurance**: During Alpha, Icebreaker One informally compared open infrastructure data with 'assured' infrastructure data provided by electricity companies. This revealed potential gaps in open data that points to a need for more assured data and the use of Assurance Levels[30] within REACT. Further research is required to quantify the extent to which improved data assurance could benefit REACT.

**Data licensing**: During Alpha, Icebreaker One presented key information about data licensing to stakeholders at REACT's inaugural Advisory Group meeting.[31] Icebreaker One also encouraged project partners to openly publish clear licence metadata for all the datasets used within the project; for a list of datasets used in Alpha with licensing information, see MapStand et al., 2024.

## Enabling effective access

**Streamlining the process for new datasets**: Before organisations can publish new datasets, they must carry out an open data triage process to determine the dataset's data sensitivity class. Streamlining the open data triage process speeds up the publication of new datasets, reducing the time from when an external data analyst requests a new dataset to when the data is published.

During Alpha, Icebreaker One surveyed existing open data triage processes, both as recommended by Ofgem and as practised by organisations who have published their data triage processes. This revealed an encouraging uniformity of process, with one

[30] For examples of assurance level metadata fields, see SSEN Distribution's open data portal.

[31] Icebreaker One, 2023c.

energy company turning Ofgem's guidance into a step-by-step document template and other companies copying this template and crediting the source.[32]

To help project partners streamline their open data triage processes, Icebreaker One highlighted [Ofgem's latest data best practice guidance] to them and provided examples of the step-by-step open data triage template extensively copied across the energy sector.

**Enabling access to shared data**: As mentioned above, there are some safety-critical datasets of potential benefit to REACT that cannot be published openly. Trust Frameworks, described below, provide an efficient way of enabling access to this kind of non-open shared data.

## Interoperability

**Data going into REACT**: During Alpha, Icebreaker One discovered inconsistencies across some of the area-specific electricity datasets relevant to REACT. For example, area-specific GIS asset data, e.g., 11kV overhead lines, often had different naming conventions for different companies. In some cases, asset information provided as separate files by one company was subsumed into larger datasets (for example, *all overhead lines*) by other organisations.

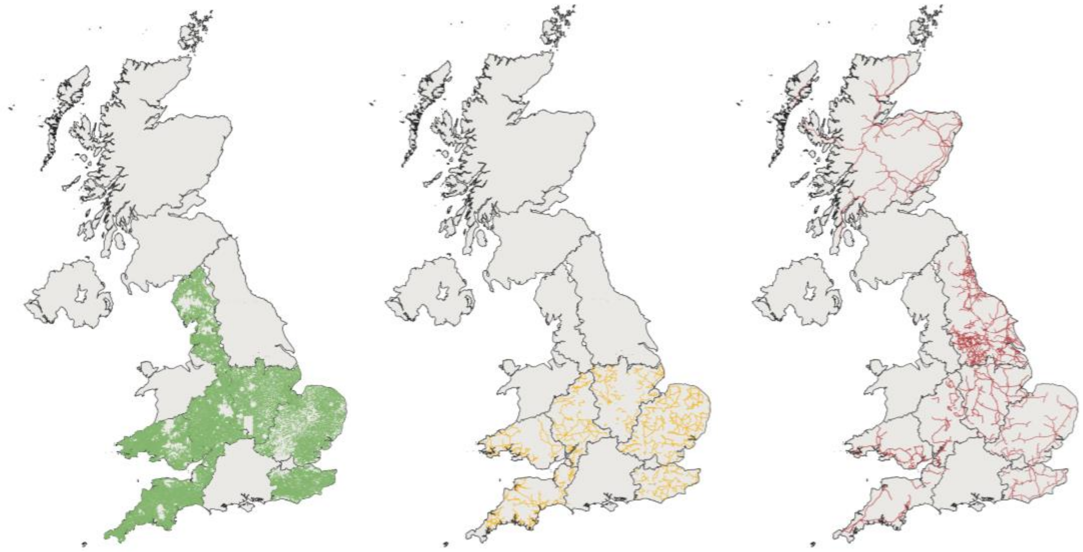
While such inconsistencies may be trivial to work around individually, risk-based solutions use a large number of datasets across a wide area - which magnifies the effort required when creating bespoke data pipelines for many geographical areas.

Lack of consistency across equivalent datasets also makes it harder for one organisation to copy the open data triage process of another organisation's dataset. If *Dataset A* has even slightly different fields to *Dataset B*, this may create new data sensitivity issues.

Icebreaker One also discovered gaps in open-data provision across electricity companies, with some companies failing to openly publish crucial datasets that are provided by others.[33] This was particularly the case with the infrastructure data relevant to REACT. The images below show gaps in open-data coverage for infrastructure data for UK Transmission Owners and Distribution Network Operators.

[32] This represents a '*Follow First*' approach, where one company takes the lead in producing an output and other companies follow by explicitly copying/crediting this, rather than recreating their own version.

[33] Ofgem's 'Presumed Open' policy seems to require that if one company publishes a specific dataset as open data, the reasonable justification for other companies *not* to do the same thing are considerably reduced. This is especially true if the former openly publishes its data triage process (hence '*open* data triage') justifying why it can openly publish a particular dataset.



**Open infrastructure data across the UK**
Electricity company open data showing 11kV (*left*), 33/66kV (*middle*) and 132kV (*right*) overhead power lines. *Image source: Icebreaker One, 2024 using multiple data sources*[34].

To address interoperability issues during Alpha, Icebreaker One proposed an informal meeting of Transmission Owners' open-data managers to resolve data inconsistency issues. It was, unfortunately, not possible to complete this process, due to lack of time within Alpha. Such meetings could nevertheless help to improve the interoperability of electricity network data and should be pursued in future iterations of the project.

During Alpha, however, Icebreaker One noted encouraging work by electricity companies in copying best practice templates (see Enabling effective access, above). This suggests one possible way to improve data interoperability as follows: a ***Follow First*** principle could be promoted by Ofgem that encourages electricity companies to closely *follow* what other companies are doing *first* - in terms of datasets' naming conventions, data composition and data fields - before creating their own different, non-interoperable versions of datasets.

More generally, the REACT project should work closely with existing initiatives, specifically Open Energy, that aim for market-scale solutions through better interoperability of energy data. This leads to the following recommendation:

[34] Electricity North West data copyright of Electricity North West Ltd under CC BY 4.0 licence; NGED data supported by NGED Open Data under NGED Open Data Licence; Northern Powergrid data copyright Northern Powergrid (licence unspecified); SSEN Transmission data copyright SSEN Transmission under CC BY 4.0 licence; UK Power Networks data copyright UK Power Networks under CC BY 4.0 licence.

**Recommendation - Embracing market-scale solutions**

To ensure REACT's solution has the widest possible applicability across the market, REACT's Advisory Groups **must** work closely with Open Energy's Steering Group to promote accessibility, agree common rules, processes and legal compliance and encourage a common rights-based approach to data access.

**Data coming out of REACT**: There are significant benefits to closer integration of the REACT tool with stakeholders' existing geographic information systems (GIS), particularly for local authorities striving to achieve Net Zero. Closer integration with councils' planning systems could enable a more collaborative and joined-up approach to Net-Zero planning - it could help derisk planning consent for Net-Zero developers and help councils collaborate with Transmission Owners to make more strategic decisions regarding Net-Zero projects.[35]

A meeting with a council-related organisation, however, revealed[36] that resource- and time-poor council staff are unlikely to have extra time to use completely different GIS systems from the ones currently in use; this is likely to be true for other stakeholders too. Neglecting the interoperability of REACT's data outputs risks creating a solution that adds to the workload, rather than assists with it.

For this reason, during Alpha, Icebreaker One highlighted the importance of 'data out' interoperability during a REACT Advisory Group meeting.[37] Icebreaker One also researched existing GIS systems currently in use (see Appendix E: Geographic information systems) to better understand scope for improving interoperability of data coming out of REACT.

More generally, future versions of REACT should embrace data interoperability of the data coming out of the tool, just as much as data interoperability of the data going into it. This will ensure REACT has maximum impact across the entire market for a diverse range of stakeholders.

[35] The idea of local authorities collaborating with Transmission Owners to deliver transmission infrastructure was suggested during a REACT Advisory Group meeting.

[36] Icebreaker One meeting with Improvement Service, 23rd January 2024.

[37] Icebreaker One, 2024a.

## Trust Frameworks - the key to REACT's success

> *A Trust Framework approach provides a scalable, robust and market-proven solution to addressing many of REACT's data accessibility and interoperability challenges.*

To work effectively, the REACT tool requires granular data from a wide variety of stakeholders - electricity companies, water companies, gas companies, councils and financial institutions. Work during Alpha also highlighted the crucial role of shared data, such as gas infrastructure data, in delivering a successful tool.

This is true for REACT's primary use case - green hydrogen in the north of Scotland - and for other potential use cases; even if a project does not require gas infrastructure data, other non-open shared data will be required to model risk. With regard to REACT's core problem statement, any solution must help Transmission Owners model risk for *all* high-demand projects.

An efficient solution must, therefore, radically improve data accessibility and interoperability at market scale and also deal with non-open shared data effectively. Trust Frameworks offer such a solution.

Trust Frameworks are specifically designed to minimise friction at every stage of the value chain and have a proven track record of doing this in the financial sector through Open Banking.[38] They are a core component of a *Data Sharing Infrastructure*[39] that enables data to flow at local, national and international scales.

Trust Frameworks achieve this by implementing and automating the adoption of rules for data providers, aggregators and users. They enable assurable data to flow between organisations at a peer-to-peer level by verifying that organisations and their data sharing are compliant with the rules.

Key elements of a Trust Framework are:

**Frictionless discovery of open and shared data:** All data is described by standard metadata and indexed in the open.

**Access control for sharing data between organisations:** Access conditions are published openly. Access controls use proven technology widely used in Open Banking.

**Agreed definitions and rules:** The Trust Framework agrees definitions and rules for licensing terms, data access and data sensitivity.

[38] e.g., NatWest Group, 2024.

[39] See "Designing our Data Sharing Infrastructure" in Icebreaker One, 2024c.

**Assurance-backed trust:** Trust is guaranteed through independently verified assurance levels that apply to data and organisations.

**Effective governance**: A key element of any Trust Framework is the establishment of effective governance processes that support policy and regulatory oversight. This typically works through the establishment of an overall Steering Group and more specific Advisory Groups focused on legal, technical and other aspects.

> *A Trust Framework provides a set of unifying standards, policies and mechanisms for shared data interchange between all the organisations in the Framework. A known, agreed Framework speeds innovation, reduces costs and de-risks investment.*

A Trust Framework approach offers a proven process for achieving market-scale accessibility and interoperability of data and a robust and secure way of dealing with non-open, shared data. It should, therefore, be embraced in future iterations of the REACT project to ensure the project has maximum impact.

A Trust Framework methodology is currently being adopted within the 'Virtual Energy System' programme whose goal is to "enable the creation of an ecosystem of connected digital twins of the entire energy system of Great Britain" (Virtual Energy System, 2023, p3). To ensure the future interoperability of REACT with the Virtual Energy System, the REACT project should also embrace a Trust Framework approach.

To ensure the REACT project has maximum impact and is forward compatible with the Virtual Energy System, Icebreaker One makes the following recommendation:

**Recommendation - Reducing friction**

To improve data assurance, reduce friction across data silos and provide forward compatibility with the Virtual Energy System, the REACT project **must** embrace a 'Trust Framework' methodology throughout its work.

# Broadening REACT - future challenges

## Introduction

*The focus of REACT's Alpha Phase was on the primary use case of green hydrogen in the north of Scotland. But there are significant opportunities to extend REACT to other geographical areas and other use cases.*

During REACT's Alpha Phase, the primary use case of green hydrogen in the north of Scotland was analysed in detail to determine key risk factors involved in these projects. During Alpha, however, Icebreaker One also considered how REACT could be extended to other UK regions and other use cases, as this is crucial to unlocking REACT's strategic potential for UK economy-wide decarbonisation.

**Other regions**: Icebreaker One reviewed datasets from a range of electricity companies to understand interoperability issues that might arise as REACT is extended to other regions. These areas might be other Transmission Owners' licence areas or the licence areas of Distribution Network Operators. Where possible, Icebreaker One aimed for UK-wide coverage of REACT-relevant datasets that were indexed in OpenNetZero.org, as this data catalogue could help streamline data acquisition as REACT is scaled up.

**Other high-demand use cases**: The REACT tool could potentially be extended to other high-demand use cases, including: battery storage; pumped-storage hydroelectricity; industrial demand, e.g., electric arc furnaces for steelmaking[40] and electric kilns for cement production[41]; data centres[42]; and, carbon capture and storage (CCS).[43]

**Other use cases**: The primary use case represents a high-demand electricity project of most interest to Transmission Owners. There may, however, be smaller demand or supply projects that Distribution Network Operators deal with that could benefit from REACT. A holistic approach to risk modelling also demands that all projects, regardless of size, are considered when making predictions about the future state of the electricity network.

[40] For further information, see Waldram, 2023.

[41] For further information, see Bizley, 2023.

[42] For further information, see Bryan, 2024.

[43] For further information, see National Grid Group, 2023b.

## How to broaden REACT

*Improving data accessibility and interoperability, including embracing an open data catalogue, would maximise scope for REACT to be extended to other geographical areas and other use cases with minimum friction.*

During Alpha, the focus of the REACT project was on the primary use case of green hydrogen in the north of Scotland. REACT can, however, be extended to other regions beyond the north of Scotland and other use cases beyond green hydrogen. We shall consider each in turn.

### Other regions

To extend REACT geographically, with minimum friction, improved data interoperability is key (see Data accessibility and interoperability during Alpha - Interoperability). The methods and processes that should be used to improve data interoperability are described above (see Data accessibility and interoperability during Alpha).

### Other use cases

To broaden REACT to other use cases, a process of **use case analysis** should be applied. This process engages relevant stakeholders to determine which specific use cases should be prioritised to address a problem statement. The process consists of the following stages:

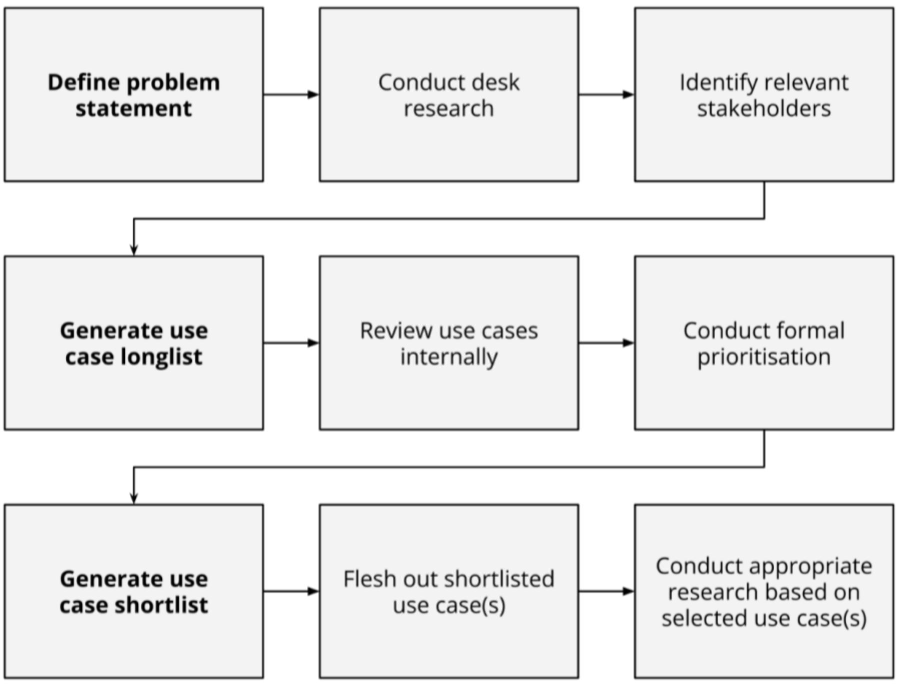



*Image source: Icebreaker One, 2024*

For a detailed explanation of use case analysis, see Appendix F: Use case analysis.

For REACT, the problem statement and primary use case were decided during the Discovery Phase and are well defined. To decide which use cases REACT should focus on in the future, during the Alpha Phase of REACT stakeholders were asked to identify use cases during a REACT Advisory Group meeting.[44] This revealed the need to focus on use cases involving a diverse range of stakeholders, including water companies/regulators and environmental agencies. Further work is required to refine and prioritise these use cases.

In addition to stakeholder-selected use cases, there are similar use cases to the primary use case (green hydrogen in the north of Scotland) where REACT potentially offers quick wins, i.e., relatively small amounts of effort are required to address these use cases. Achieving these quick wins could provide an efficient way of addressing more of the problem statement.

These similar use cases are high-demand electricity projects, for example, battery storage; pumped-storage hydroelectricity; industrial demand; data centres; and, CCS.

Many of the datasets used for the primary use case of green hydrogen can be applied to these other use cases with little change:

**Electricity network**: Datasets about substation capacity and connection queues and geographic information about the location of high-voltage wires and substations are relevant to every high-demand electricity project. In addition, connection request data and tools that leverage data to streamline connections, e.g., new connection cost estimators,[45] will speed up the connection process for all high-demand projects.

**Electricity curtailment**: During Alpha, the REACT tool included location-specific data on 'curtailed electricity', i.e., electricity (typically from renewables) that is discarded because the electricity network cannot transport it.[46] Data on curtailed electricity is relevant to battery storage, pumped-storage hydroelectricity and CCS, all of which may depend on curtailment costs for their business models to operate.

[44] See Icebreaker One, 2024d.

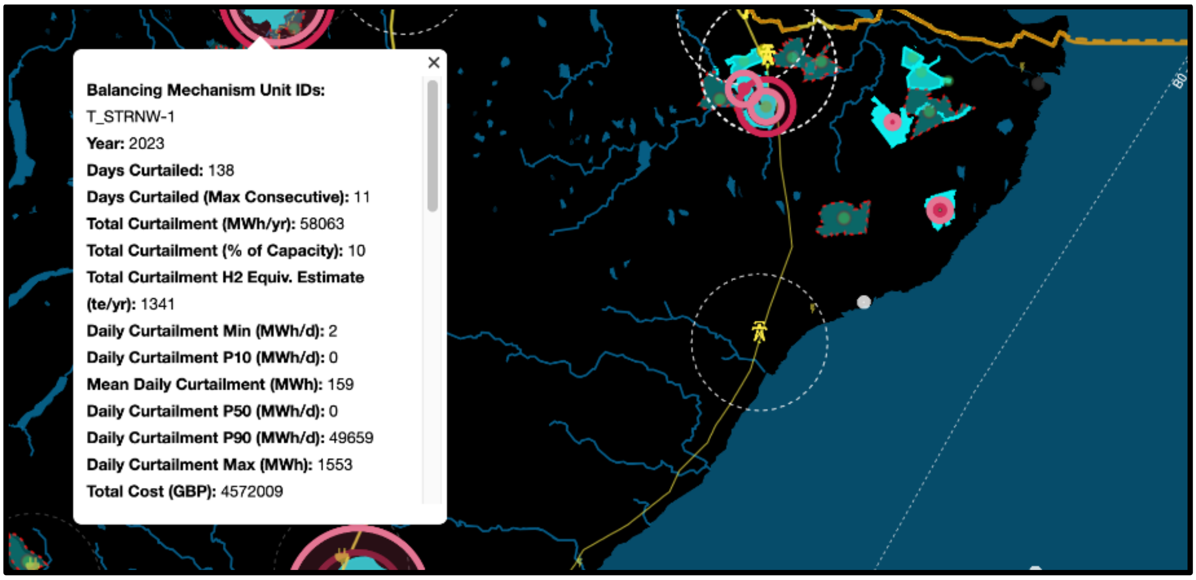
[45] e.g., National Grid Electricity Transmission"s ConnectNow application.

[46] This is particularly a problem in the north of Scotland during windy days when the transmission network cannot transport excess power from wind farms - see Thomas-Peter, 2023.

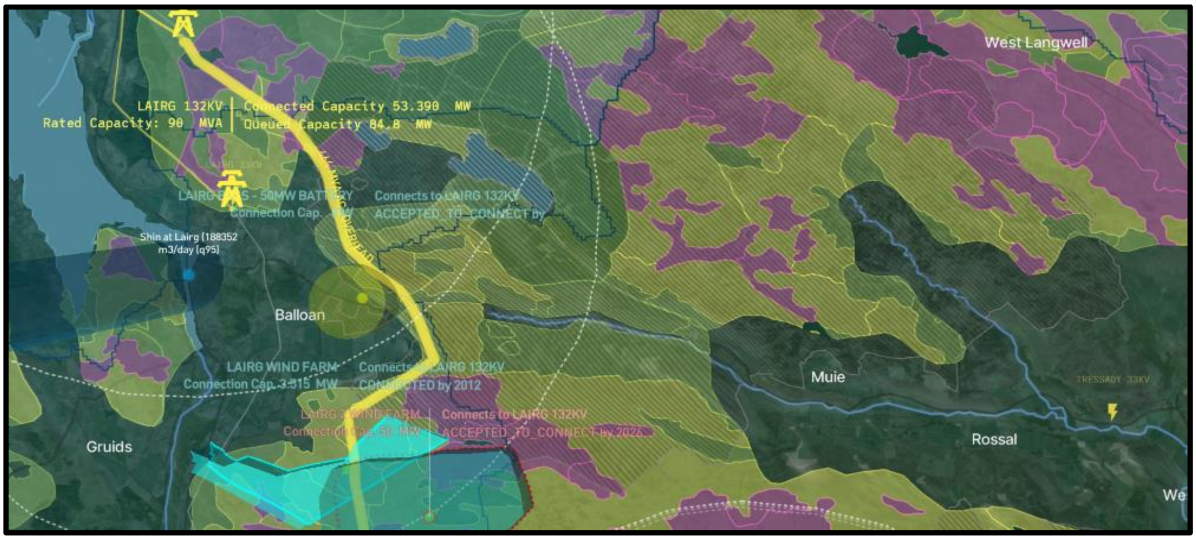
**Water data**: Water data, e.g., water catchment areas and river flow rates, is crucial to hydrogen site selection and the siting of pumped-storage hydroelectricity.[47]

**Planning / safety data**: Much of the planning constraint data relevant to green hydrogen, e.g., GIS data for Sites of Special Scientific Interest (SSSIs), is relevant to any construction use case. In addition, local authority designations for industrial use and local/national strategic plans setting out priority industrial sites are relevant to green hydrogen and other industrial, high-demand projects. Safety constraint data is also relevant to green hydrogen and heavy industry projects.

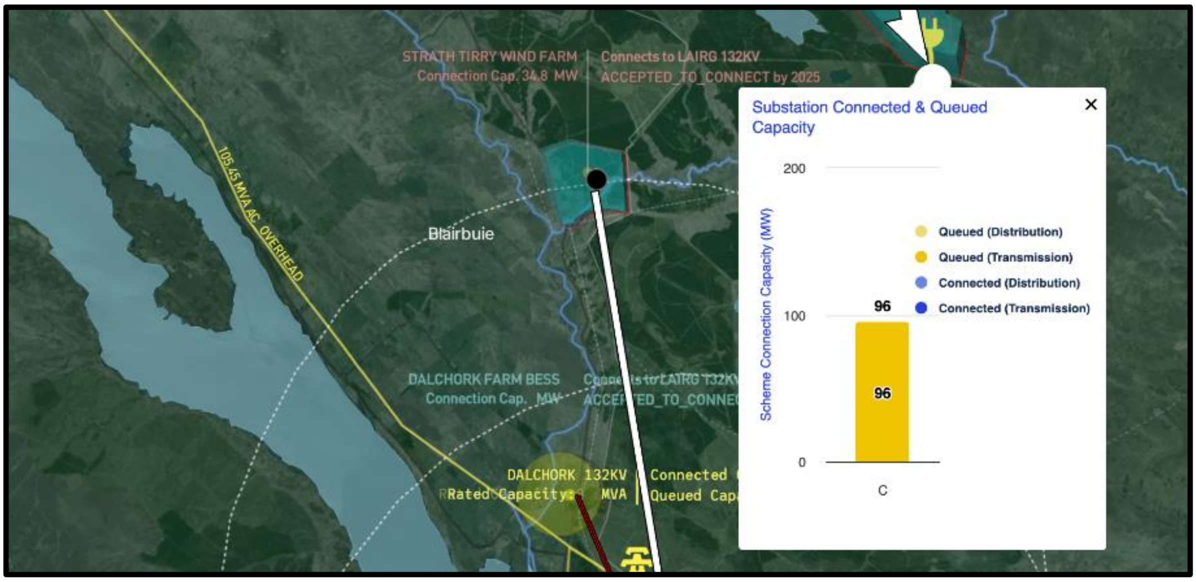
**Public consent**: Datasets tracking public support for projects and related electricity network upgrades are relevant to every high-demand project, as they may affect whether the project is likely to go ahead.




[47] How water data is used in site selection for pumped-storage hydroelectricity may differ from green hydrogen. For further information about water-related siting requirements for pumped-storage hydroelectricity, see [Renewables First, 2024].




**REACT screenshots showing different data layers within the tool**
Curtailment data (*top*) and land use (*bottom*)




**REACT screenshots showing different data layers within the tool (continued)**
Substation queues

There is sufficient commonality between the primary use case (green hydrogen) and other high-demand use cases to justify exploring ways to support these other use cases. The commonality of data across these use cases is significant, so any solution should place data at the heart of its approach.

One practical way for REACT to achieve this is to use a DCAT-compliant open data catalogue - like Icebreaker One's OpenNetZero.org - to collate the large number of datasets that are involved. This would serve as a searchable index of datasets, holding information *about* the datasets, e.g., their licences and when the dataset was last updated, rather than storing the actual data.

A DCAT-compliant open data catalogue would help track dataset updates for existing datasets used by REACT, fast track the acquisition of new datasets for new use cases[48] and provide effective management of data licensing. While the management of existing datasets and licences and the acquisition of new datasets can be manually handled for a small number of datasets, this is not a scalable approach when dealing with large numbers of datasets.

An open data catalogue provides a unique opportunity to address multiple use cases efficiently. The use of 'tags' or 'groups' within the data catalogue would make it possible to collate useful **dataset collections,**[49] particularly collections of energy datasets, that can be easily applied to multiple use cases. For example, a 'UK overhead power lines' tag that includes datasets from multiple Transmission Owners (TOs) and Distribution Network Operators (DNOs) would allow REACT to be easily extended to DNOs, just as much as TOs.

The existence of high-quality, curated, open dataset collections in OpenNetZero.org also helps share the data curation expertise of the project with the widest possible audience. For this reason, during Alpha, Icebreaker One began the process of creating a 'REACT Data Collection', in OpenNetZero.org, of all datasets used in REACT (see REACT-tagged OpenNetZero.org datasets).

An open data catalogue is a key component of the Trust Framework methodology, described earlier.[50] To minimise friction and achieve market scale, it is vital data accessibility and interoperability are radically improved, which can best be achieved through a Trust Framework approach.[51]

## Use cases with complex 'connection pipelines'

REACT's core approach - of collating diverse datasets to mitigate risk around complex connection processes - could be applied to radically different use cases and stakeholders with their own complex 'connection pipelines'. These include:

> **Utility companies**: Other utility companies with time-consuming connection processes could benefit from a REACT approach to mitigating risk around these processes. Water companies, for example, may face increasing pressure to connect more 'high-storage'[52] water projects, such as new reservoirs, whether for pumped-storage hydroelectricity or to deal with increased water scarcity due to

[48] OpenNetZero.org indexes datasets from a large number of other open data catalogues.

[49] SSEN Distribution's CKAN open data portal uses 'groups' to manage collections of datasets.

[50] See Why data accessibility and interoperability matter.

[51] See Data accessibility and interoperability during Alpha - Trust Frameworks.

[52] 'High-storage', here, echoes the high-demand focus of electricity Transmission Owners.

climate change. They may face similar challenges to those faced by Transmission Owners, in terms of increased connection queues and (often unpredictable) public opposition to new infrastructure.

**Local and national planning bodies**: From a project developer's perspective, the planning-approval pipeline represents a complex, time-consuming[53] and mission-critical process that has elements in common with the network connection request process:

- Developers are frustrated with the uncertainty and delay inherent in the planning process.[54] They may seek pre-application meetings with planners to gather crucial information before submitting formal planning applications.
- Developers must deal with resource-poor[55] local or national planners under increasing pressure to deliver Net Zero. A growing number of Net-Zero projects leads to increased backlogs and 'planning queues.'
- Public consent / public consultation is often a critical factor in the process pipeline - even if local authorities are better placed to understand and manage public consent issues.

There is, therefore, scope to apply a REACT approach to mitigating planning risk and streamlining the planning process more generally.

**Finance**: As with a grid connection, a 'connection to finance' is a critical milestone in any electricity project. Yet, the financial connection process is potentially similar to the network connection process, in terms of complexity and duration. A REACT approach could be used to streamline the 'financial connection' to project capital, helping unlock the significant investment needed for Net Zero.

Improving risk modelling for these different sectors would help REACT improve its own risk modelling for the primary use case of green hydrogen, reliant as it is on water, gas, finance, council planning and public consent. This would create a virtuous circle, where the expansion in REACT's secondary use cases leads to steady improvements in addressing REACT's primary use case.

[53] "Overall, participants' most significant concerns with the wider planning process in the UK were the level of complexity (and therefore the time and resources required to prepare and navigate the process), and the significant resource constraints in examining bodies and other statutory consultees." (Department for Energy Security & Net Zero, 2023b, p. 4).

[54] "Participants consistently viewed the planning process for hydrogen projects as slow and unpredictable" (op.cit., p. 30).

[55] "... the significant resource constraints in examining bodies and other statutory consultees." (op. cit., p. 4).

## Conclusion

During REACT's Alpha Phase, diverse and granular data was found to be crucial to addressing REACT's problem statement in order to estimate the **probabilities needed for modelling risk** in the network connection process[56] (Recommendation 4: Improving prediction). The primary use case of green hydrogen in the north of Scotland also highlighted the **need for a diverse range of data** to address this use case.[57]

To access the wide range of datasets required, **data accessibility issues must be addressed.**[58] Some required datasets have data sensitivity classifications that go beyond conventional 'open data'.[59] The complex nature of the network connection request process also highlighted the need to publish internal process diagrams to improve data accessibility[60] (Recommendation 3: Improving data accessibility). The creation of a virtual 'sandbox' representation of this process is recommended as a result of the complexity of the process[61] (Recommendation 5: Embracing innovation).

In addition to improving data accessibility, there is a need for **greater data interoperability**, especially of data coming out of REACT, to ensure it helps, rather than hinders, existing workflows.[62] Considering the primary use case alone, a **Trust Framework is required to address data accessibility and interoperability** (Recommendation 2: Reducing friction).

Alongside the primary use case of green hydrogen, there are **similar high-demand or high-risk use cases** where REACT could quickly add value, e.g., battery storage, pumped-storage hydroelectricity and hard-to-abate heavy industries.[63] There are also **sectors with complex 'connection-like' pipelines,** similar to the network connection process, who could benefit from REACT's approach to modelling complex risk.[64]

Embracing a Trust Framework approach would **help REACT expand to these other use cases efficiently and geographically scale up.**[65] A Trust Framework approach also ensures REACT benefits from existing electricity data initiatives, such as Open Energy

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56 See Appendix B: Deep analysis of problem statement.

57 See Appendix C: Deep analysis of primary use case.

58 See Data accessibility and interoperability - addressing the challenge.

59 See Data accessibility and interoperability during Alpha - Metadata and data licensing.

60 See Data accessibility and interoperability during Alpha - Discoverability.

61 See Appendix C: Deep analysis of primary use case - Phase 2: Network connection request process.

62 See Data accessibility and interoperability during Alpha - Interoperability.

63 See Broadening REACT - future challenges - Other use cases.

64 See Broadening REACT - future challenges - Use cases with complex 'connection pipelines'.

65 See Data accessibility and interoperability during Alpha - Trust Frameworks.

and the Virtual Energy System (Recommendation 1: Embracing market-scale solutions and Recommendation 2: Reducing friction).

# Recommendations

### 1. Embracing market-scale solutions

To ensure REACT's solution has the widest possible applicability across the market, REACT's Advisory Groups **must** work closely with Open Energy's Steering Group to promote accessibility, agree common rules, processes and legal compliance and encourage a common rights-based approach to data access.[66]

### 2. Reducing friction

To improve data assurance, reduce friction across data silos and provide forward compatibility with the Virtual Energy System, the REACT project **must** embrace a 'Trust Framework' methodology throughout its work.[67]

### 3. Improving data accessibility

To improve the discoverability of datasets and encourage process innovation, Transmission Owners **should** publish internal process diagrams that describe the workings of complicated internal processes - such as the Network Connection Request process.[68]

### 4. Improving prediction

To improve long-term planning for Transmission Owners and for other stakeholders, a statistical model of projects **should** be embraced that tracks a project's estimated probability of success according to the best available data.[69]

### 5. Embracing innovation

To radically embrace innovation around processes, such as the Network Connection Request process, virtual 'sandbox' representations of these processes with

[66] See Data accessibility and interoperability during Alpha - Interoperability.

[67] See Data accessibility and interoperability during Alpha - Trust Frameworks.

[68] See Data accessibility and interoperability during Alpha - Discoverability.

[69] See Appendix B: Deep analysis of problem statement - How to embrace a holistic approach to planning.

representative data **should** be created. This will enable innovators to safely experiment with innovative solutions without affecting Business as Usual.[70]

[70] See Appendix C: Deep analysis of primary use case - Phase 2: Network connection request process.

# Appendix A: Discovery Phase recommendations

| Recommendation | Status |
|---|---|
| **Friction recommendation 1**: *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.* | In progress |
| **Friction recommendation 2**: *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.* | In progress |
| **Friction recommendation 3**: *Stakeholders must monitor and analyse the cumulative effect of power generation and demand developments on public opinion.* | In progress |
| **Friction recommendation 4**: *NGESO [National Grid Electricity System Operator] and the Transmission Owner must decongest connection application backlogs, which could happen through a 'use it or lose it' policy.* | Complete |
| **Friction recommendation 5**: *The REACT project must align with SSEN Transmission's existing data automation project, the Data Action Plan 2022-2026.* | In progress |
| **Innovation recommendation 1**: *Stakeholders could make a reduction in constraint costs an organisational key performance indicator (KPI).* | In progress |
| **Innovation recommendation 2**: *Stakeholders must create a digital twin of the power system with existing data, rather than waiting for the perfect data to become available.* | In progress |
| **Innovation recommendation 3**: *A new information and visualisation tool should support decision making at a local community level.* | In progress |

| | |
|---|---|
| **Innovation recommendation 4**: *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.* | Complete |
| **Innovation recommendation 5**: *Partners in the project must increase visibility and shareability of the datasets relevant to the project under appropriate open or shared licences.* | In progress |

REACT's Discovery Phase produced a number of recommendations, listed above. At the start of the Alpha Phase, these recommendations were reviewed, both to check their continued relevance and to ensure they properly informed subsequent Alpha Phase research.

During the Alpha Phase the following tasks were carried out in response to Discovery's recommendations:

**Friction recommendation 1:** Network substation capacity data and other datasets relevant to the primary use case of electrolytic hydrogen, e.g., water data, were integrated within the REACT tool.

**Friction recommendation 2**: Icebreaker One obtained internal process schematics from SSEN Transmission indicating discoverable datasets involved in the network connection request process. Icebreaker One also supported SSEN Transmission in conducting dry runs of the open data triage process for datasets relevant to REACT.

**Friction recommendation 3**: Project partners connected with the community energy sector and local authorities with a view to better engaging with local communities. The possibility of making a public-facing version of the REACT tool was also explored.

**Friction recommendation 4**: Media monitoring by Icebreaker One revealed that Ofgem had implemented new policies to clear 'zombie projects'[71] from the connection queue.

**Friction recommendation 5**: Icebreaker One obtained SSEN Transmission's internal documentation outlining the future direction of SSEN Transmission's Data Action Plan. This helped the project team anticipate future developments and avoid potential duplication of effort.

**Innovation recommendation 1**: The project team explored ways to integrate and visualise network constraint data within the REACT tool.

[71] Ofgem, 2023a.

**Innovation recommendation 2**: The project team used a combination of trusted electricity network data and crowdsourced open data to create a digital twin of the power system.

**Innovation recommendation 3**: Project partners connected with the community energy sector and local authorities with a view to better engaging with local communities. The possibility of making a public-facing version of the REACT tool was also explored.

**Innovation recommendation 4**: During the Alpha Phase, project partners directly engaged with NGESO and sectors outside of energy, including hydrogen developers, water companies, the Scottish Environment Protection Agency (SEPA) and local authorities. Invaluable multi-stakeholder feedback was also received through Icebreaker One's REACT Advisory Group meetings.

**Innovation recommendation 5**: All open data used within REACT was indexed on Icebreaker One's OpenNetZero.org data catalogue. Icebreaker One also explored ways to publish SSEN Transmission's internal process schematics to improve the discoverability of data.

# Appendix B: Deep analysis of problem statement

## Introduction

For the Alpha Phase of REACT, the problem statement for the project was defined as follows:

> *"Currently, the process for reviewing connection requests is carried out in isolation, i.e., other potential developments are not considered, so there is little time to explore solutions that are optimal for the network.*
>
> *"The current system only provides a static view of the potential network impact a connection will have; however, this view changes each time a new project is contracted, making it difficult to assess the long-term cumulative impact each request has on the grid.*
>
> *"The existing connections process is complicated, with large numbers of, sometimes unrealistic, requests clogging the system, undermining the strategic aims."* (Problem statement as articulated by SSEN Transmission).

This problem statement makes specific reference to "the process for reviewing connection requests," so it is helpful to put this process into the wider context of the project lifecycle for an energy-related construction project.

A typical energy-related construction project requiring a grid connection will consist of three overlapping phases:

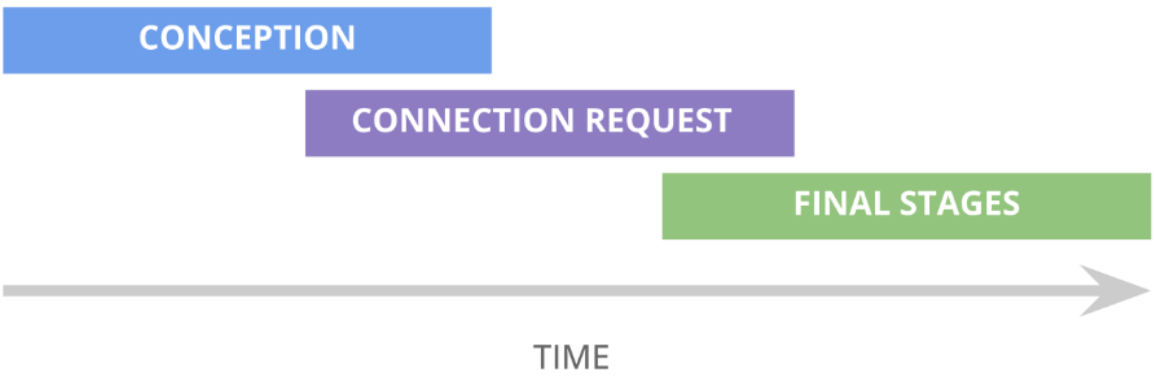


*Image source: Icebreaker One, 2024*

**Phase 1 - Project conception**

During this phase, the initial concept for the project is developed, including site selection and financial feasibility; this may involve advanced feasibility studies at considerable cost. The exact location of the project may be heavily dependent on available capacity within specific substations and likely connection dates to these substations, information which is often obtained from electricity networks at the start of the network connection request phase.

**Phase 2 - Network connection request**

During this phase, project developers typically have at least one pre-application meeting with the electricity networks to determine estimated connection dates and cost to connect to specific substations. In certain circumstances, the project developer may radically revise the site location or the scope of the project to better match what the electricity networks can provide, or for financial or timing reasons.

Once a substation selection has been agreed with the electricity networks, a project developer submits a formal Network Connection Request application to the electricity networks. Assuming this application passes specific technical criteria, a Connection Agreement Offer is then made by the electricity networks, completing this 'network connection request' phase of the project lifecycle.

**Phase 3 - Final stages**

Before a project developer receives a formal Network Connection Agreement Offer from the electricity networks (which determines whether or not the developer is guaranteed a grid connection at some point in the future) work may begin on other aspects of the project.

This may include conducting detailed site surveys, achieving the necessary safety compliance for the project plans from environmental and safety bodies and investigating whether or not appropriate planning permission will be granted. Securing a Final Investment Decision (FID), however, is unlikely to occur before a Network Connection Agreement has been signed with the electricity networks.

Once a project has been connected to the electricity network and is up and running, the 'final stages' phase of the project is complete. It is worth noting, however, that there are a significant number of projects that receive a Network Connection Agreement Offer that do not go into construction, e.g., the developer may fail to secure the necessary planning consent or investment after receiving a connection offer.

## Multiple projects at different stages

At any point in time, a number of projects may be considering making a grid connection request, may be in the process of making such a request or may have signed a Network Connection Agreement and are waiting to be connected. A typical situation might look like this:

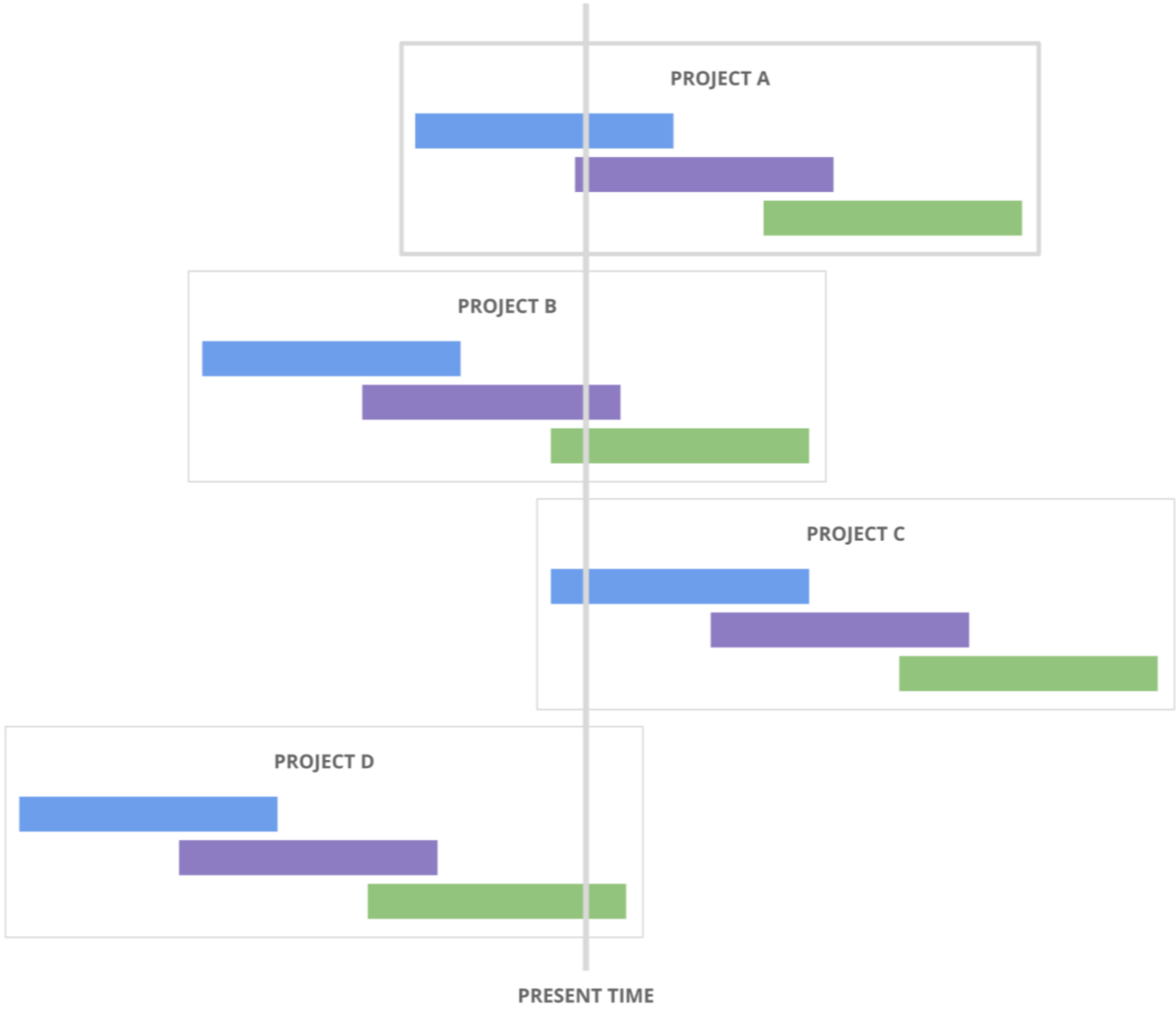


*Image source: Icebreaker One, 2024*

In the diagram above, **Project A** is in the process of making pre-application enquiries with the electricity network, **Project B** is close to receiving a Network Connection Agreement Offer, **Project C** is in the early stages of project conception and **Project D** has signed a Network Connection Agreement and is waiting to be connected.

It is worthwhile revisiting the REACT problem statement with reference to the diagram above:

> *"Currently, the process for reviewing connection requests is carried out in isolation, i.e., other potential developments are not considered, so there is little time to explore solutions that are optimal for the network.*
>
> *"The current system only provides a static view of the potential network impact a connection will have; however, this view changes each time a new project is contracted, making it difficult to assess the long-term cumulative impact each request has on the grid.*

*"The existing connections process is complicated, with large numbers of, sometimes unrealistic, requests clogging the system, undermining the strategic aims."* (Problem statement as articulated by SSEN Transmission).

Interpreting the problem statement with regard to example projects **A** to **D**, above, would suggest the following:

> When **Project A** is being evaluated, **Project B** and **Project C** - which are yet to sign a Network Connection Agreement - would not be considered in terms of overall network planning.

Such a scenario can be represented by the following diagram, where **Project B** and **Project C** are greyed out:

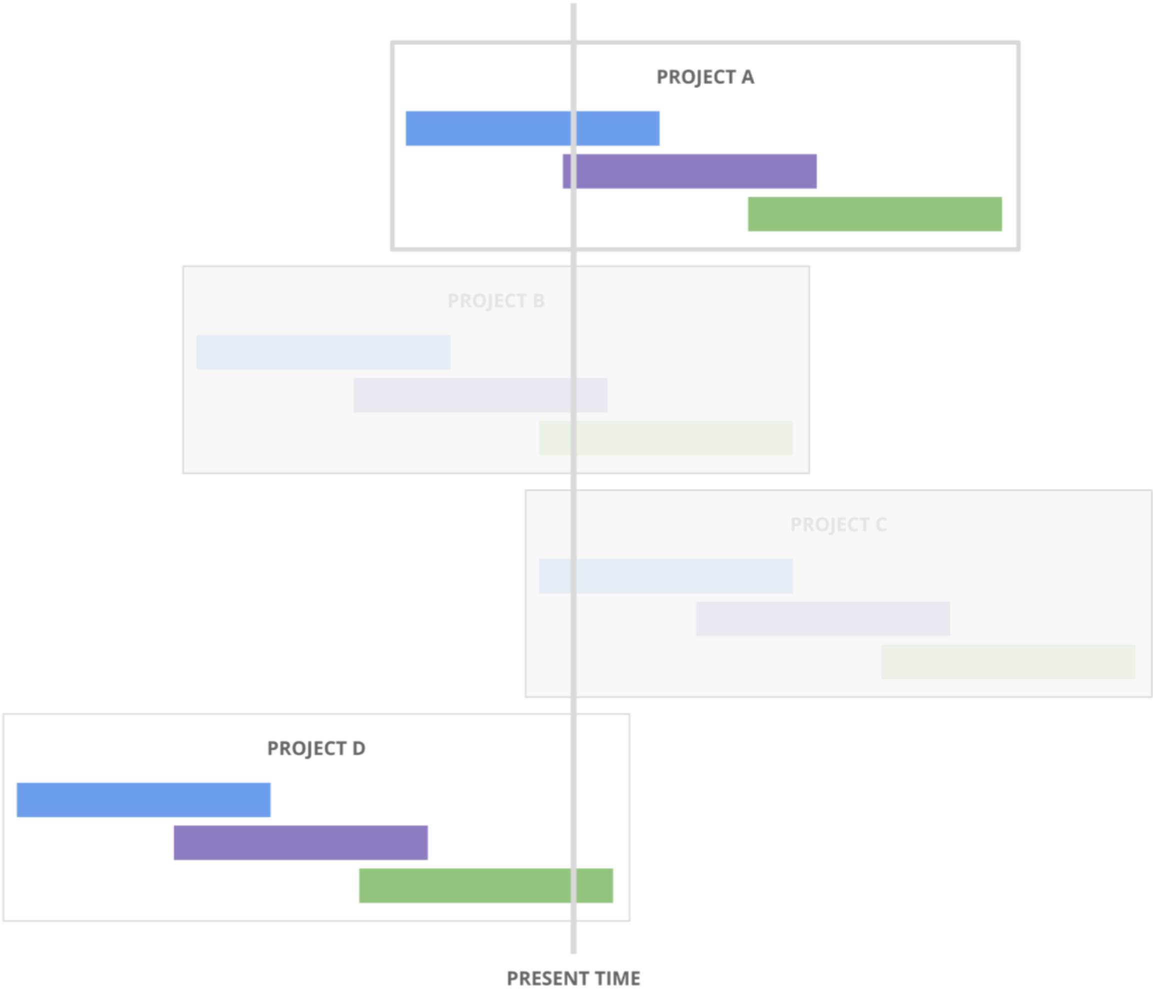


*Image source: Icebreaker One, 2024*

However, there is a possibility **Project B** and **Project C** may be hoping to connect to the same substation as **Project A** and their cumulative impact may require considerable network upgrades. There is also the possibility that **Project D**, which *has* signed a Network Connection Agreement, could be an exceptionally high-risk project that is destined to fail. There is, therefore, a risk that giving it greater importance than early stage **Projects A** and **B** - which could be ‘safe bets’ that will easily achieve a Network Connection Request Offer - could distort long-term network planning.

Moreover, **Project A** and **Project B**’s sudden change in influence in network planning when their status moves from ‘pre-contracted’ to ‘contracted’ represents a problematic *discontinuity* for long-term planners. The view for long-term planners “changes each time a new project is contracted, making it difficult to assess the long-term cumulative impact [of] each request” (from *Problem statement as articulated by SSEN Transmission*).

A more ‘holistic’ approach that considers all projects, regardless of their position in the project lifecycle, would lead to better and more cost-effective strategic decisions for Transmission Owners. It might become clear, for example, that major upgrades to a substation are needed to support multiple low-risk projects ‘coming down the pipe,’ as opposed to upgrading the substation piecemeal after each individual project signs a Network Connection Agreement contract.

## How to embrace a holistic approach to planning

How might a more holistic approach to network planning be achieved? The biggest barrier to future planning for Transmission Owners is the uncertainty inherent in even the most low-risk projects. This situation is exacerbated for the primary use case of electrolytic hydrogen, which represents a higher risk electricity project compared to more mature sectors, such as wind and solar.

Managing this uncertainty is, however, partially mitigated through the use of the Network Connection Request process. This lengthy process helps filter out potentially weaker projects that are higher risk due to their inherent weakness.

Nevertheless, an implicit assumption with the current process is that once a project has signed a Connection Agreement, the project is likely to proceed. On this assumption, the list of contracted projects published in the *Transmission Entry Capacity Register* (or *TEC Register*) can be viewed as a reliable estimate of the likely future state of projects and their associated impact on the network (in terms of the future supply/demand of electricity and the future electricity infrastructure that will be constructed for these projects).

There are, however, a number of problems with this approach:

1. **Blurs risk**: It doesn’t distinguish high-risk projects, such as hydrogen production, from low- or medium-risk projects, such as wind farms or battery storage. Given a large number of low-risk projects connecting to *Substation A* versus the same number of high-risk projects connecting to *Substation B*, it is plausible network planners would want to prioritise upgrades to *Substation A* over *Substation B* - as

there's a greater chance some kind of *Substation A* upgrade will be required in the future.

2. **Ignores crucial information**: The current approach leaves out crucial information about projects that have yet to sign a Connection Agreement contract. A high-impact low-risk project, for example, could be hours away from a signed connection agreement and would be ignored. There could also be 'strength in numbers', i.e., a large number of similar high-risk projects would mean the probability of at least one of them happening is high. To ignore high-risk projects per se - whether due to them being at an early stage or because they are inherently high-risk - is to discount a potentially significant contributor to the future state of the network.
3. **Incorrectly ascribes certainty or similar probabilities to uncertain events**: Even if a project developer signs a Connection Agreement with a Transmission Owner, there is no guarantee the project will go ahead, if, for example, the project fails to secure funding or planning consent. At the very least, modelling the future state of the network based on signed Connection Agreements is to assume all post-agreement projects have a similar probability of proceeding, i.e., it blurs risk.
4. **Potentially introduces delay into decision making**: Reliance on the network connection process to achieve reasonable certainty of outcome may introduce an arbitrary delay when attempting to make future network predictions. For example, if all substations have queued connections until the end of 2029, there may be a tendency to wait until the 2030 queue fills before making predictions about 2030 - on the assumption the existence of a signed contract is the safest indicator of actual certainty.
5. **Reasonable certainty does not suit long-term prediction**: To make increasingly longer-term predictions about the future state of the network requires greater precision about the probability of each project going ahead.
6. **Succeed-fast/fail-fast has limited applicability**: A succeed-fast/fail-fast approach can mitigate uncertainty by quickly removing projects that are 'doomed to fail', e.g., removing badly sited projects early using planning constraint data, rather than waiting for planning rejection later on. This is less applicable, however, to more complex projects where the probability of success or failure slowly evolves over time.

A **probabilistic model of projects**, where projects are ascribed an objective, evidence-based probability they will succeed, is needed to solve many of these problems. Objective, evidence-based probabilities provide the most reliable indication of the future based on the best available evidence and are a tried and trusted methodology for other sectors dealing with variable risk over the long term, e.g., finance and medicine.

By applying objective, evidence-based probabilities to projects and then weighting projects according to their likelihood of occurring, it is possible to generate statistical estimates for the future state of the world. For example, it would be possible to prioritise substation upgrades by weighting connections according to projects' different success probabilities:

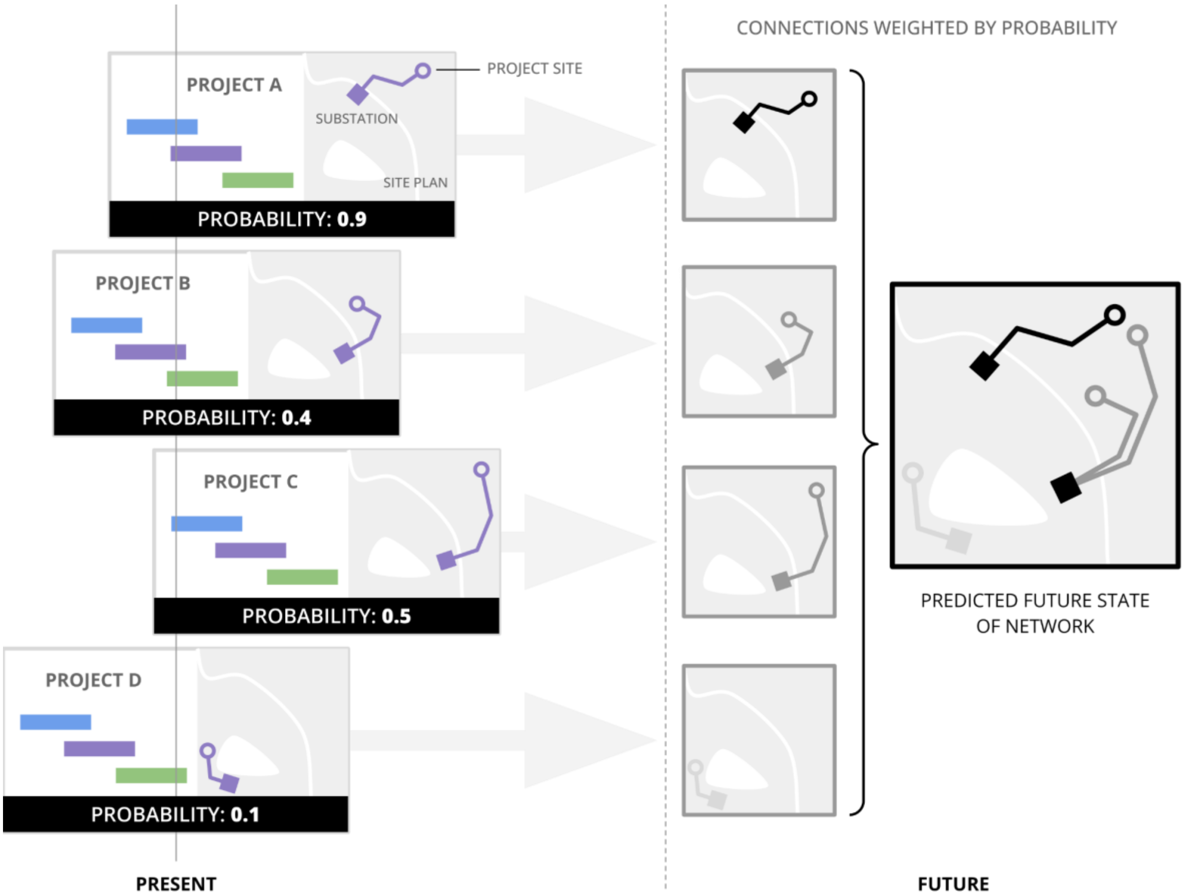


*Image source: Icebreaker One, 2024*

This probabilistic future state, whether for the next day or the next decade, would then fully reflect *all* projects - from early-stage projects, which may not necessarily have a low probability of succeeding, to advanced projects about to be connected (which may also not be guaranteed to succeed).

As more information about projects becomes available, probability estimates for the projects would alter dynamically - and ideally continuously. Failure to secure first-round investment within a certain timeframe, for example, would partially reduce a project's probability of going ahead.

Where there is a risk of sudden and unexpected events radically shifting a project's probability, these would be factored into the 'error bars' for the probability estimate. For example, projects that avoid early public engagement risk a sudden public backlash, which would drastically alter probabilities in a volatile way. Such projects would, therefore, have correspondingly large error bars.

In contrast to the 'reasonable certainty' approach currently employed, a probabilistic approach, which tracks a project's likely success as it moves through its lifecycle, would provide strategic planners with a more reliable guide to the future state of the network, thus enabling more accurate long-term planning. It would also mitigate some of the discontinuity ("view changes each time a new project is contracted", ibid.) that exists in the current system. It would help:

- Transmission Owners exploring options for current projects during the network connection request process.
- Transmission Owners attempting to predict the future state of the network, with regards to planning possible transmission upgrades.
- Other stakeholders, such as water companies and local authorities, who must make critical and costly strategic decisions about the future based on the best available evidence.

A probabilistic approach would also address key elements of the original problem statement:

- To properly consider other potential developments during the network connection process, their objective probability of succeeding should be factored in to ensure their influence is weighted according to the likelihood they will occur.
- To better explore solutions that are optimal for the network, it is vital to have the most accurate picture of the likely future state of the network. This requires a probabilistic approach that is dynamically updated as soon as new information becomes available.
- Probabilistic weighting provides a way to accurately assess the "long-term cumulative impact" (ibid.) of multiple grid requests. It should be noted, however, that safety compliance may require the cumulative impact of even low-probability projects to be taken into account *as if they are certain*, to ensure maximum resilience of the network.

This report, therefore, recommends the following:

**Recommendation - Improving prediction**

To improve long-term planning for Transmission Owners and for other stakeholders, a statistical model of projects **should** be embraced that tracks a project's estimated probability of success according to the best available data.

# Methods for estimating objective, evidence-based probabilities

To achieve ever more precise probability estimates of a project's likelihood of success requires data from a diverse range of stakeholders. However, it is still possible to achieve less precise probabilities, i.e., probabilities with larger error bars, using more limited or readily available data.

Proven techniques for estimating objective, evidence-based probabilities range from simple estimates using small datasets to more sophisticated systems employing 'big' data. As methods become more sophisticated, the precision of the probability estimate improves, i.e., the error bars are reduced.

The following diagram illustrates the range of techniques, from simple estimates on the left, to sophisticated, deep-modelling techniques on the right:

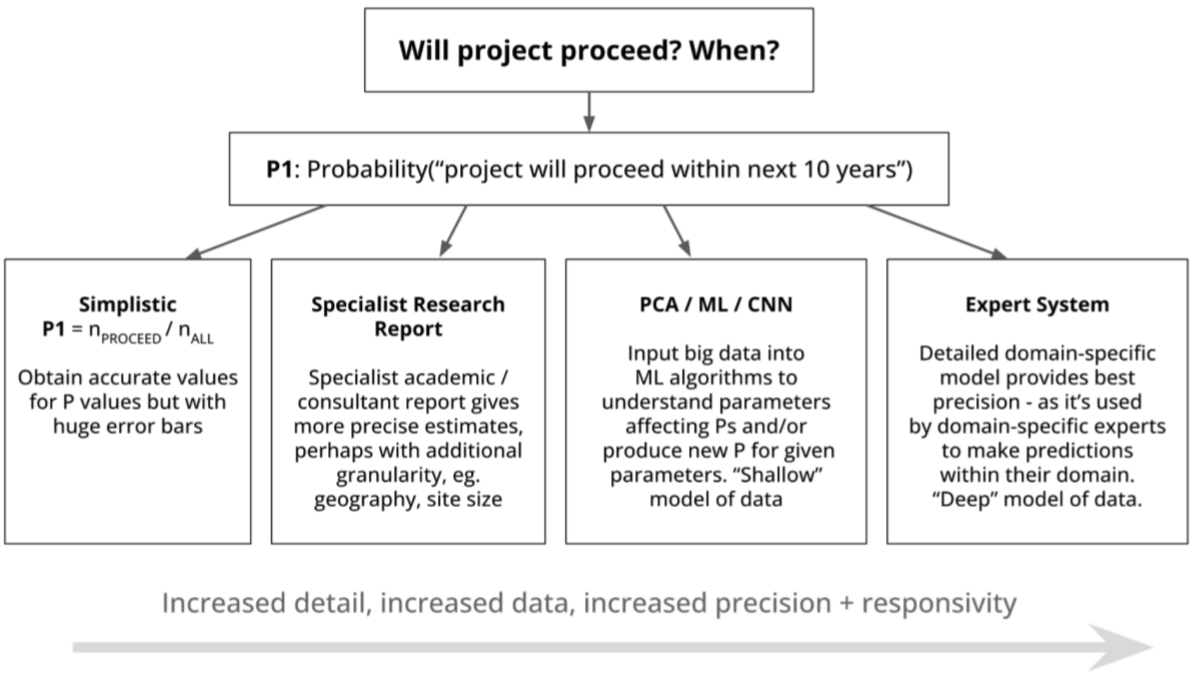


*Image source: Icebreaker One, 2024*

**Simple approach**: A very (and potentially too) simplistic approach to estimating probabilities of success would involve counting successful projects and then dividing by the total number of projects. This is, however, likely to lead to large error bars on the probability estimate and takes no account of key parameters differentiating projects.

**Specialist research report**: A specialist research report, ideally peer-reviewed in an academic journal, would consider multiple parameters and employ robust statistical techniques before making probability estimates.

**Advanced data analytics**: Machine Learning (ML) techniques, e.g., Principal Component Analysis (PCA) or Convolutional Neural Networks (CNN), operating on large datasets can rapidly analyse and model many more parameters than a traditional human data analyst. This would allow for more precise probability estimates, especially when used as data processing tools by experienced data analysts.

**Highly advanced 'expert systems'**: An 'expert system' might attempt to model the uncertainty resulting from a particular process, e.g., planning consent, by duplicating the technical systems involved in that process. While this assumes any human input into the process is relatively minor, it is sometimes good organisational practice to remove human-specific variability in decision-making.

Advanced expert systems that closely replicate *what actually happens* are likely to produce probability estimates with the smallest error bars. Improving risk modelling in this way is a side effect of one of this report's key recommendations - to create a digital twin 'sandbox' of the network connection request process (see Deep investigation of primary use case - Phase 2: Network connection request process).

A more detailed discussion about probability sampling and probability estimates is unfortunately beyond the scope of this report. However, it is worth noting in conclusion:

- More precise probability estimates require larger amounts of diverse data, which in turn requires improved data accessibility and interoperability.
- New machine learning techniques for analysing 'big' data have rapidly evolved in recent years.
- Probability sampling and probability estimates are a well-understood area of statistics with a substantial body of literature and well-established methodologies.

# Appendix C: Deep analysis of primary use case

Transmission Owners will deal with a wide range of projects requiring a connection to their networks, so it is helpful to focus on specific use cases to understand some of the detail involved in project lifecycles.

During REACT's Discovery Phase, the primary use case of green electrolytic hydrogen production in the north of Scotland was selected; hydrogen production is 'green' if it uses renewable electricity to produce hydrogen from water by electrolysis.

A deep investigation into the project lifecycle of electrolytic hydrogen projects was carried out during REACT's Alpha Phase to understand key risk factors and how they can be better modelled using relevant datasets. This included desk research reviewing project timelines and interviews with hydrogen developers and related stakeholders, e.g., local councils, water companies and environmental agencies.

The risk elements and related datasets of green hydrogen projects can be classified according to which phase of the project lifecycle they broadly relate to:

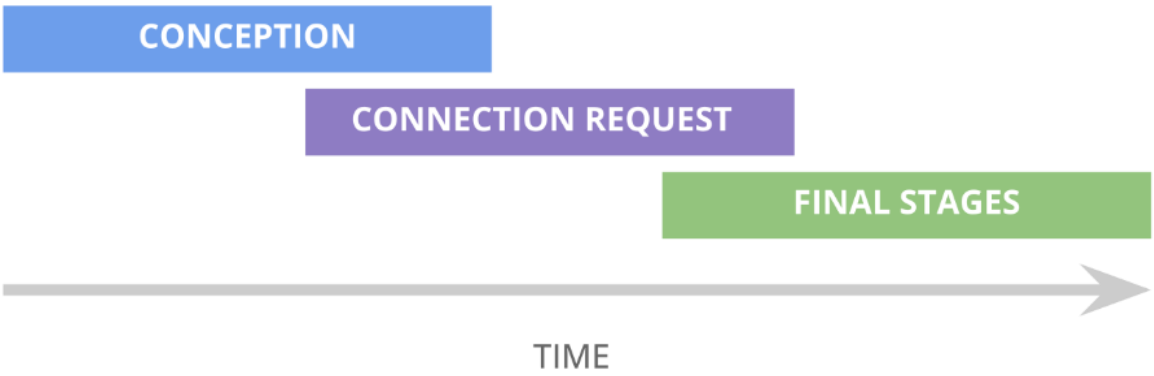


*Image source: Icebreaker One, 2024*

## Phase 1: Project conception

During the project conception phase, green hydrogen developers are concerned with selecting the optimal site for their projects, with increased risk being associated with non-optimal site selection. Based on research carried out during Discovery and Alpha Phases (see Appendix D: Research on hydrogen developers), key data for the optimal siting of green hydrogen projects include:

- **Electricity grid information**: Being close to an electricity grid connection point/substation with an early connection date. For projects intending to use 'constrained electricity', i.e., localised electricity generation that is wasted because the grid cannot transport it, it is crucial to know where this is likely to occur.

- **Water connection**: Being near to a supply of high-volume freshwater. Green hydrogen production requires at least 2.4 gallons of water for every kilogram of hydrogen produced.[72]
- **Hydrogen 'offtakers'**: Being near to hydrogen 'offtakers', i.e., consumers of the hydrogen, or pipe networks that can transport hydrogen to customers/consumers.
- **Planning constraints**: Ensuring any potential site satisfies relevant planning constraints, e.g., is not on a Site of Special Scientific Interest (SSSI) or Special Protection Area (SPA), to reduce the likelihood the project will not receive planning consent.

Openly available sources for some of this data were identified during REACT's Discovery Phase (see REACT Discovery Data Sources). During the Alpha Phase, additional open data sources focused on planning constraints[73] were located, together with open datasets from Icebreaker One's NIMBUS and Stream projects, which had collated weather and water datasets, respectively.[74] SSEN Transmission also developed a new dataset specifically for the REACT project that provided electricity network capacity information. During Alpha, all sourced datasets were, where possible, added to Icebreaker One's OpenNetZero.org data catalogue.[75]

The Alpha version of the REACT tool focused on this project conception phase of the green hydrogen project lifecycle. It brought together a diverse range of datasets from those listed above into a single accessible visualisation, from electricity grid capacity and constraint data to water data and planning constraints data.

The REACT tool attempts to *reduce* risk for hydrogen project developers by helping them identify better sites, i.e., sites more likely to succeed. But it also helps *model* risk for Transmission Owners who benefit from a deeper understanding of whether specific network request applications are likely to succeed, i.e., given a specific green hydrogen application, how does its site selection affect likely success?

[72] Lampert et al., 2015.

[73] These datasets were based on the Centre for Sustainable Energy's "Identifying suitable areas for onshore wind development" (Centre for Sustainable Energy, 2016). However many of the planning constraint datasets listed in this guide are relevant to any energy project.

[74] Icebreaker One's collaborative/co-working ethos helped supplement formal discoverability of datasets through data catalogues with informal 'human discoverability' through internal Show and Tell sessions.

[75] OpenNetZero.org is a DCAT-compliant open data catalogue with over 50,000 datasets from 400+ organisations globally.

## Phase 2: Network connection request process

During the network connection request process, a hydrogen developer initiates contact with the electricity network with the ultimate goal of connecting their project to the network.

However, due to the time it takes to construct connections, frequent long connection queues and the criticality of a connection to any project, the connection request process usually happens early on in any project. For the purposes of this discussion, therefore, the end of the network connection request process occurs when a developer signs a network connection contract, rather than when they are actually connected.

The network connection request process for hydrogen developers can be briefly summarised as follows:[76]

1. A hydrogen developer has at least one pre-application discussion with the electricity networks before submitting a formal application to connect.
2. Assuming the formal application passes a 'competency check,'[77] the electricity networks conduct a detailed technical and financial evaluation of the developer's application, before offering the developer a Connection Offer contract. This offer includes estimated costs and timelines to make the connection.
3. Once the developer signs this contract, they are guaranteed a connection to the network - though it is often impossible to guarantee exactly when this connection will occur.

Key risk factors during this phase that affect a green hydrogen project's success include:

- **Competency**: Will a project pass the network's 'competency check'?
- **Substation availability within practical timeframes**: Will it be possible to connect the project to the preferred substation within a timeframe that's practical for the project?
- **Cost**: Is the estimated cost to make the connection within the budget of the project?
- **Additional network infrastructure**: How much additional infrastructure will the electricity networks need to construct for the project, in terms of the direct connection between project and network and also any 'reinforcements' required within the wider network?

During REACT's Alpha Phase, Icebreaker One conducted a 'deep dive' into the connection request process to better understand some of these risks and explore ways

[76] The process as described here is an extreme simplification to focus on the risks involved. For a detailed description of the Network Connection Request Process, see National Grid ESO, 2024.

[77] 'Competency' in this context refers to specific technical checks that the network carries out on electrical details of the project, rather than any general evaluation of the competency or viability of a project.

of potentially mitigating them. Icebreaker One reviewed Discovery Phase interviews, conducted further interviews with SSEN Transmission staff and reviewed SSEN Transmission's detailed internal documentation describing the connection process.

SSEN Transmission's internal documentation was particularly informative, revealing the complicated range of datasets and processes involved in the connection process. Such a detailed knowledge of the 'inner workings' of the connection process could be potentially advantageous to developers, giving them scope to identify time-critical stages of the process and provide better data to minimise delays or improve outcomes. In this way, the sharing of process information - and not just datasets - could help derisk network requests for developers.

A more detailed understanding of the datasets involved in the connection process also pointed to a huge - and seemingly untapped - potential to apply Machine Learning on historical 'big data' datasets within the connection process. This could lead to radical improvements in process that mitigate risk in the following ways:

- **'Intelligent agents'**: Intelligent agents trained on big data could automatically flag up potential weaknesses in a developer's application, giving them ample opportunity to interactively improve (and so derisk) their proposal before making a formal network request application.
- **Improve probability assessments**: Machine Learning algorithms could automatically estimate the likely probability of projects going ahead, based on a comprehensive set of parameters, thus improving the precision of probability estimates and enabling better long-term forecasting (see Appendix B: Deep analysis of problem statement - Methods for estimating objective, evidence-based probabilities).

This is an area with huge potential for innovation - but also huge risks in terms of data sensitivity and security. However, a virtual 'sandbox'[78] representation of the connection process, populated with dummy data, would avoid many data sensitivity issues while providing maximum scope for external innovation around the network connection process. To encourage innovation around this process, Icebreaker One, therefore, recommends:

**Recommendation - Embracing innovation**

To radically embrace innovation around processes, such as the Network Connection Request process, virtual 'sandbox' representations of these processes

[78] The Deeside Centre for Innovation already exists as a physical 'sandbox' for safely testing physical innovation pertaining to the electricity network.

with representative data **should** be created. This will enable innovators to safely experiment with innovative solutions without affecting Business as Usual.

SSEN Transmission's internal documentation also provided key insights into the future direction of travel that might result from the organisation's Digital Strategy and Action Plan. One possible option being considered is for SSEN Transmission to embrace a 'Common Information Model' within the network request process. This creates the possibility of developers dynamically checking the 'competency' of their network requests in real-time, which would help derisk the connection process for developers.

With regard to substation capacity and likely connection dates, significant work was carried out during the Alpha Phase to model this within the REACT tool. Open data from the Transmission Entry Capacity Register and other sources, together with bespoke data created by SSEN Transmission for REACT, was used to create a visualisation of substation capacity and connection queues within the north of Scotland.

The REACT tool's accessible visualisation of substation capacity/queues could help hydrogen developers derisk network request applications by giving them substation capacity/queue information early on. In addition, automating the provision of information usually provided by network staff could help reduce staff workload, freeing up time for more strategic planning.

With regard to estimating connection costs, this area was not specifically explored during REACT's Alpha Phase due to an awareness of existing tools already providing this information, e.g., National Grid Electricity Transmission's 'ConnectNow' Research Assistant. The project team are, however, open to collaboration with these existing tools and this is an area that could be explored in future versions of REACT.

In terms of risks associated with additional network infrastructure, this represents an increasingly high-risk area, due to growing public opposition to infrastructure projects.[79] While there are proposals to address this issue directly, e.g., compensation payments to affected communities,[80] tracking and predicting public opposition to infrastructure projects is challenging; once an opposition group has achieved sufficient profile to be detectable, it is usually too well advanced in support to allow constructive engagement.

Nevertheless, the REACT tool could provide a powerful way of proactively engaging communities early on in an inclusive way, while simultaneously derisking the project lifecycle. Accessible visualisations, like REACT, could provide an early 'heads up' on projects at the conception stage, so communities are free to vocally support, critique or

[79] See, for example, Fraser, 2023 and Roy, 2023.

[80] "We suggest two components: (i) Lump sum payments for individual households close to new lines. (ii) A community fund to be established and distributed in the locality of new lines." Winser, 2023, p. 10.

outright oppose what is planned. While not preventing opposition per se, it could help move the critical risk factor of public consent to earlier in the project lifecycle - so projects succeed fast or fail fast.

## Phase 3: Final stages

The main risks for green hydrogen projects during the 'final stages' phase of the project lifecycle are:

- **Planning and safety consent**: Will the project receive planning and safety consent?
- **Investment**: Will the project secure the necessary investment for construction to proceed?

A comprehensive set of datasets relating to planning consent[81] were identified during the Alpha Phase of the REACT project. These datasets can be used to model planning consent risk, helping developers derisk this aspect of a project by moving elements of planning consent to earlier in the project conception phase, i.e., so sites under consideration potentially fail fast.

Some elements of planning consent risk may be harder to model, however, such as the issue of public consent discussed above (see Phase 2: Network connection request process). Nevertheless, there is huge scope for REACT to proactively engage communities on new projects early on, capturing crucial data points that can then be used to track and mitigate this area of risk.

During the Alpha Phase, conversations with local authorities in Scotland also revealed the crucial role of planning data in guiding future development plans. These plans heavily inform whether or not planning applications are approved. Examples of plans that local authorities use include:

- **Development Plans** "set out how places will change into the future, including the long-term vision for where development should and shouldn't happen" (TransformingPlanning.scot, 2024).
- **Local Area Energy Plans** (LAEP)[82] are "recognised as the leading method for translating national Net Zero targets into local energy system action with plans that are collaborative, data-driven and cost-effective" (Energy Systems Catapult, 2024).

[81] Planning consent datasets that were identified included Sites of Special Scientific Interest (SSSI), Special Protection Areas (SPA), Ramsar wetlands, National Parks/National Scenic Areas, National Nature Reserves (NNR), conservation areas, registered monuments and historic parks and gardens. See Icebreaker One, 2023a and Centre for Sustainable Energy, 2016.

[82] For an example of a LAEP with a hydrogen focus, see Arup, 2024.

- Some local authorities also publish **Wind Turbine Spatial Framework**[83] maps indicating potential wind turbine sites more or less likely to receive planning consent.

The REACT tool could potentially integrate with local authorities' Development Plans to help mitigate planning risk for project developers. It might also be used to co-create spatial framework maps for green hydrogen (or other use cases), so projects compliant with these maps are effectively 'pre-approved' for planning consent at an early stage. More generally, closer integration of REACT with local authorities' existing planning tools and processes would support local authorities in their Net-Zero ambitions and should be explored in future versions of REACT.

With regard to safety consent, the REACT team conducted in-depth discussions with the Scottish Environment Protection Agency (SEPA) during Alpha; ongoing discussions with project partner SGN were also invaluable. These discussions suggested that a broadly similar approach to safety consent existed as for planning consent, i.e., 'safety buffers' are automatically generated from geographical datasets that define where it is and is not appropriate to site projects. It is, therefore, assumed that a broadly similar technical approach to modelling and mitigating safety consent risk can be adopted as for planning consent risk.

One important element of safety consent, however, distinguishes it from planning consent - the safety-critical element of such datasets that often prevents them from being published openly. For example, SGN's granular geographical information about the high-pressure gas network, often used to generate safety buffers for council planners, cannot be published openly for safety reasons. Similar security- and safety-related issues preclude the publishing of other datasets, e.g., the precise locations of high explosives and military flight paths.

Open data describing safety-critical assets does exist, but has the following problems:

**Imprecise**: It is usually imprecise, incorporating significant buffers to ensure nothing safety-critical can be identified.[84] More precise, granular data, however, is key to improving the precision of long-term planning.

**Poor assurance**: With crowdsourced open data,[85] it is often difficult to judge 'assurance', i.e., how reliable it is, how often it will be kept up-to-date and who is held accountable for minimising or resolving data errors. This represents a potentially fatal flaw when data is used to inform major strategic decisions.

[83] Improvement Service, 2024.

[84] e.g., NATS Limited, 2024.

[85] e.g., OpenStreetMap.

A safe, secure and scalable way to share non-public, assured, granular data - such as safety-critical data - is, however, outlined earlier in this report (see Trust Frameworks).

With regard to understanding investment risks during the final stages of the green hydrogen project lifecycle, research work during REACT's Alpha Phase was limited. This was mainly due to challenges engaging with sufficient green hydrogen developers (see Appendix G: Research limitations and suggestions for future research).

During Alpha, however, work was completed on incorporating electricity constraint information into the REACT tool, so as to identify areas where there was a financial incentive to using constrained electricity.

More generally, Icebreaker One's mission is to connect "financial, industry and environmental data to help inform net-zero decisions" (Icebreaker One, 2023d). Icebreaker One is also involved in several finance-related projects, e.g., PERSEUS, Impact Investing, that could potentially complement REACT. Incorporating financial-risk modelling into the REACT tool represents an exciting possible direction in which to take the REACT project in the future.

# Appendix D: Research on hydrogen developers

## Overview

During the Alpha Phase of REACT, Icebreaker One contacted 20 hydrogen developers and received responses to structured interview questions from four developers. The following questions were asked:

**Question 1:** Can you describe your top five requirements when selecting a location for a hydrogen project?

**Question 2:** Can you score the following site requirements in terms of their importance, from 1 (least important) to 5 (most important)?

- Proximity to supply of high-volume freshwater
- Proximity to existing heavy industry
- Proximity to potential hydrogen demand
- Proximity to grid connection point that will guarantee connection earlier than other grid connection points
- Proximity to ports
- Proximity to major roads
- Located in a hydrogen-supporting local authority area
- Proximity to existing or proposed hydrogen hub

**Question 3:** The REACT team are engaging with a number of stakeholders in different sectors, from electricity transmission owners (SSEN-T, NGET) to water companies and local authorities. Which datasets would you most like to access from each of these stakeholders that could assist you in the process of delivering a hydrogen production project?

- Electricity Transmission Owners
- Water Companies
- Local Authorities
- Other relevant stakeholders

## Analysis of results

### Question 1

The responses of interviewees to this question were scored (a '5' score for 1st place through to '1' for 5th place) and then summed for broad subject areas. This produced the following results:

| **Subject area** *ordered by highest score* | **Score** |
|---|---:|
| Hydrogen offtaker or hydrogen transportation infrastructure | 20 |
| Electricity grid connection / renewable electricity | 17 |
| Water supply or waste-water treatment | 12 |
| Land availability or land satisfying planning constraints | 8 |
| Local support, regulations or incentives | 2 |

### Question 2

The scores given by interviewees to this question were averaged for each site requirement. This produced the following results:

| **Site requirement** *ordered by highest score* | **Averaged score** *'1' least important, '5' most important* |
|---|---:|
| Proximity to grid connection point that will guarantee connection earlier than other grid connection points | 4.3 |
| Proximity to potential hydrogen demand | 4.1 |
| Proximity to supply of high-volume freshwater | 4.1 |
| Located in a hydrogen-supporting local authority area | 3.3 |
| Proximity to existing heavy industry | 3.1 |
| Proximity to existing or proposed hydrogen hub | 2.8 |
| Proximity to ports | 2.5 |
| Proximity to major roads | 2.3 |

Despite the small sample size, the broad consistency of results from **Question 1** and **Question 2** reflects the primary importance of the following site requirements to hydrogen developers:

- A grid connection
- A hydrogen offtaker, i.e., a customer to consume the hydrogen
- A connection to the water network

Proximity to major roads or ports, existing heavy industry, a hydrogen-supporting local authority area or an existing or proposed hydrogen hub were seen as of secondary importance.

### Question 3

The responses of interviewees to this question are summarised below:

| Stakeholder | Desirable dataset(s) from these stakeholders |
|---|---|
| Electricity Transmission Owners | • Infrastructure data<br>• Capacity data<br>• Position in queue<br>• Background harmonic data, i.e., how much 'noise' in network<br>• Minimum and maximum short circuit power<br>• 'Swing' and 'sag' powerline data<br>• Projected grid capacity and network connection cost during speculative project siting<br>• Project liability regarding reinforcements<br>• Location of existing and planned substations<br>• Geographical information on circuits<br>• Contact information for substation-specific network experts<br>• Access to renewable profiles from wind and sun, at different weather conditions and seasons |
| Water Companies<br>*Note: some water-related datasets may be the domain of non-water companies, e.g., environmental organisations* | • Water supply connection points<br>• Water abstraction licences<br>• Prediction of drought areas<br>• Actual and predicted capacity data<br>• Cost estimations for providing water 'reinforcements'<br>• Restrictions on peak water use<br>• Water demand in different regions |

| | |
|---|---|
| | • Water quality profiles |
| Local Authorities | • Filtered projects based on planning decision<br>• Notification of new hydrogen project applications<br>• Aggregated data across all councils<br>• Council planning policy GIS layers<br>• Estimated planning consent timescales (realistic estimates rather than statutory timescales)<br>• Regulations |
| Other | • GIS data around current and predicted gas infrastructure<br>• Gas consumption data<br>• Hydrogen plans of key landowners, e.g., Associated British Ports<br>• Data around consenting queues for regional/national environmental agencies<br>• Operational performance profiles from OEMs |

The results of this question indicated there is a significant range of data, both from Transmission Owners and other stakeholders, that is of potential benefit to hydrogen developers.

# Appendix E: Geographic information systems (GIS)

## ArcGIS

ArcGIS provides a desktop GIS application and a cloud-based GIS solution for managing and presenting GIS information. Of the 32 Scottish local authorities contacted during REACT's Alpha Phase, 15 local authorities use ArcGIS to deliver their GIS planning data in a public way.

## Idox Uniform

Idox Uniform is a desktop or cloud-based software solution for managing planning information. All Scottish local authorities use Idox Uniform for planning.[86]

## QGIS

QGIS is a free and open-source standalone GIS application that runs on multiple platforms that can import and export GIS data in a large number of industry-standard data formats. It allows bespoke plugins to be created for a range of functions, including accessing DCAT-compliant open data portals, such as CKAN and OpenNetZero.org

## Mapbox

Mapbox provides a range of mapping software, tools and cloud-based services for delivering map-based information on the web via desktop or mobile devices. The REACT project uses Mapbox to provide its core 'base map.'

[86] Idox plc, 2022

# Appendix F: Use case analysis

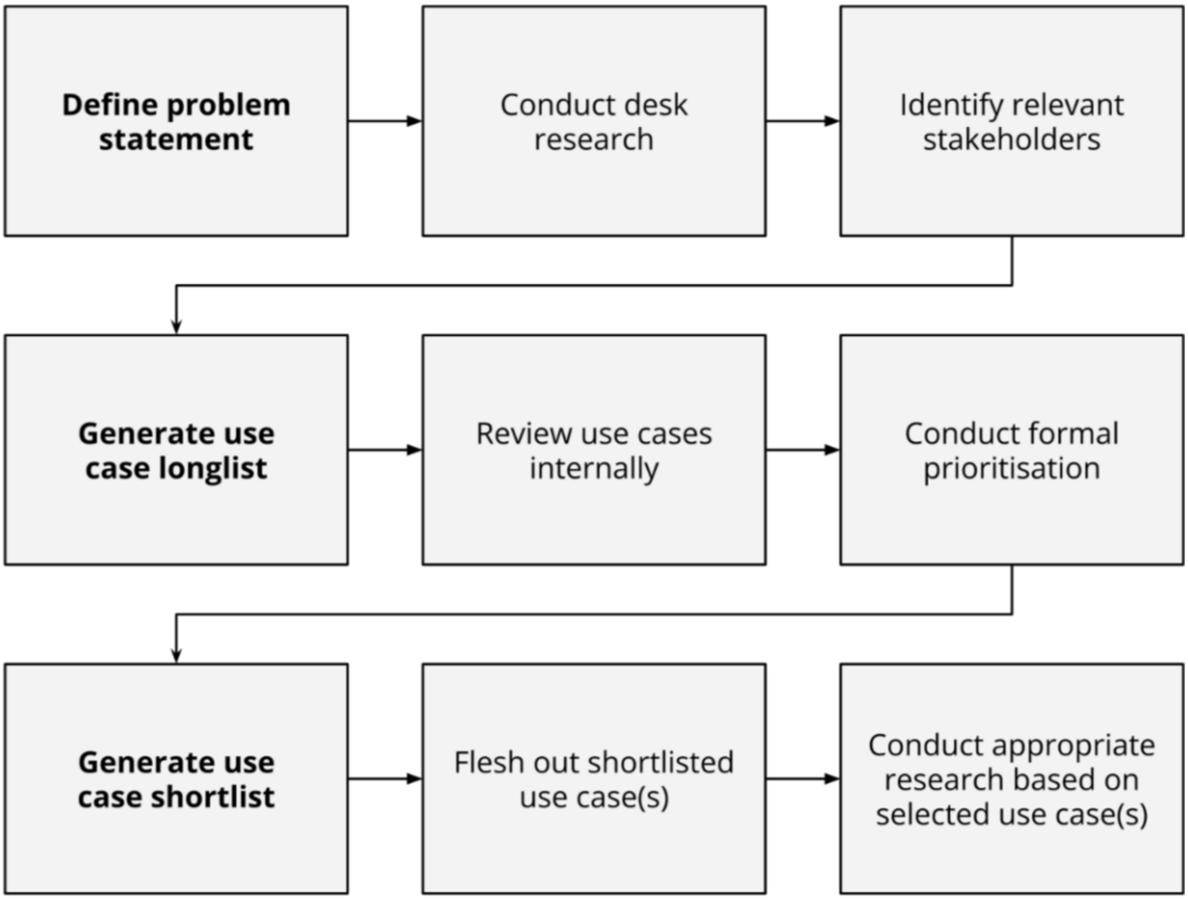


*Image source: Icebreaker One, 2024*

## Step 1: Define clear problem statement

Defining a clear problem statement helps achieve clarity on the problem to be solved through any work or research. To help stakeholders address a particular business problem through better data, it is crucial to work with those stakeholders to understand and capture the core problem they are trying to solve.

A typical problem statement should be written in plain language so it is easy to understand for all stakeholders and avoids confusion or ambiguity. Ideally, it should be short and succinct, for example:

> *"The EV charging infrastructure in the UK is currently inadequate to support the needs of current and potential EV drivers."*

## Step 2: Conduct desk research

Once a clear problem statement has been decided, in-depth research around the problem can begin. However, researchers are often asked to carry out research on a topic they are unfamiliar with. It is, therefore, good practice to carry out secondary or 'desk' research to help gain a better understanding of the problem area. This can then be used to inform the use cases and aid with interviews.

Desk research might include carrying out a literature review, for example, reviewing government or industry regulator reports. When attempting to understand the role of data in addressing the problem statement, it is also helpful to assess what existing open data is already published by key stakeholders.

## Step 3: Identify relevant stakeholders

It is important to identify relevant stakeholders and speak to the 'right people' to understand all aspects of the problem. This is necessary if one is to make appropriate sector-specific recommendations and potentially implement change.

Depending on the project, this may involve internal stakeholders, external stakeholders or both. Where possible, start with your existing contacts to select 'warm' stakeholders who are easier to approach. You can also include client(s) in this process and ask them to reach out to their 'warm' contacts.

In a new area of research, desk research, such as a literature review or LinkedIn search, may be required to identify relevant individuals or organisations. A concise 'cold' email to people/organisations can then be used to connect with these stakeholders; this method was used successfully during Alpha to connect with hydrogen developers and local authorities.

Note that stakeholder identification is often an evolving process as one speaks to more and more people. It is good practice, for example, to ask anyone you interview if they can recommend any other stakeholders.

## Step 4: Generate use case longlist

A problem statement can often seem overwhelmingly wide in scope - and thus intimidating to solve. However, by creating a longlist of 'use cases' from the problem statement, the problem is broken down into manageable chunks that can be effectively focused on. A pragmatic action plan can then be delivered to the client that tackles the problem statement *through* a specific use case.

Like the problem statement, each use case should be specific and well-defined, avoiding ambiguity and confusion where possible. For REACT, the use case of "green hydrogen in the north of Scotland" was selected from the REACT use case longlist created during the Discovery Phase.

In some cases, the client may already have a preferred long list of use cases. However, as this list may be incomplete, Icebreaker One recommends key stakeholders are always consulted when identifying use cases. From Icebreaker One's perspective, ideal use cases must illustrate the real-world benefits of better access to data so that clients can prioritise which data to focus on.

## Step 5: Review use case longlist internally

Sometimes longlists are too long to be usable or specific use cases are simply not practical, e.g., it may not be possible to obtain useful data for the use case within project deadlines. An internal review of the longlist, involving the project team and possibly key client representatives, is, therefore, desirable to reduce the length of the longlist.

One way to review the use case longlist is to send it to key stakeholders for feedback. Stakeholders can be asked:

- Which use cases would they like removed?
- Does each use case satisfy certain key criteria? For example, does it have a narrow, clearly defined goal and a 'primary actor' to make it an effective use case?
- Does a list of datasets readily exist that supports each use case? More generally, how feasible is each use case?
- What is the value of each use case?

Based on stakeholders' feedback, the longlist can then be reduced in length.

## Step 6: Conduct formal prioritisation

Once the use case longlist has been refined, the remaining use cases must be formally prioritised by the client and/or external stakeholders. This is to ensure the right use cases are prioritised for development before further stakeholders, who may be use-case-specific, are brought into the project.

Depending on the project, prioritisation can be approached in different ways. Regardless of the method used, any prioritisation criteria chosen must be defined at the outset before stakeholders carry out any ranking.

**Method 1 - Quick ranking:** Convene a meeting with stakeholders and perform a 'quick and dirty' ranking exercise. Stakeholders should be asked to select their 'Top 3' or 'Top 5' use cases and rank each use case in order of importance.

**Method 2 - Extended consultation**: If time permits, stakeholders can be sent the list of use cases and asked to score each use case against the pre-agreed criteria. In this method, consideration will need to be given to how to 'weigh' each criteria to produce a final ranking.

## Step 7: Generate use case shortlist

The formal prioritisation process should lead to the creation of a shortlist of use cases. A use case shortlist helps the client understand where they should focus their efforts by specifying which focused use cases will be explored further.

The exact number of shortlisted use cases should have been defined in the project scope. However, it is unlikely to exceed two or three and, in some instances, there may only be one use case.

## Step 8: Flesh out shortlisted use case(s)

To ensure the shortlisted use cases have the level of detail required for implementation, it is necessary to 'flesh out' the shortlisted use case(s) with more detail.

This may involve in-depth interviews with stakeholders likely to be key actors or beneficiaries of the selected use cases. It may also be appropriate to review datasets to ensure they are clearly defined, e.g., in terms of the level of granularity required. Finally, it is advisable to carry out further research on the benefits and challenges of implementing the use cases to ensure these are adequately understood.

## Step 9: Conduct appropriate research based on selected use case(s)

Once one or more use cases have been finalised, more detailed research can then be carried out on the use case(s). The nature of the research will depend on the project scope, but is likely to include a written report; it may also include a spreadsheet capturing the datasets required for use case implementation. For some projects, the report will be used to inform a final project workshop.

The finalised use cases also ensure both client and stakeholders have a solid foundation on which to carry out further work, whether research-related or more practically focused, e.g., software pilots like the REACT tool.

# Appendix G: Research limitations and suggestions for future research

## Research limitations

**Difficulty engaging with key stakeholders**: During the initial stages of Alpha, Icebreaker One experienced challenges connecting with green hydrogen developers - none attended the first REACT Advisory Group and few responded to direct communications. This may have been due to a combination of factors:

- **Small sector**: There are not that many hydrogen developers in existence.
- **High-risk sector**: Being a high-risk, relatively immature sector, hydrogen developers are more guarded about commercial sensitivity and wary of joining shared forums with other developers.
- **Unclear relevance of REACT / Advisory Groups**: Developers may have their own GIS tools for identifying hydrogen sites and may have felt the REACT tool was of limited relevance to them. The purpose and benefits of joining the REACT Advisory Groups may also have seemed unclear.
- **Time pressures**: Hydrogen developers may have been too busy trying to make their projects happen to spare time to feed into REACT.
- **Timing**: The timing of the Alpha Phase - spanning the 2023 winter break - reduced the time available for effective outreach. The short duration of Alpha also made outreach more challenging.

During the second half of Alpha, however, Icebreaker One scaled up its outreach efforts effectively. Following positive responses to emails, several hydrogen developers attended the final Advisory Group and a number of structured interviews with hydrogen developers were successfully completed.

**Challenges communicating the benefits of improved data accessibility**: The REACT project is a practically-focused solution and there was sometimes confusion from stakeholders as to the benefits of improved data accessibility.

This was a particular problem as concepts became more abstract and less technically focused, e.g., Trust Frameworks focused on data governance. While this issue didn't affect research work as such, it made it more challenging to deliver certain key Alpha Phase project milestones. Icebreaker One, however, addressed this effectively by improving its communication of key data accessibility concepts and taking the time to listen to and understand stakeholders' concerns.

## Suggestions for future research

During Alpha, the following questions emerged that merit further research:

**How accurate is crowdsourced open data?** Crowdsourced OpenStreetMap data is used extensively within the REACT tool and also within the Open Infrastructure Map of electricity infrastructure. However, it is unclear how accurate or reliable this OpenStreetMap data is, particularly with regard to electricity infrastructure data. It would be desirable to conduct more detailed research to ascertain the data quality of this crowdsourced open data.

**How do electricity companies decide which datasets to publish?** During Alpha, some inconsistency was noticed regarding the datasets different electricity companies publish. It would, therefore, be desirable to understand the internal processes through which different companies decide to publish specific datasets in detail. This would also help to identify better ways of achieving interoperability of datasets across electricity companies.

A related question worth exploring is: what is the exact process within electricity companies of translating an external need for a dataset (needed to solve a specific problem or use case) into a published dataset?

**How does the 'securing investment' process work for a large electricity project?** Connecting to investment is as important to the success of a large electricity project as connecting to the electricity network. This important area, however, was relatively unexplored during Alpha and requires further research. Such research would also help in the application of REACT to radically different use cases beyond green hydrogen.

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