SP Energy Networks

Predict4Resilience

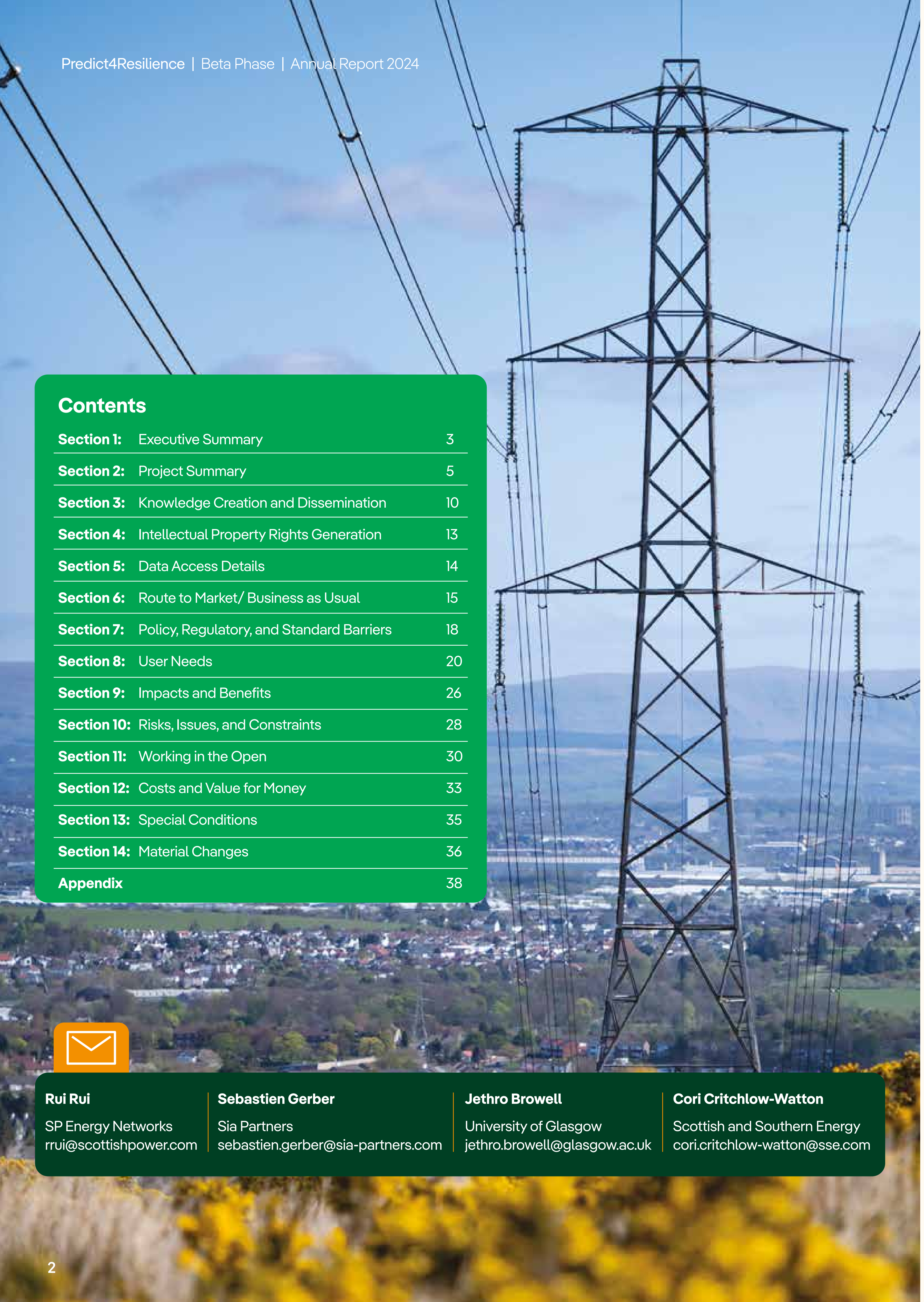
Beta Phase – Annual Report

November 2024

SIAPARTNERS

University of Glasgow

Scottish & Southern Electricity Networks



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Section 1: Executive Summary

Predict4Resilience (P4R) is a cutting-edge software platform designed to enhance the resilience of electricity networks during severe weather events by providing accurate fault predictions and actionable insights. Leveraging real-time weather data, historical fault information, LIDAR, and land cover data, P4R forecasts potential network faults up to five days in advance. This empowers network operators to proactively deploy resources, minimising outages and improving response times, especially for vulnerable customers.

Rationale:

P4R was conceived in response to severe weather events like Storm Arwen in 2021, which exposed the limitations of reactive fault management approaches. The platform enables data-driven, proactive responses that reduce downtime, operational costs, and customer impact. It aligns with UKRI and Ofgem's Innovation Challenge 2 on Data and Digitalisation (SIF Round 1) by advancing planning, forecasting, and coordination across energy networks.

Projected Impact and Benefits:

P4R aims to deliver tangible benefits, including cost savings for consumers, reduced operational costs for networks, and minimised carbon emissions through more efficient fault response. By providing advanced fault predictions, the platform will help operators restore power faster, reducing downtime and mitigating the impact of severe weather events on vulnerable customers.

Project Foundations (Discovery and Alpha Phases):

During the Discovery Phase, the potential benefits of the proposed solution and an initial relationship between wind and fault were effectively demonstrated. In the Alpha Phase, the project team leveraged data science, design expertise, and software development to design and develop a first prototype, resulting in a Fault Forecast Engine that utilises advanced statistical methods and the future user-centric interface wireframes. The statistical models achieved high accuracy in forecasts for days 1-7, a critical timescale for operational planning in the Control Room. Additionally, the model effectively predicted severe weather events leading to significant fault occurrences. User engagement and collaboration with UX experts were at the heart of the project's strategy to co-design an interface that met user needs, including displaying the entire fault probability distribution alongside the RAG status for improved decision-making.

Achievements in the Last 12 Months:

Building on the success of the Discovery and Alpha Phases, the Beta Phase has focused on transforming the initial prototype into a fully functional solution, that was approved as ready for trials.

Over the past 12 months, significant progress has been made, including setting up the infrastructure (repository management, CI/CD, AWS…), integrating live weather data, enhancing and industrialising fault models to produce live fault forecast and incorporating weather events. The Alpha Phase models have now been deployed into production and further enhanced, where models have undergone training, testing, and evaluation. Additionally, weather forecast bias correction has been implemented to further enhance prediction accuracy.

The user interface has been developed with a range of comprehensive features, including license area and district dashboards with fault forecast pop-ups, an event library, an event simulator, and tools for monitoring forecast quality. Other technical components, such as user preferences and platform settings, have been customised to meet the specific needs of users.

As the project has progressed through the Beta phase, several important lessons have been identified, which have shaped the ongoing development and refinement of the platform.

Key Achievements:

Automatic Live Forecasts:
Successfully automated live weather forecasts and fault forecasts, enhancing predictive capabilities

Multi-model Ensemble:
Implemented in July 2024, improving forecast accuracy and platform resilience

Approval for Business Trials:
Secured approval for Business Live Trials, enabling real-world platform testing.

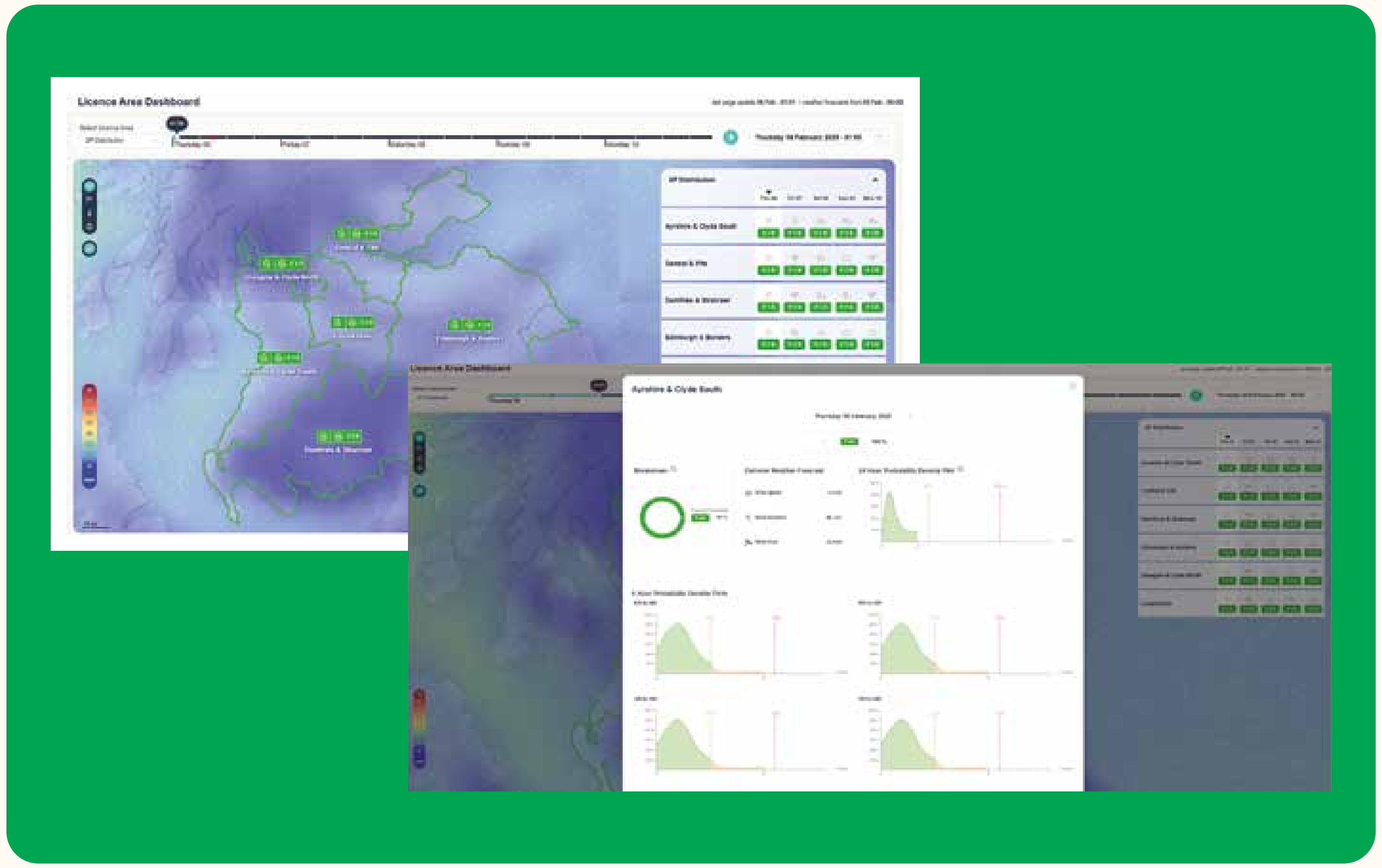

Figure 1: P4R User Interface

Key Beta Phase Activities:

In the first 12 months, the Beta Phase has seen the following:

- User-centric development and feedback loops proved critical in ensuring the platform aligned with real-world operational requirements.
- Technical innovations, such as optimising weather data collection points and adopting the Zarr format for efficient data storage and processing, greatly enhanced system scalability.
- Addressing the operational challenge of delayed fault reporting following storm events improved resource planning and response capabilities.
- Transparent communication and collaboration with stakeholders, facilitated through live trials and public outreach, played a crucial role in further refining the platform's features and functionality.
- Streamlining contract processes, managing technical complexity, and refining user roles contributed to greater overall operational efficiency.

Live Trials and Next Steps:

The P4R project has entered Live Trials with SP Energy Networks (SPEN) as of October 2024, with Scottish and Southern Electricity Networks (SSEN) expected to join in early 2025. Trials will continue until Summer 2026, validating the platform's performance during normal operations and extreme weather events. The successful first year of the Beta Phase has prepared the platform for large-scale testing.

Key stakeholders at SPEN, including Control Room Engineers and District Fault Leads, have been trained and are participating in the trials. Their feedback is essential for refining the platform. The trials will cover two winter storm seasons and two summer seasons, providing a thorough evaluation of the platform's resilience, adaptability, and fault prediction accuracy, and preparing it for commercial deployment.

Section 2: Project Summary

Addressing the Challenges of Weather-Driven Network Disruptions

Predict4Resilience (P4R) is a software platform that will provide accurate fault insights and forecasts for electricity networks during adverse weather events.

By utilising hourly data from state-of-the-art weather forecasts and overlaying this onto historic network fault data, LIDAR data and land cover data, P4R will provide Control Room operatives short-term predictions regarding the expected number of faults and range of uncertainty in each district across the licence area, up to 5 days in advance. Using hourly data available enables P4R to provide the most accurate 6-hourly weather forecasting possible as well as providing the platform with the most granular weather imagery for the map.

This capability allows for the proactive placement of resources—such as engineers, mobile generation units, welfare provisions, and customer liaison staff—in areas most likely to be affected. This can be especially important in remote locations where travel distances are significant, and the proactive response will enable power supply to be restored sooner than is currently possible, creating a more resilient network and minimising disruption and stress for customers, particularly for the vulnerable.

The P4R project was developed in response to the electricity network sector's vulnerability to severe weather events, which can cause widespread outages and significant economic losses. Events like Storm Arwen in November 2021 highlighted the need for a more proactive approach to network fault management. With over a million customers affected and many losing power for over a week, the storm exposed gaps in preparation and resource management.

Until now, Distribution Network Operators (DNOs) have primarily relied on experience-based risk assessments which, while valuable, can be constrained by limited data-driven insights. This approach can result in reactive fault management and longer outage durations. The P4R system leverages real-time weather data and predictive analytics to forecast faults, helping to shift DNOs from reactive management to a more proactive strategy. This approach will minimise downtime and reduce operational costs.

Aligned with UKRI and Ofgem's Innovation Challenge 2 on Data and Digitalisation (SIF Round 1), P4R enhances network planning, modelling, and forecasting through the innovative use of data. It improves resilience by integrating real-time analytics with weather insights, enabling faults to be predicted well in advance. This not only enhances operational planning and resource allocation but also fosters better communication across energy networks and key stakeholders, promoting coordination as outlined in the Innovation Challenge.

5 DAYS

Advance Forecasts Network Faults

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Strategic Milestones

P4R project rollout has been shaped around a clear objective: delivering a robust solution by October 2024 (M2.6), in preparation to conduct trials during the critical storm season.

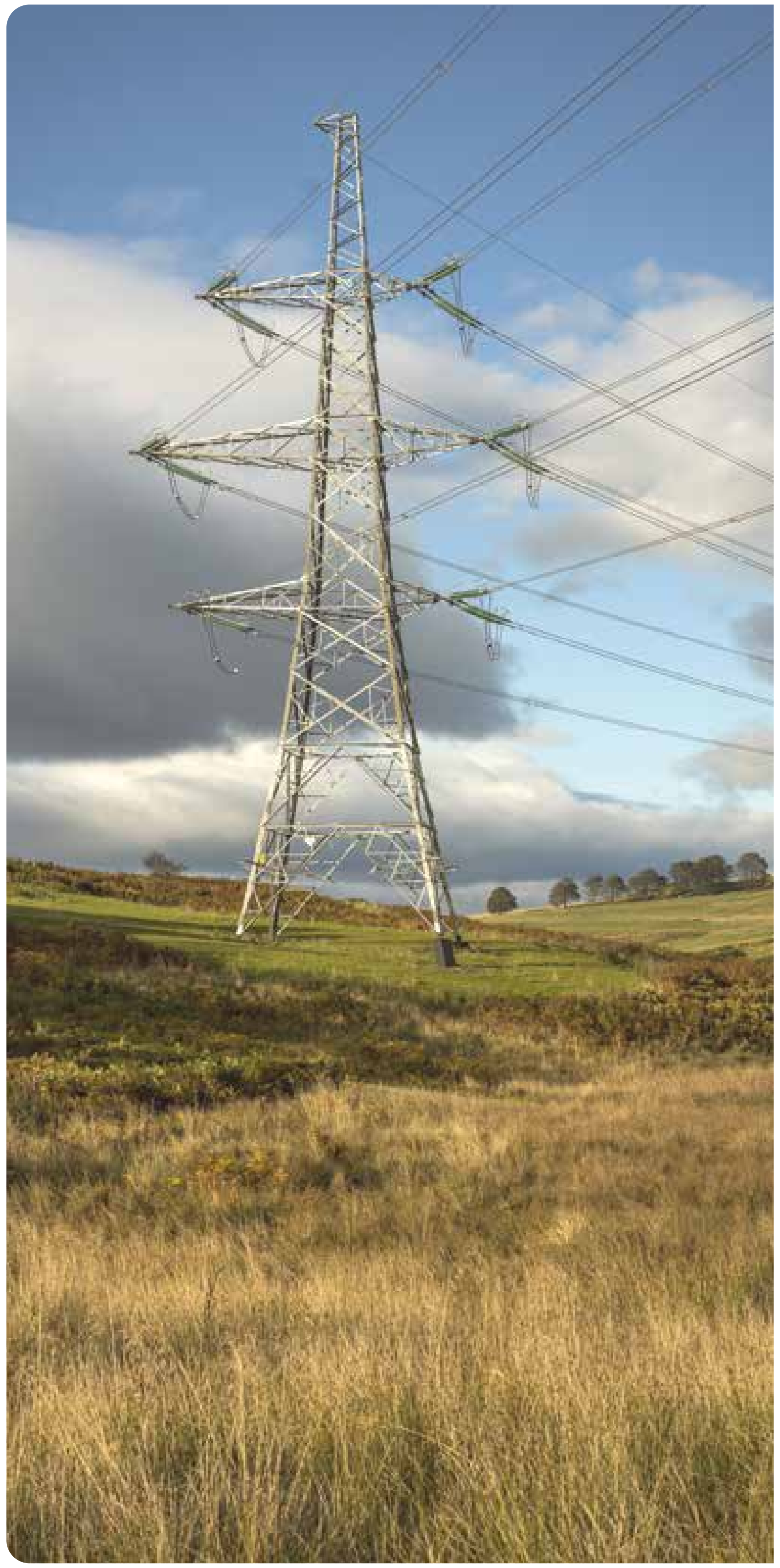
This milestone has always been central to the project's strategy, ensuring that the platform is fully operational for live testing in real-world conditions ahead of extreme weather periods. To meet this goal, the first 12 months of the project were streamlined to focus on delivering essential capabilities, while less immediate milestones were deprioritised to maintain momentum.

To support this strategy, the project passed a Stage Gate review (M2.7) designed to ensure readiness for the upcoming Business Trials in Autumn 2024, without the need for additional investment. This has enabled the team to move forward confidently, aligning technical advancements with strategic objectives.

Despite an initial delay due to contract arrangements, which pushed the start date back, the project plan was recut in November 2023 to recover lost time. This realignment focused on ensuring that critical milestones would be achieved within the required timeline.

Key Progress Has included:

- **Infrastructure Setup (M2.1):** A major accomplishment was the successful creation of the project's entire technical infrastructure, established from a minimal starting point. This included the deployment of repositories, databases, logs, and APIs, which were fully implemented by Sia Partners in December 2023. This foundational work was crucial for enabling the project's future technical developments and ensuring a solid operational framework.
- **Automatic Live Forecasts (M2.3):** One of the earliest technical achievements, live weather forecasts are now automatically generated, greatly improving the platform's predictive capabilities.
- **Multi-Model Ensemble for Weather Prediction (M4.1):** Implemented in July 2024, this advancement improved the accuracy and resilience of weather forecasts, enhancing the platform's overall functionality.
- **Several Additional Technical Milestones:** Were completed by August 2024, including the availability of the solution interface (M2.4) and the completion of security penetration tests (M2.5). These steps ensure the solution is secure, accessible, and documented for the ongoing trials.



Ref	Milestone Title	Success Criteria	Partner Responsible (dd/mm/yyyy)	Due Date	Status
M1.1	All Teams Onboarded	All contracts signed and resources recruited	SPEN	31/12/2023	✓
M2.1	Infrastructure Setup	Repositories, database, logs and APIs in place	Sia Partners	31/12/2023	✓
M2.2	Data Pipelines a Automated	Data extraction processes scheduled and running	Sia Partners	28/02/2024	✓
M2.3	Forecasts Produced	Live forecasts produced automatically	Sia Partners	30/06/2024	✓
M2.4	Solution Interface Available	User interface developed and endpoints connected	Sia Partners	31/08/2024	✓
M2.5	Solution Secure	Successful penetration tests	Sia Partners	31/08/2024	✓
M2.6	Solution Ready for Use	Finished prototype & documentation	Sia Partners	31/08/2024	✓
M2.7	Stage Gate - Business Trials Green light	Solution on track and expected to be fit for trials. No additional Investment expected	University of Glasgow & Sia Partners	31/07/2024	✓
M4.1	Multi Model Ensemble	New model published using multiple weather models	University of Glasgow	31/07/2024	✓
M4.2	Worst Case Scenario	New model published using extreme theory	University of Glasgow	30/09/2024	‖
M4.6	New DNO Requirements	Implement final comments from other DNO	SSEN	31/01/2025	‖
M5.1	SIF Learning	Events organised with other SIF funded project and interactions captured	Sia Partners	31/12/2024	▶

Figure 2: Summary Of Milestones Up To January 2025

Key Chart

✓ **Milestones were met**

‖ **Milestones not on the critical path have been pushed back to ensure the Business Live trials could start properly in Autumn 2024**

▶ **Milestones are on track**

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Key Technical Advancements to Date

On the technical front, a major advancement was the transition to the Zarr format for data storage, which has enabled P4R to handle large, complex weather datasets more efficiently.

By integrating Zarr with Xarray, the project improved the scalability and speed of its data management pipelines, particularly in cloud environments.

Additionally, an optimisation study reduced the number of weather data collection points across SPEN's network from 500,000 to 3,504, using precise distance calculations to ensure comprehensive coverage while maintaining efficiency. Moreover, the development of a method to redistribute fault timestamps to their actual occurrence dates improved the models' performance, enhancing operational planning, particularly during post-storm recovery.

In addition to these improvements in fault prediction, the platform's usability has been enhanced with several new features. Live data feeds, Forecast Quality Pages, and a Resource Calculator have been integrated into the user interface, providing users with real-time insights and tools to make informed decisions more effectively.

For More Information:

Please Refer to Section 3 of this Report on Knowledge Creation and Dissemination

Project Governance & Partner Collaboration

The governance framework established during the Beta Phase emphasises collaboration and transparency among the Funding Party, project partners, and stakeholders.

Regular Meetings — including quarterly Monitoring Office and Steering Committee sessions, along with monthly Partner meetings—facilitate effective communication and enable comprehensive reviews of financials, risk assessments, and technical progress. The Steering Committee plays a vital role in providing high-level oversight and strategic guidance.

The Integration of Insights from Project Partners — Sia Partners, University of Glasgow, SPEN, and SSEN — has been essential in shaping P4R's development with several teams from within SPEN offering inputs to the project including the Innovation, Control Room, Asset Management and Network Planning & Regulation teams. The partnership between Sia Partners and the University of Glasgow enhances technical capabilities by leveraging diverse expertise. Ongoing consultations with representatives from partner organisations ensure that strategies benefit from a comprehensive array of knowledge and experience.

This iterative approach to collaboration drives continuous enhancements to the P4R solution, particularly in areas such as fault data processing and algorithm development. Insights gained from technical partnerships lay the groundwork for transparency and shared learning.

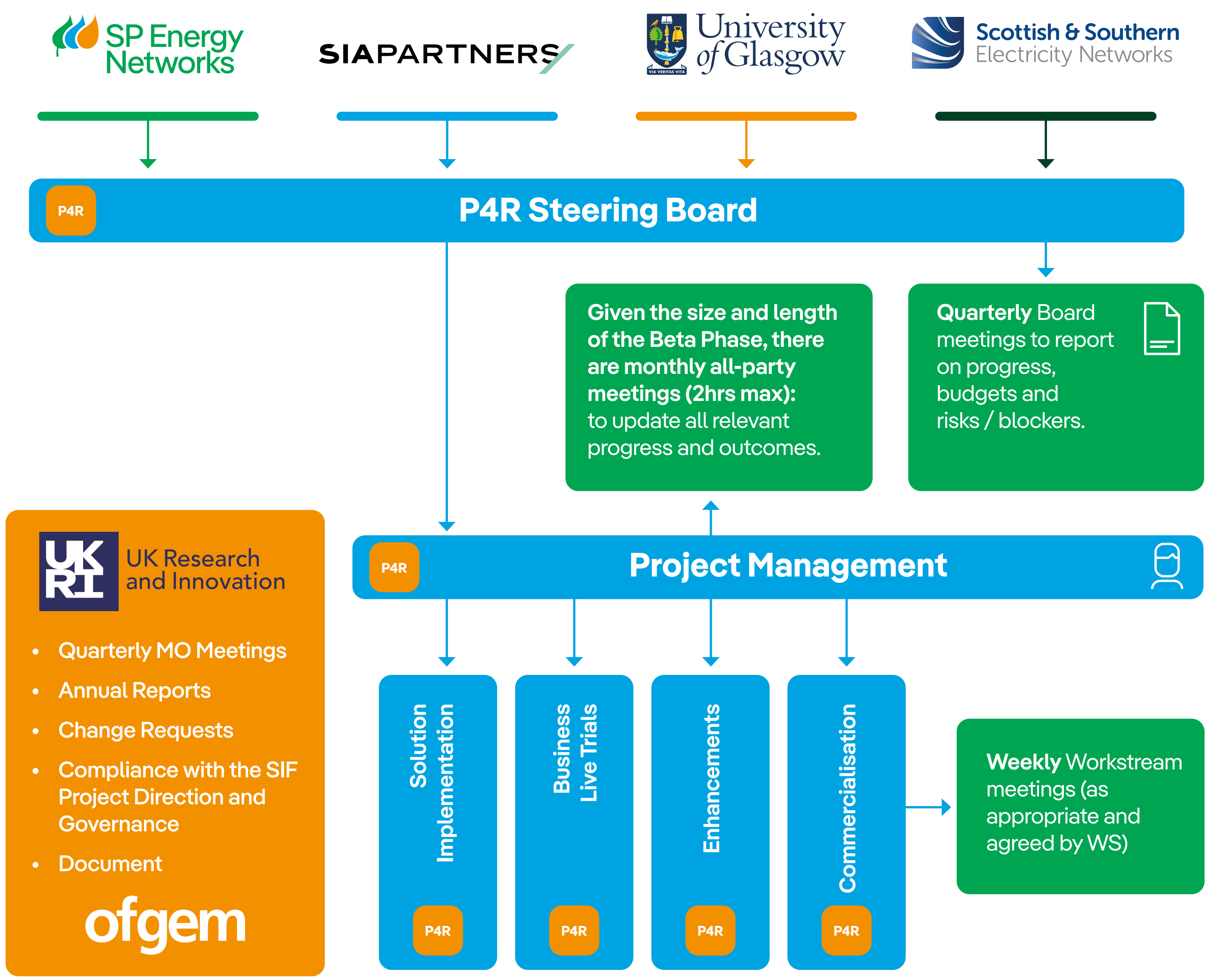

Figure 3: Predict4resilience Project Governance

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Section 3: Knowledge Creation and Dissemination

Improving Data Management Using Zarr Format

One major lesson came from the decision to adopt the Zarr format for storing weather data, which proved superior to alternative methods Initially, CSV files and traditional storage methods were used.

While these approaches worked for smaller datasets, they quickly became inefficient as the complexity and size of the data increased. CSV files, being flat and lacking support for multi-dimensional data, required extensive memory and processing time, resulting in slower performance and higher storage costs.

The transition to Zarr, a modern storage format for large, multi-dimensional arrays, effectively addressed these challenges. Zarr's chunking and compression capabilities allowed for efficient storage while enabling access to specific data subsets, significantly reducing memory and processing demands. Additionally, Zarr's support for parallel I/O and its seamless integration with cloud storage improved scalability and performance, especially in the context of large weather datasets.

The full potential of Zarr was realised when combined with Xarray, a powerful Python library for working with multi-dimensional labelled data. Xarray's intuitive tools for slicing, grouping, and transforming data arrays greatly simplified the handling of complex weather models, which often include dimensions such as latitude, longitude, time, and various climate variables. Moreover, Xarray's native support for Zarr format enables efficient workflows, allowing large datasets to be processed without needing to load them fully into memory. This combination of Xarray and Zarr resulted in significant improvements in both data handling efficiency and the scalability of processing pipelines in local cloud-based environments.

500,000

SPEN's Extensive Distribution Poles on the Network.

Optimising Weather Locations

Another critical insight was gained from optimising the collection of weather data across SPEN's extensive 500,000-pole distribution network.

Collecting weather data for every pole would have been both financially prohibitive and computationally intense. To address this, an optimisation study was conducted to minimise the number of data collection points while still ensuring comprehensive network coverage. The initial phase of optimisation focused on the circuit level, successfully reducing the number of weather locations from 500,000 to 13,000 key points. This process was further refined at the district level, ultimately reducing the number of weather data collection points to just 3,504, while guaranteeing that every pole remained within a 2 km radius of a designated weather location.

The approach employed integer programming techniques to solve the optimisation problem, with constraints ensuring that each pole had at least one nearby weather location. To accurately measure distances between poles, the Haversine formula was used to calculate the distance between latitude and longitude coordinates, accounting for the curvature of the Earth. This method provided precise distance measurements, essential for determining viable weather locations. The optimisation was carried out using the CBC (COIN-OR Branch and Cut) solver, which is well-suited for handling large-scale integer programming problems. A time limit of 50 seconds per optimisation run was set to balance solution accuracy and computational efficiency, though future runs with extended time limits could yield further improvements.

An example from the study highlights the results for a specific circuit, which has four weather locations. **Figure 4** offers a full view of the circuit, while **Figure 5** zooms in to show

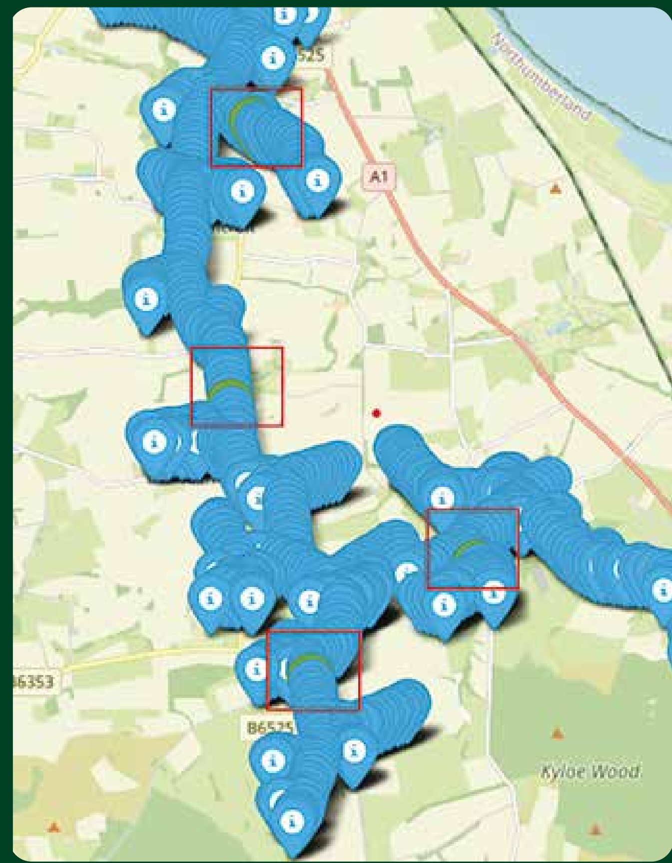

Figure 4: Example Of Weather Location Optimisation On One Circuit

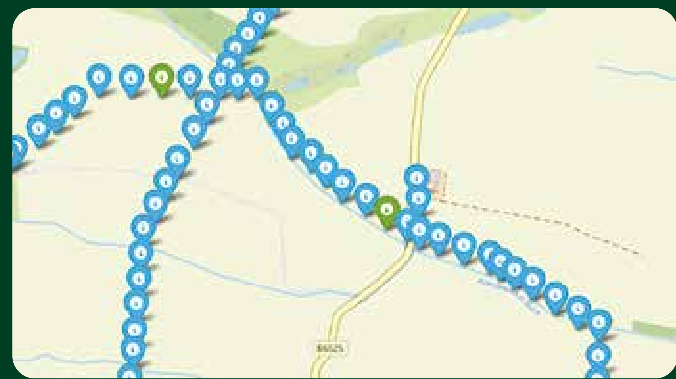

Figure 5: Example Of Weather Location Optimisation On One Circuit - Zoomed-In

the selected locations. Blue markers represent all poles, while green markers indicate the optimised weather data collection points, highlighted within a red rectangle. This visual clearly illustrates how the optimisation effectively reduced data collection points while maintaining robust coverage across the network.

Improving Model Performance – Adjusting Fault Timestamps

Another important lesson learned was related to the representation of fault timestamps. Initially, faults were recorded based on their discovery dates, which often did not reflect the date the fault occurred which has a clear impact when using this data to train the fault forecast model.

To address this, a thorough analysis of the distribution of faults over time was conducted, leading to the development of rules for re-attributing timestamps. Event days, defined as days when fault counts exceeded the 99th percentile, and aftermath days, identified as days with faults within three days of an event, were used to create four re-attribution rules. These rules redistributed fault data from aftermath days to event days, ensuring a more accurate reflection of fault occurrences. This re-attribution process significantly enhanced the model's ability to learn the relationship between weather conditions and faults as they occurred, leading to overall greater reliability in P4R predictions.

Overall, these innovations and insights highlighted above contributed to enhancing the operational efficiency and data reliability of P4R during the Beta Phase and demonstrate the project's innovative approaches to data management, and collection.

For More Information:

Please see Addendum A - Lessons Learned in the Appendix at the end of the report

Lessons Learned

1. **Efficient Data Management**
   Transitioning to the Zarr format improved handling of large datasets, reducing memory and processing demands while enhancing scalability through cloud integration and parallel I/O.
2. **Optimised Data Collection**
   A data optimisation study reduced the number of collection points significantly, cutting costs while maintaining effective coverage through advanced optimisation techniques.
3. **Streamlined Data Processing**
   Integrating Zarr with Xarray allowed for more efficient workflows by enabling large datasets to be processed without being fully loaded into memory, improving scalability and performance.
4. **Adapting to Delayed Fault Reporting Post-Storm**
   One of the key operational challenges identified during the Alpha phase was the delay in fault reporting after extreme weather events. The Project Team learned that predictive models need to account for these delayed fault reports in resource planning, ensuring that teams are prepared for post-storm fault backlogs, cloud integration and parallel I/O.

Section 4: Intellectual Property Rights Generation

P4R maintains an IP Register listing background and foreground IP generated by and used within the project. Foreground IP falls into three categories: knowhow, database rights, and computer software, which will be addressed separately below.

Knowhow developed to date relates to fault modelling and forecasting methodology. Fault modelling involves processes for preparing fault data analysis (cleaning, correcting, aggregating etc) as well as model selection and evaluation. The fault forecasting models currently used are quantile generalised additive models estimated using the Bayesian framework of Fasiolo et al 2020 and implementation in the R package "qgam".

Fault forecasting knowhow comprises the combination of methods for post-processing ensemble numerical weather predictions and combining these with fault prediction models to produce the final fault forecast. This represents a combination of existing methods, but details of their integration and implementation comprise this IP.

Foreground IP relating to statistical methods developed for fault forecasting will be shared with network licensees and more broadly through an academic publication to be submitted to a peer-reviewed academic journal and a pre-print made publicly available. Knowhow will also be disseminated via reports as required by the SIF, at industry events such as the Energy Innovation Summit, and other media as appropriate.

Database Rights: P4R has produced multiple databases that are used in fault modelling and forecasting by processing and combining a combination of open datasets (with Licence Terms that allow commercial and non-commercial use), paid-for datasets, and data assets owned by network licensees.

Open datasets include weather re-analysis (ERA5), land use maps, topographic maps and so on. Access to historic weather forecasts from ECMWF is paid-for, but data may be shared under the CC-BY licence. This data can either be shared on request with licensees or can be accessed directly from source by licensees themselves. Operational (live) weather forecast data is procured on a commercial basis by Sia Partners to produce fault forecasts based on the latest weather forecast; the terms of this data restrict sharing until it is no longer valid (the time of the forecast has passed).

Fault and network data owned by a given network licensee is used in the fault forecasting process for that licensee's network and is considered sensitive for commercial and security reasons and can therefore not be shared with other licensees. For the same reason, databases created within P4R that link fault, network and other data (e.g. weather), are potentially sensitive and will undergo a triage process to establish their level of sensitivity. These databases include linked weather and fault data, parameters of statistical models, network/user preferences for forecast display, and model and forecast evaluation metrics. For example, processed fault data linked with weather data for the purpose of fault modelling is considered sensitive; however, fault forecast evaluation metrics from the P4R Alpha Phase were deemed safe and shared in end of project reporting.

P4R is currently engaging with partners and Ofgem on aspects of data sharing, including how Ofgem's Data Best Practice applies to data held by innovation delivery partners.

Computer Software has been developed to implement the P4R fault forecasting methodology and manage the multiple data pipelines required to set-up P4R models for a given licence area/district, produce operational forecasts, and provide a user interface to those forecasts and additional related features. This software combined with necessary database comprises the "P4R solution" which is accessible to users via a web browser. All computer software is hosted and stored by Sia Partners and is considered commercially sensitive. How this software and service will be made available to network licensees will be determined by activities in the Commercialisation work package of P4R. The full range of options will be explored; however, it should be noted that there is a significant cost associated with setting-up and running this Computer Software and required databases. Costs include cloud computing infrastructure, data storage, weather forecast subscriptions, and human resources to operate and maintain the system. Therefore, it is anticipated that the preferred route for network licensees to access this IP with be to procure "P4R-as-a-service".

Section 5: Data Access Details

Data Access

The data generated from the project is published on the P4R platform, which is hosted by Heka, part of the Sia Partners' ecosystem of artificial intelligence solutions. All partners involved in the project have access to the platform's user interface, which allows for seamless interaction with the data and insights.

The primary output of the P4R platform is fault forecasts, which are generated using fault bands and forecast probabilities. These forecasts are updated every 6-hours over a 5-day horizon and are available for each district within the licence area of the DNO. Additionally, the platform provides weather forecasts for the same locations and time periods, to help understand the fault predictions.

Other Functionalities of the P4R Platform Include:

- Calculating the resources needed to address the forecasted faults.
- Replaying past weather events and associated fault bands for any chosen date.
- Comparing current weather conditions and fault predictions against historical events to identify trends or anomalies.

Users are only able to access pages and data relevant to their own DNO and are not able to see any content belonging to a different DNO.

Published Insights

The University of Glasgow presented work in progress of P4R at the International Symposium on Forecasting held in June. An academic paper is currently being drafted for submission in the coming months. This paper will expand upon the technical report completed at the end of the Alpha Phase, incorporating detailed production models and results, as well as enhancements related to the "worst case scenario."

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Section 6: Route to Market/ Business as Usual

Steps and Additional Work Needed for Adoption

The implementation of P4R follows a phased approach, beginning with a trial period from Winter 2024 to Summer 2026.

These trials, limited to a select group of Champions, span two winter and two summer seasons. Restricting initial access to Champions ensures focused testing and collaboration, maximising the potential for successful adoption in the future. The strategy also includes gradually expanding access in subsequent trial phases, facilitating a smooth transition into business-as-usual (BAU) operations and broader commercial deployment.

This phase will evaluate the platform's performance under diverse weather conditions and allow for necessary adjustments to support daily operations. Feedback collected during the trials will inform improvements and the addition of new functionalities, ensuring P4R is continuously optimised for broader integration.

Deployment at Large Scale

In the Beta Phase, P4R will initially be deployed at SPEN and SSEN, marking the beginning of its rollout. The complete implementation at these two DNOs is scheduled for Q4 2026, after which the focus will shift towards expanding to the remaining four DNOs in Great Britain. All of them were engaged with during the Alpha Phase, to understand their current storm impact prediction systems, assess their interest in P4R, and explore the feasibility of a broader rollout. Both Electricity Northwest and UK Power Networks responded positively, entering into detailed discussions that are ongoing. This nationwide deployment is projected to take place between Q4 2026 and Q4 2028.

In addition, international expansion is being explored, with targeted regions identified based on the presence of Iberdrola Group subsidiaries and utilising Sia Partners' established footprint in the Energy and Utilities sector. These include Western Europe and North America as a priority, followed by South America and Asia Pacific. These international discussions will continue until Q4 2026, laying the groundwork for broader global adoption of P4R.

Moreover, P4R demonstrates potential applicability across other UK sectors with weather-sensitive assets, such as transport (e.g., Network Rail, National Highways, Local Government Association), telecoms (e.g., Openreach, CityFibre, Virgin Media), and water utilities (e.g., Yorkshire Water, Northumbrian Water, South West Water), requiring minimal modifications for adaptation. This broad applicability suggests a strong potential for widespread deployment of P4R, both domestically and internationally, across multiple sectors. Engagements with these sectors are anticipated at the end of the Beta Phase, with discussions set to commence in Q1 2027 and continue through 2029.

To understand the likelihood that P4R will be deployed in a large scale, a comprehensive competitor analysis was conducted, examining a range of global tech offerings, weather-focused offerings, GB DNO-specific offerings, and research-led offerings. By comparing the advantages and disadvantages of these offerings with those of P4R, it was determined that no direct competitors exist, particularly in the UK. The analysis also highlighted three key differentiators for P4R. First, P4R's strong emphasis on user engagement makes it a user interface tailored to meet specific needs. Second, it's standalone nature means it operates independently without requiring additional software. Finally, P4R benefits from being developed by a team of experts with extensive industry knowledge, including Control Room experts, developers, UX designers and weather data specialists. Given these factors, and the potential for adaptability across various sectors, P4R is well-positioned for extensive deployment both domestically and internationally.

5 Validated in Relevant Environment

Is the Current Progression of the IRL

Exploiting the Outcomes of the Project

To fully capitalise on the potential of P4R, both the fault forecast engine and the weather data can be applied in the adjacent sectors previously mentioned. This will allow for the identification of additional use cases where P4R's predictive capabilities can enhance operational efficiency and infrastructure resilience. In the transport sector, for instance, P4R could support proactive maintenance and improve response strategies by forecasting weather-related disruptions. Similarly, in the telecom sector, the solution can assist in predicting infrastructure impacts from adverse conditions, aiding in service continuity and infrastructure protection. In the water sector, P4R's data could be used to foresee risks, helping prevent disruptions and maintain service quality. By expanding the application of P4R's predictive analytics across these sectors, its deployment can maximise impact, enabling organisations to better anticipate and address weather-related challenges while improving reliability and resilience.

Innovation and Commercial Readiness Levels

At the time the Beta Phase application was written, the Commercial Readiness Level (CRL) of P4R was assessed at 6 (Product Optimisation), with an expected progression to CRL 8 (Market Introduction) by the end of the Beta Phase. Currently, the CRL remains at 6. Although the user interface has been developed and is undergoing testing—with further improvements planned based on user feedback—the product design is not yet fully finalised, and some agreements are still pending. It is anticipated that CRL 8 will be achieved by the end of the Beta Phase, with P4R expected to be fully deployed at both SPEN and SSEN.

Regarding the Innovation Readiness Level (IRL), the initial assessment set it at 4 (Quality and Assurance of Integration), with a target of reaching IRL 7 (Verified and Validated) by the end of the Beta Phase. The IRL has now progressed to 5 (Validated in Relevant Environment), as the first version of the solution has been developed and is currently being tested by Control Room engineers at SPEN. The expectation remains that IRL 7 will be attained by the end of the Beta Phase, with P4R fully operational at SPEN and SSEN. Further product improvements will be necessary for international deployment and adaptation to other sectors.

Enabling Commercialisation

There have been no changes to the plans for enabling the procurement and utilisation of P4R across Great Britain and internationally, except for SSEN requesting to bring their trial forward. The roles of other partners in maintenance, ongoing development, and royalties/licensing are still being defined. Intellectual property (IP) matters are currently being addressed, with the commercial agreement expected to be finalised in 2025.

Following trials with SPEN and SSEN, no additional capital investment is anticipated for the commercialisation of the innovation. All partners, both network and non-network, have sufficient expertise and do not require further support as they move toward commercialisation.

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SECTOR

ELECTRICITY (UK)

Northern Powergrid; UK Power Networks; Electricity North West; Western Power Distribution; Scottish & Southern Electricity Networks

Core Focus

- Roll-out priority is to the 5 other GB DNOs
- P4R benefits case based on assumed roll out over the 5 years following SPEN implementation

OTHER (UK)

Network Rail; Highways England; Openreach

Target Area

- Other sectors in the UK with networks of assets vulnerable to weather-related faults/disruption have been identified
- P4R model could be used with limited rework

GEOGRAPHY

ELECTRICITY (Global)

ESB Energy for generations; Northern Ireland Electricity Networks; i-DE Grupo Iberdrola; Enedis L'Electricite en reseau; Avangrid

Target Area

- Other countries have been identified for roll-out based on the location of other Iberdrola Group subsidiaries and Sia Partners Energy & Utilities hubs

OTHER (Global)

Currently Out of Scope

- Use cases in sectors beyond electricity distribution and transmission outside of the UK are out of scope as each target would require both market penetration and model rework

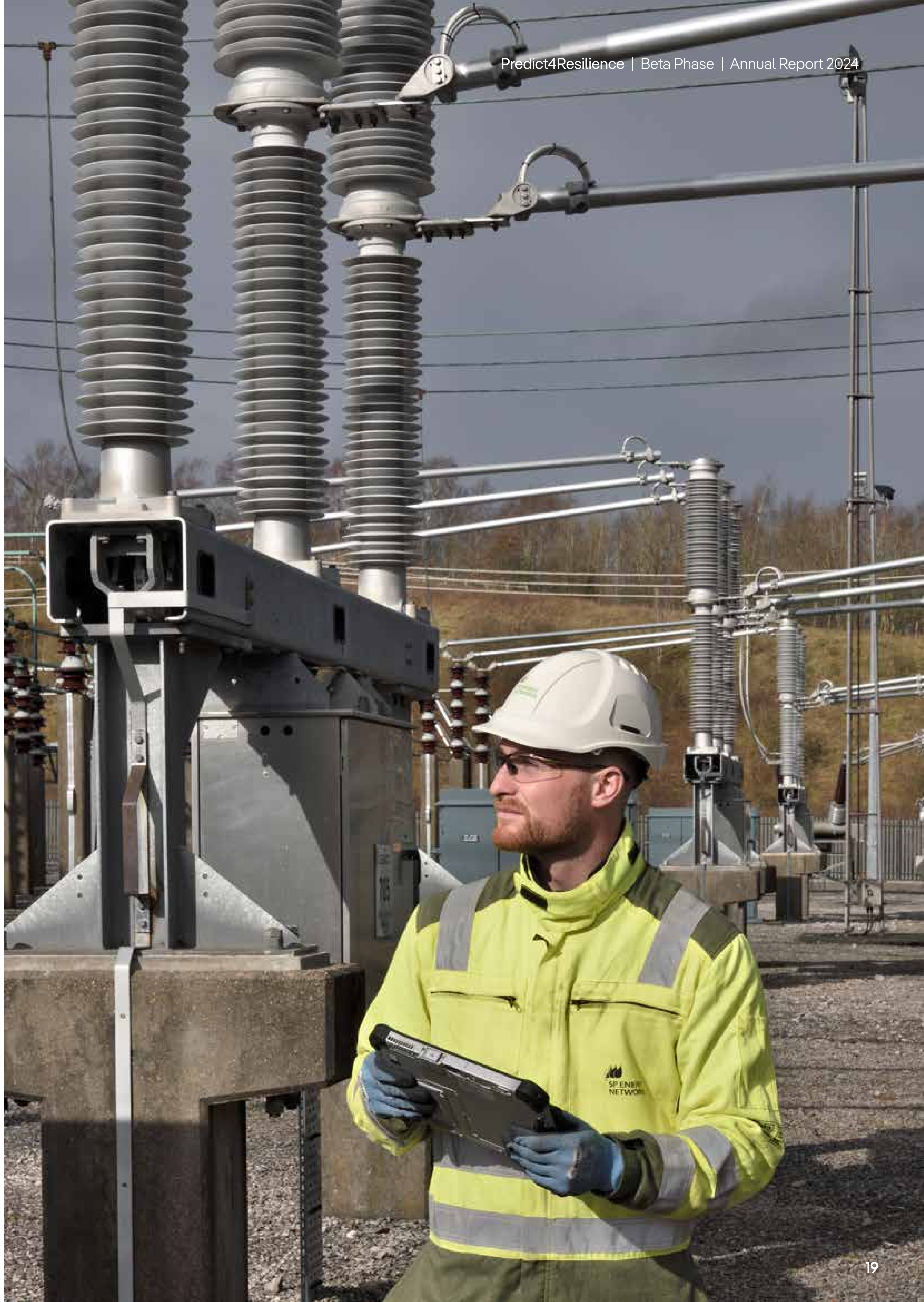
FIGURE 6: GO-TO-MARKET TARGET AUDIENCE

Section 7: Policy, Regulatory, and Standard Barriers

No regulatory barriers or regulatory uncertainties have been identified by SPEN, or the project partners, or expert assessors in the assessment so far.

Additionally, there are no derogations, licence exemptions or regulatory sandboxes which would be required to continue the project till completion. Nor are there ongoing conversations with Government, Ofgem, and other relevant organisations which are pertinent to the Beta Phase of this project.

Finally, no longer term policy considerations have been identified so far which would need to be incorporated into the Business-as-Usual rollout of this solution. In a later stage of the project, after the first year of the business live trial, both SPEN and SSEN plan to engage with internal teams to revisit this topic before BAU roll-out.



Section 8: User Needs

During the Beta Phase of P4R, the platform's design has been shaped directly by user feedback gathered through interviews and workshops. While the extensive user workshops during Alpha led to initial designs, the Beta Phase has been pivotal in refining the platform based on detailed codesign and collaboration as the solution was developing. Specifically, multiple interviews were conducted with Control Room Leads, District Fault Leads, and other key stakeholders at SPEN.

Alongside SPEN, workshops were also held with SSEN, which helped compare expectations and processes between two different Distribution Network Operators and evaluate key themes such as the plausibility of user flows and the differences between BAU and extreme weather scenarios. These interviews provided actionable feedback that influenced the definition of User Types, clarified user journeys, and informed the implementation of key platform updates. They also led to the identification of weather conditions particularly pertinent for SSEN's network (e.g. line icing and lightning). Below is a comprehensive summary of how these interviews impacted the system's development and functionality.

User Profiles

During the Beta Phase of P4R, the Project's prioritised users (established in Alpha) have been confirmed as Control Room Engineers, Emergency Action Centres (EACs), District Fault Leads, Data Scientists, and IT/System Administrators. Each of these user types plays a crucial role in the overall resilience of the energy network, and their specific needs have shaped the design of the P4R platform.

1. **Control Room Engineers (CREs):** CREs are responsible for monitoring and managing real-time network operations. During normal business hours, they do not have direct control over district resources and must rely on contacting the Fault Lead in the affected district to request resources. The P4R platform enhances their visibility, especially outside business hours, by providing comprehensive data and predictive insights. This allows them not only to request resources more efficiently but also to anticipate fault occurrences and coordinate responses proactively, significantly reducing the manual effort involved and streamlining the overall fault management process.

   Emergency Action Centres (EACs): EACs are responsible for managing resources and coordinating responses during extreme weather or critical events. The P4R platform provides EACs at both district and head office levels with a real-time strategic overview of network faults and resource distribution. By centralising this information and allowing access to a tactical overview, P4R enables EACs to quickly mobilise resources across districts. This streamlines communication and reduces the response time to fault events. The platform also includes an event comparison function to assess current faults against similar past events, assisting in rapid decision-making.

2. **District Fault Leads (DFLs):** DFLs serve as the primary coordinators for dispatching resources in response to fault indications. They utilise the platform to access a wide range of functionalities, including maps, forecasts, and updates relevant to their district. Their interaction with the platform includes but is not limited to assessing fault details, planning resource allocation, and leveraging tools like the resource calculator to determine response needs. The Beta Phase has improved the P4R team's understanding of their operational requirements by providing more granular forecasts and enabling comparisons of forecast quality with historical event data. This ensures DFLs can make informed decisions with greater confidence and adaptability.

3. **Data Scientists:** Data scientists support predictive modelling and data analysis for the P4R platform. Their role requires access to vast amounts of system data to refine models and recalibrate predictions. P4R has been designed to provide enhanced access to raw data and the ability to interact with real-time system analytics, ensuring that data-driven insights are incorporated into the platform's predictions.

4. **IT and System Administrators:** System admins ensure the platform's functionality and configuration, managing access, system updates, and configuration to align with user requirements. P4R has integrated user-friendly admin features to allow seamless updates and configuration, minimising downtime and enhancing overall system efficiency.

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User Journey and Project Design

The feedback recorded during the interviews was directly used to improve the user journeys of the different roles; in particular, Control Room Engineers (CREs), Emergency Action Centres (EACs), and District Fault Leads (DFLs). These user journeys are crucial as they form the foundation for designing a user interface that fully supports the specific needs and workflows of its users.

For **CREs**, the journey was enhanced to better support their role in fault detection and resource dispatch. Dashboards now provide real-time data on weather conditions and fault predictions, allowing them to anticipate and manage issues more effectively. Key tools, including the Licence Area Dashboard, Fault Detail Pop-Up, and District Dashboard, were refined to streamline fault monitoring and improve communication with DFLs.

DFLs' journeys were tailored to improve decision-making in resource deployment, incorporating features like the Resource Calculator and Forecast Quality Assessment, allowing them to assess fault severity and allocate resources more accurately using historical data and forecast reliability.

EACs, who oversee coordination during extreme weather events, saw updates to their journey with tools such as the Similar Events Carousel and Weather Event Report, helping them compare current and historical weather conditions to make informed decisions about resource mobilisation across multiple districts.

These tailored refinements to user journeys significantly reduced manual tasks, optimised decision-making processes, and enhanced team collaboration.

Comprehensive Feedback from User Interviews

Beyond just improving user journeys, the feedback from Control Room Leads, District Leads, and other key stakeholders during the Beta Phase also directly informed several key improvements to the platform.

These changes have been implemented to align the platform more closely with the real-world needs of Control Room operations and fault management. The critical areas reviewed during these interviews along with actions undertaken in response are outlined below:

Key Areas Reviewed:

1. Fault Bands

- **Discussion:** A Control Room Manager at SPEN noted that some thresholds seemed a bit high considering operational constraints, and discussions were held about the right thresholds to adequately differentiate between low- and high-risk periods.

- **Actions Taken:** The P4R Team performed a percentile-based analysis (Q33%, Q66%, Q99%, Q99.9%) to recalibrate the fault band thresholds before adjusting them to enhance clarity between amber and red bands. These changes were implemented across both the 24-hour and 6-hour forecasts and validated by the Control Room Manager.

2. Fault Data Post-Processing

- **Discussion:** A Control Room Manager at SPEN explained that when a storm takes place, faults are often recorded a few days after they actually occurred.

- **Actions Taken:** The P4R Team developed a fault post-processing algorithm that attributes faults to the date they occurred, not when they were recorded. See Section 3 for more detailed information on this adjustment.

3. User Rights & Roles

In the P4R platform, various user roles are defined to accommodate different access levels and responsibilities. Here is a comprehensive overview of these roles. Changes made in the Beta Phase are listed under "Actions Taken."

a. **User:** Basic user with read access to all pages, including dashboards, weather events, simulators, and model performance.

b. **Super User:** An advanced user capable of creating and editing weather events, modifying fault band thresholds, adjusting resource parameters, and managing user permissions, including granting or removing "Super User" status.

c. **IT Admin:** Manages the platform's technical aspects, including user access, permissions, and all CRUD (Create, Read, Update, Delete) operations.

d. **Control Room:** Limited to read-only access via Control Room TVs, ensuring operators can view critical real-time data without making changes.

- **Discussion:** The P4R team worked with a Control Room Manager at SPEN to identify necessary roles for efficient operation across DNOs. These roles were introduced and refined during the Beta Phase to ensure appropriate rights management across users.

Actions Taken

- **IT Admin Role:** Introduced to manage user access and permissions.

- **Super User Role:** Super Users gained the ability to modify fault band thresholds and adjust resource parameters based on district needs.

- **User Role:** Regular Users can use all the functionalities of the solution but don't have access to the configuration.

4. Visibility of Model Performance

- **Discussion:** There was a discussion regarding whether model performance metrics should be visible to all users or restricted based on user roles.

- **Actions Taken:** During the Beta Phase, it was decided that all users would have access to model performance metrics. Depending on user feedback from business trials, access restrictions may be implemented later.

5. New Designs and Quick Wins

- **Discussion:** The P4R Team discussed new features to improve user experience within the P4R solution with a Control Room Manager at SPEN.

- **Actions Taken:** Based on user feedback, several quick wins were implemented in Beta to further refine the user experience:

Detailed Fault Table: The fault table was updated to include an additional row of information that provided greater detail on fault probability at the district level, improving transparency and aiding operational decision-making.

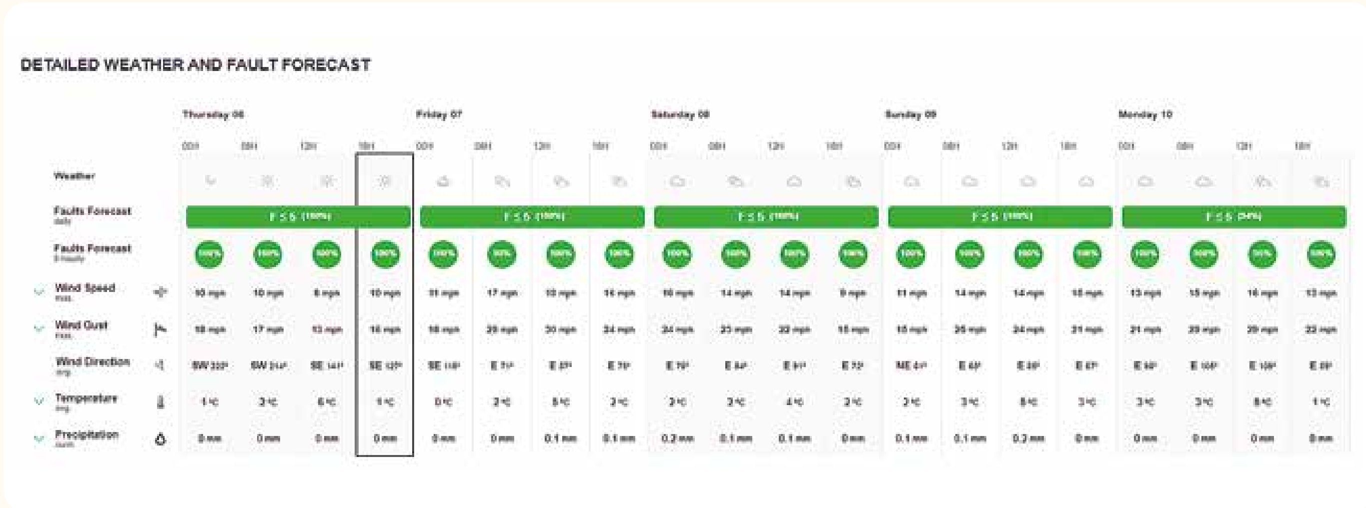

FIGURE 7: DETAILED FAULT AND WEATHER FORECAST TABLE

District Dashboard KPI Banner: A KPI banner was added to the district dashboard. This improvement helps users track critical metrics at a glance, such as fault occurrences and weather KPIs. It also explicitly displays weather conditions on an hourly basis, while faults are shown over a six-hour period for clearer operational insights.

FIGURE 8: DISTRICT DASHBOARD KPI BANNER

Weather Event Page KPI Banner: The weather event page was redesigned to include a new KPI banner for better visibility of key weather variables impacting fault predictions.

FIGURE 9: WEATHER EVENT PAGE KPI BANNER

Future Enhancements in Development

Based on the insights gathered from these user interviews, the P4R platform's roadmap includes several key future enhancements.

These improvements directly address the needs and challenges identified during the interviews, ensuring that the platform continues to evolve in alignment with user requirements. The following enhancements are on the P4R roadmap and aim to further refine the system's accuracy, improve operational visibility, and enhance overall functionality in preparation for extreme weather events.

1. Substation Visibility

Based on feedback already captured, a new map layer displaying critical or all Primary substations, Bulk Supply Points (BSPs) and Grid Supply Points (GSPs), is being developed to improve operational planning and infrastructure visibility.

2. Asset Health

Plans were made to integrate circuit health data into the fault prediction model. This addition will enhance storm readiness by factoring in the varying conditions of circuits, providing a more accurate prediction of fault vulnerability.

Live Trials and User Feedback

Feedback from Live Trials:

The Live Trials, running from Winter 2024 to Summer 2026, are essential for refining and validating the P4R platform. Designed to test the system's performance during both extreme weather events and BAU operations, the trials aim to ensure the platform aligns with the real-world needs of its key users.

These trials will allow the P4R Team to simulate real-world user journeys and gather critical feedback to refine platform features and enhance operational workflows. They are designed to meet several key objectives:

- **Validating User Journeys and Product Design:** The trials will observe how users, including CREs, EACs, and DFLs, navigate through the platform in real-time scenarios. By tracking their workflows in both routine and emergency situations, the trials will ensure that the platform is designed around the specific needs of its users. This hands-on approach will help refine user journeys, ensuring solution features are optimised for efficiency and ease of use.
- **Translating User Feedback into Continuous Improvement:** The trials will act as a feedback loop, allowing the Team to adjust platform features like dashboards, weather forecasts, and resource allocation tools. This direct engagement with users ensures that the platform evolves continuously based on real-time user experiences.
- **Confirming and Refining Understanding of User Needs:** As the trials progress, feedback will provide deeper insights into user needs that may not have been identified in earlier development phases. This iterative approach enables ongoing adjustments to features like fault prediction and resource mobilisation, ensuring the platform adapts to operational realities.
- **Assessing Forecasting Models:** The trials will evaluate how well the forecasting models perform operationally and highlight areas for improvement to continuously enhance the model's accuracy.
- **Leveraging Forecasts for Decision-Making:** The trials will assess how users utilise these forecasts to inform and support operational decisions, ensuring the platform optimally supports proactive management.
- **Minimising User Burden and Avoiding Duplication of Effort:** A key objective is to reduce user workload by automating processes and offering an intuitive interface. The trials will test how well the platform simplifies workflows, streamlines decision-making, and prevents redundant efforts. The goal is to ensure P4R serves as an all-in-one tool for fault management, offering clear, practical insights without overburdening users.

Key Aspects of the Trials

Training for Trials:

Extensive training has been provided to all users during the trial phase. This training aimed to ensure that users fully understand how to use the platform, interpret fault forecasts, and engage with the user interface. This preparation is essential for users to provide meaningful feedback on the platform's usability and functionality, which will be critical for making final adjustments before full deployment.

The P4R Team has delivered five training days across Prenton (September 4th-5th, 2024) and Glasgow (September 18th-19th, 2024) covering a range of critical topics related to the P4R platform. The sessions generated significant interest among future users, leading to the addition of an extra training session in Glasgow on October 22nd 2024 to accommodate more participants.

Feedback Mechanisms:

The trials are fundamentally user-centric. By focusing on the operational workflows of users, they will ensure that the platform seamlessly fits into their day-to-day operations. This approach is designed to improve decision-making, fault management, and resource allocation during both normal and extreme weather conditions.

1. **Live Feedback Via UI:** Users can submit real-time feedback, report bugs, or ask questions directly through the user interface. This allows for immediate reporting of issues and suggestions, creating a direct communication line with the development team. It ensures that feedback related to usability or any technical issues can be swiftly addressed.

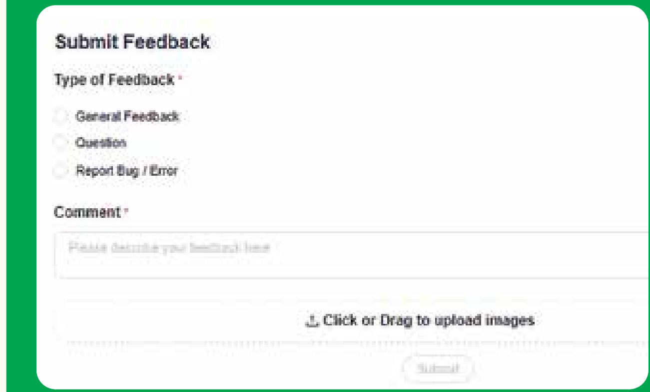

FIGURE 10: FEEDBACK FORM VIA USER INTERFACE

2. **Weather Event Feedback Forms:** During storm events, teams will collaboratively complete feedback forms to capture insights and reactions from the field. These forms allow the collection of data on how well the solution performed in real-time crisis situations, and what improvements might be needed for forecasting, user interface, or resource management. This is a crucial aspect for refining the system based on real event outcomes.

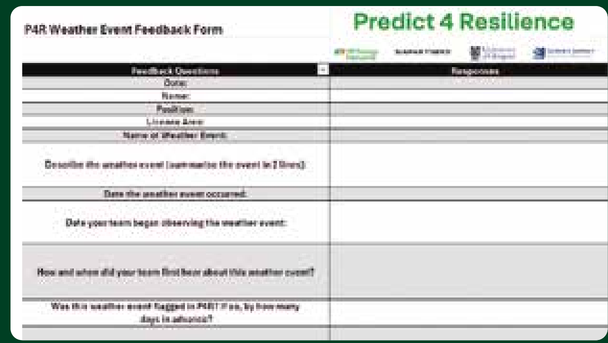

FIGURE 11: WEATHER EVENT FEEDBACK FORM

3. **Monthly Feedback Forms:** A structured monthly feedback process ensures that ongoing operational use is continuously monitored. Users will provide feedback on their experiences, which will be reviewed by Sia Partners and discussed in monthly meetings. This mechanism ensures that the tool's performance during non-storm periods is also optimised, making it a continuous improvement process.

The Beta phase of the P4R platform has been pivotal in its development, emphasising direct user engagement and iterative improvement. By prioritising a user-centric approach, the P4R team has effectively incorporated critical feedback from key stakeholders, ensuring the platform aligns with the specific needs of its core users. These enhancements have strengthened the platform's functionality.

FIGURE 12: MONTHLY FEEDBACK FORM

Lessons Learned

1. **Continuous User-Centric Development**
One of the primary takeaways from the Beta Phase has been the importance of a continuous, iterative user-centric approach. The feedback loop established through direct engagements has been crucial in ensuring that the platform meets the specific operational needs of all user types.
2. **Flexible User Roles and Permissions**
Enhance Operational Efficiency Feedback from various user types highlighted the importance of flexible user roles and permissions. This insight led to the refinement of distinct roles in the Beta Phase, ensuring that each group had the appropriate level of access and control over the platform.

Section 9: Impacts and Benefits

Expected Benefits of P4R for Adoption

By accurately predicting how many and where network faults are likely to occur up to 5 days in advance, P4R will enable teams of engineers to be proactively placed in those areas most likely to be impacted.

This is expected to lead to a reduction in travel time for those faults where an onsite presence is required and enable power supply to be restored sooner than is currently possible, minimising disruption for customers to bring about financial, social and environmental benefits.

These benefits were assessed and calculated as part of the Alpha Phase as part of the Benefits Case as well as for the Beta Application for funding. Since the Beta Phase began 12 months ago, the priority has been the development of the platform, and the fault forecast engine that sits behind it. Part of this process has involved in-depth user engagement during the design phase as well as detailed conversations with a broader audience of end users during the Training Sessions held prior to the start of the Live Trials in SPM and SPD.

The outcome of these various interactions with the end users within the businesses have validated the assumptions that were made during the benefits assessment previously and no new benefits have been identified.

Cost Savings to Consumers (£m)

A loss of power supply increasingly inconveniences individuals and businesses, especially the vulnerable and with working from home becoming more prevalent. Living without modern conveniences can cause anxiety, with appliances' battery life diminishing, particularly for the medically dependent. Places of work may be closed, causing lower-income families further stress because of lost wages. P4R's social benefits were calculated by multiplying the expected CML savings from P4R by the societal CML value in the CBA provided by Ofgem/UKRI.

Cost Reductions in Operating the Networks and Wider Energy System (£m)

CML Savings: DNOs are set targets for the number of unplanned CMLs on their networks (the outage duration multiplied by the number of customers affected). Performance against these targets is linked to financial rewards and penalties. Having resources strategically positioned ahead of time in those areas most likely to be impacted will lead to a reduction in outages which in turn creates a financial CML payment saving to the DNO. It is worth noting that these figures do not include extreme weather events which are excluded from the incentive mechanism.

Guaranteed Standards of Performance (GSP) Savings: GSP sets out how quickly DNOs must restore power following an interruption in supply. Should DNOs not meet these standards, customers are entitled to statutory compensation. With quicker restoration, some customers' outage duration will therefore be brought under a GSP time threshold, creating a financial saving to DNOs.

Storm Support: As part of DNO's Storm Support, they may provide meal vouchers, alternative accommodation (e.g. hotels) and warm packs (e.g. hats, gloves, blankets, torches etc.) to customers who are off supply for extended periods. P4R will drive a reduction in the need to provide Storm Support to affected customers, creating another financial saving to DNOs.

Fuel Savings: When power supply restoration is anticipated to be longer than usual, DNOs will provide onsite diesel generators to supply back-up power to its customers while that fault is repaired. P4R will result in both a reduction in the need to provide a generator as well as shortening any time they are required. A reduction fuel consumption creates a financial saving to DNOs.

Carbon Reductions - Direct or Indirect (MTCO2e)
Renewable generators need a reliant connection to the network to operate and sell their electricity. Long network outages therefore prevent renewable generation accessing the grid with potential carbon impacts. Additionally, as part the Storm Support, when any power restoration is anticipated to be longer than usual, DNOs aim to provide onsite diesel generators to supply back-up power to its customers while that fault is being repaired. Given P4R is expected to deliver a potential improvement to those restoration times, it was expected that this should result in both a reduction in the need to provide a generator as well as shortening any time they are required. This reduction diesel has an associated carbon emission reduction benefit.

Assessment of the Benefits

During previous phases of the project, the Benefits Case for P4R was calculated and refined at several junctures. The benefits were modelled using actual SPEN fault data from the last 5 years and only weather-related faults included within the assessment. Additionally, given different network faults could result in a range of different restoration profiles (depending on the type of fault and network architecture), only those faults where an individual is required onsite before restoration can be completed were assessed (any faults where switching is performed offsite were excluded as P4R is not expected to provide any benefits in these use cases).

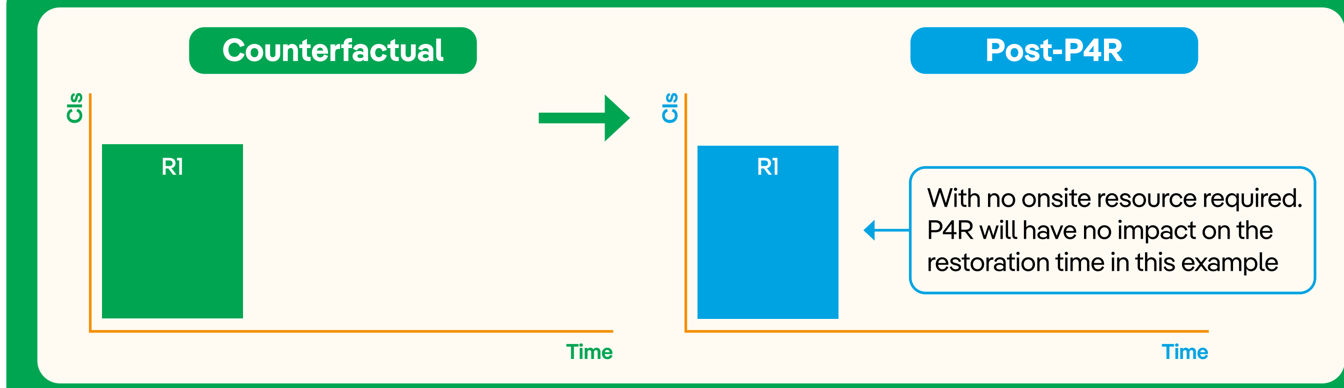

FIGURE 13: EXAMPLE OF A FAULT RESTORATION PROFILE WHERE P4R WOULD HAVE NO IMPACT DUE TO THE ABILITY TO RESTORE POWER REMOTELY

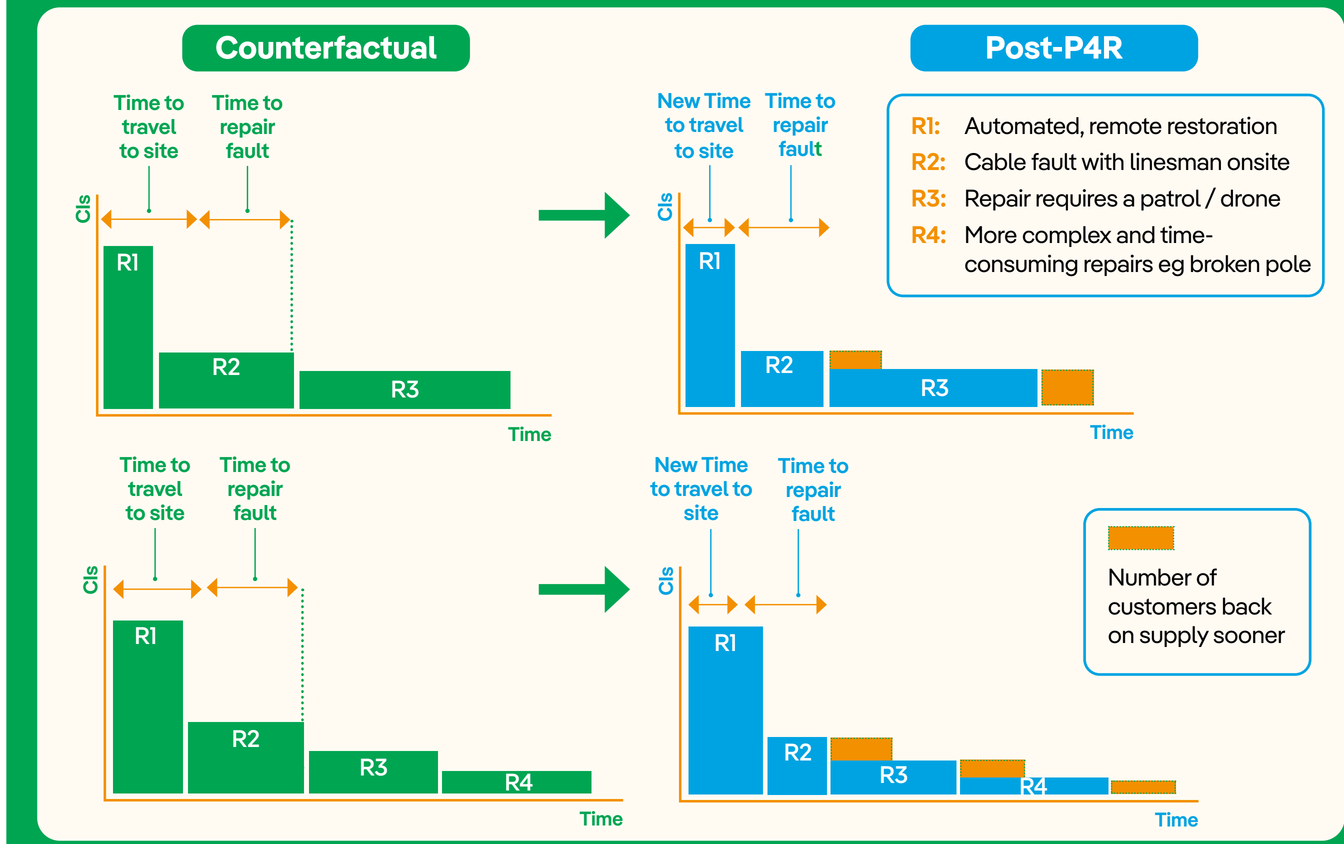

FIGURE 14: TWO EXAMPLES OF FAULT RESTORATION PROFILES WHERE AN ONSITE PRESENCE IS REQUIRED

The calculation of the potential benefits of P4R focused on the premise that the platform will enable teams of engineers to be proactively placed in those areas most likely to be impacted and therefore lead to a reduction in travel time for those faults.

Having established those faults where P4R would enable an earlier restoration time, the size / scale of that time saving was applied to potential benefits. The impact of the new restoration time was modelled for the relevant faults and the new value compared against the counterfactual.

Changes Since the Beta Submission

As developed earlier in this section, the bulk of the work carried out over the first 12 months of the project has been to develop the P4R solution, in line with refined user needs, and its fault forecast engine in preparation for the start of the Live Trials in Autumn 2024. Additionally, given the solution is not yet in production nor generating any benefits to its users, there has been limited focus on recalculating the benefits as tracking them is not yet possible.

The one significant change from the Beta submission is the likelihood that the project will not be able to capture any benefits during the first trial phases. During the submission, it was estimated that the benefits for SPEN Trial Phase 1 would be 25% of those generated during Business as Usual and SPEN Trial Phase 2 would be 75%. However, after further discussion with the Control Room and other related business functions at SPEN, the decision has been taken that given P4R will not actively drive decision-making for how the network responds to potential inclement weather. Instead, during the first Winter Trial session, the Control Room will continue to utilise existing sources of information while also monitoring the outputs of the platform, providing feedback to the project team around the UX and suitability of the fault bands, as well as the model performance. The performance of P4R will be assessed at the end of the first Winter trial and inform the strategy to the next Business Live Trial session. The benefits associated with the Summer trial session and further trial sessions will be reevaluated in time. Those will be highly linked with P4R demonstrating its performance over a sustained period and give the network the confidence to move away from more traditional methods of estimating the fault impact.

While not a benefit per se, it is worth noting how positive the response to the solution has been from staff within the business who were previously unaware of P4R and who had not been involved in prior stages. The engagement during the training sessions and the early feedback from future users has been encouraging and provides us with confidence that the tool will be utilised by the Control Room in the future, displacing previous methodologies and thereby generating the proposed benefits outlined in the Beta Submission.

Section 10: Risks, Issues, and Constraints

Risk management has been a key focus for project partners, enabling them to identify, assess, and mitigate potential obstacles that could slow progress. Acknowledging that innovation inherently involves uncertainty, the partners have actively embraced risk management to anticipate challenges and develop proactive solutions.

By systematically evaluating risks, they have efficiently allocated resources, made informed decisions, and maintained project momentum despite unforeseen issues. This proactive approach has fostered a culture of resilience and adaptability among partners, ensuring that creative ideas are pursued confidently, resulting in stronger outcomes.

To enhance risk governance, the project management team employs a comprehensive and structured approach to risk logging and management. Risks are systematically logged, shared amongst the project team weekly and monthly and shared with the SteerCo and UKRI on a quarterly basis, ensuring transparency and alignment. Monthly meetings among project partners include thorough discussions of the risk register, where new risks are comprehensively reviewed and existing risks are closely monitored. These discussions ensure that all relevant aspects are addressed, allowing for robust management of risks on a continuous basis. Throughout the development of the P4R solution in 2023 and 2024, the most significant risk was ensuring readiness for the Live Business Trials in Autumn 2024, a critical phase for testing P4R in a live Control Room environment within SPEN. Any delay would have severely impacted readiness for the high-impact storm season in the UK. Early in the project, resource allocation and budget management were key concerns, particularly with the use of part of the **£150,000** contingency fund to cover essential improvements. This was necessary to ensure that the project stayed on track for the critical October 2024 milestone. Currently, **£28,000** remains in contingency, and as the majority of development work has been completed, no further delays are expected.

Additionally, given the importance of ensuring that the solution was fit for purpose ahead of being deployed in a live environment, during the Beta submission the project team had put in place a Stage Gate to ensure that the solution had appropriate approvals from both the SPEN internal business and UKRI/Ofgem. If the Success Criteria were not met, there were possibilities of project delay and even termination.

As such, during this build phase of the project, most of the risks of most significant impact were related to the workflows associated with ensuring the solution was ready for the trials. To mitigate these risks, the project team proactively managed them on a weekly basis as part of its Project Management workstream, communicating with UKRI/Ofgem and briefing SPEN internal stakeholders as necessary throughout the project to receive steering and guidance.

Clearly defined Success Criteria for the Stage Gate were also established through a collaborative process across all delivery partners and shared with UKRI/Ofgem for their approval. The project team were able to demonstrate they had fulfilled all the Success Criteria and received an Unconditional Pass, the highest score in the rating system, from UKRI/Ofgem.

Ongoing and Closed Risks

As of October 2024, the risk register identifies several ongoing risks, while a number of significant risks have been successfully closed. Examples of closed risks include:

- **Development Delays:** Early delays related to contract finalisation and resource onboarding were mitigated by reallocating resources and using contingency funds, ensuring key milestones were met.
- **Integration of Features:** Risks related to the integration of key technical features, such as live weather forecasting, were addressed through phased rollouts and testing, ensuring the platform's functionality.

Examples of ongoing risks (subject to constant monitoring) include:

- **Commercial Strategy Risk:** A delayed or inadequate commercial strategy could affect the solution's rollout. An updated strategy is being prepared, with discussions planned following the winter trial performance review.
- **Contingency Activation Risk:** With **£28,000** remaining in the contingency fund, there is limited financial flexibility for future changes. However, with most development complete, the risk of needing additional resources is low.

Further Training Risk: Inadequate user training could affect feedback during trials. This is mitigated through additional training sessions and clear communication, with potential BAU support for further training.

All ongoing risks are classified as low likelihood, none with high impact, and are monitored weekly by the PMO team. Updates are shared regularly to ensure timely intervention, keeping the project on track.

The P4R project demonstrates the importance of proactive risk management in innovation projects. By identifying risks early and implementing effective mitigation strategies, the team ensured timely delivery and successful progress toward key milestones, particularly the critical October 2024 deadline. This structured approach not only safeguarded the project's success but also provided valuable insights for future innovation initiatives.

Section 11: Working in the Open

The Beta Phase of the P4R project has focused on transparency, clear public communication, active stakeholder collaboration, and the integration of external input.

These efforts have ensured the project meets both public interests and the technical requirements of all involved parties. In this phase, P4R has concentrated on technical improvements and strategic partnerships to prepare the platform for broader implementation.

This section outlines the methods used to ensure transparency, engage stakeholders, and apply external insights to refine the solution and guide its future rollout.

Public Communication

Ensuring that the P4R project's progress is communicated effectively to the public has been a priority throughout the Beta Phase. A multi-channel approach has been used to provide regular updates, ensuring that the project remains accessible and transparent.

Media Outreach and Traditional Channels

Press releases and media appearances have been crucial in keeping the public and stakeholders well-informed throughout the P4R project. Major media outlets, including The Independent, The Scotsman, Evening Standard, and STV News, have served as key platforms for communicating significant milestones and providing updates on the project's progress. These updates have ensured that both the technical community and the general public are kept aware of the developments, objectives, and broader implications of P4R's advancements.

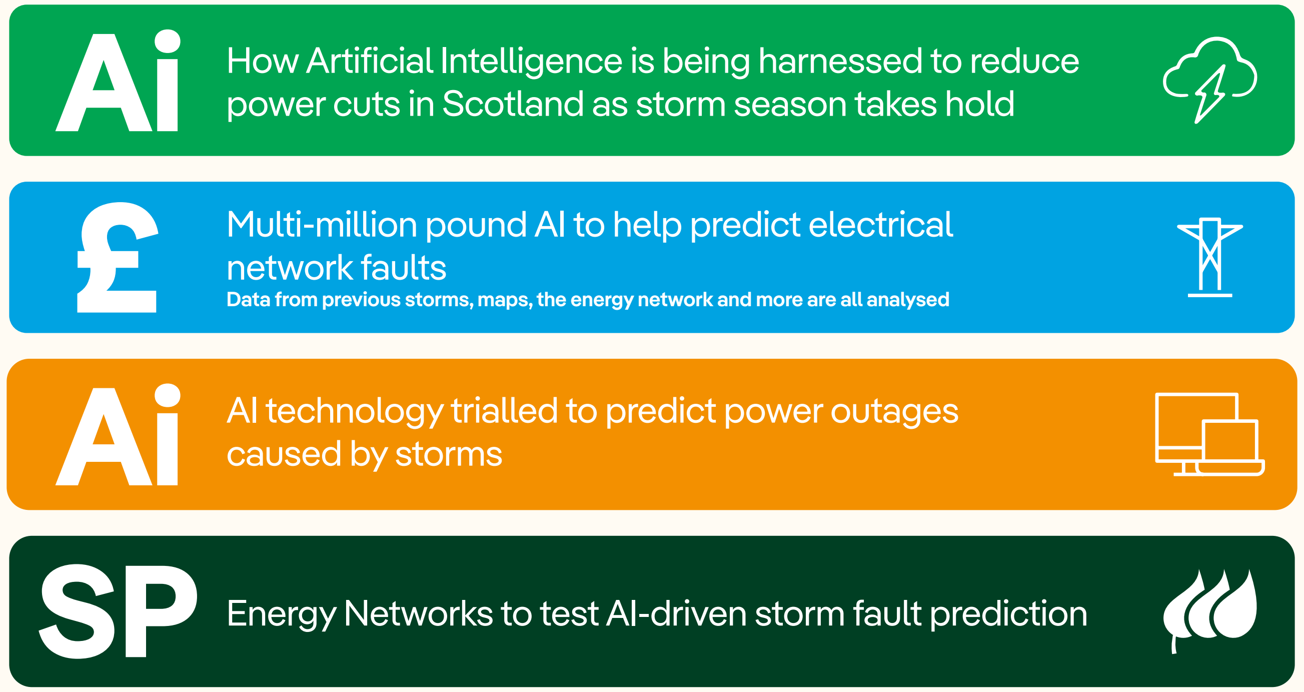

FIGURE 15: SELECTED MEDIA COVERAGE OF THE P4R SOLUTION

In addition to traditional press engagement, as part of the Project Specific Conditions stipulated within the SIF process, the P4R project team produced a 60-second promotional video designed to simplify and communicate the project's goals to a wider audience. This video ensures that the technical aspects of the project are accessible and understandable for non-specialist audiences, while still conveying the project's significance and impact.

For more information, please see Addendum B - P4R Video in the Appendix Attachments Folder.

Industry Conferences

At the 2023 Energy Innovation Summit, P4R was featured in a poster session, providing an opportunity for direct engagement with stakeholders. Organised by the Energy Networks Association in partnership with Ofgem, the summit is the UK's flagship event for energy system innovators and network operators. During this session, representatives from UK Power Networks (UKPN), National Grid Electricity Distribution (NGED), and Northern Power Grid (NPg) were among those who expressed interest in the solution, asking questions and requesting to be kept informed of its development. Approximately a dozen individuals engaged with the team, highlighting the significant interest in P4R's capabilities. Prior to the Beta phase, SSEN and Electricity North West (ENWL) had already expressed interest in joining as key partners, further underscoring the demand for P4R's fault prediction capabilities.

At the Actuary Convention, P4R was presented to an audience of approximately 50 participants, with 5-10 individuals engaging directly with project representatives to enquire about the solution's applicability across various sectors and user groups. This interest has demonstrated the solution's broad appeal and its potential for cross-industry implementation.

P4R was also presented at the 44th International Symposium on Forecasting (ISF), held in Dijon, France, from June 30 – July 3, 2024. This premier international forecasting conference provided a unique platform for the P4R team to interact with leading forecasting researchers and practitioners. The ISF attracted participants from around the world, creating a valuable networking environment through keynote presentations, workshops, and academic sessions. P4R's presence at the event highlighted its cutting-edge fault prediction technology and allowed for meaningful exchanges with global forecasting experts.

In addition to the presentation at the ISF, an academic paper is being drafted to expand on the technical report produced at the conclusion of the Alpha phase. This paper will enhance transparency by providing detailed methodologies, models, and results, ensuring accessibility to both the academic and broader public communities. It aims to facilitate external feedback, contribute to industry advancement, and promote collaboration, while helping to prevent duplication of efforts.

The project team is also preparing for a key presentation at the upcoming Energy Innovation Summit in Liverpool this Autumn. The 2024 summit will focus on the theme of "Accelerating Innovation to Deliver Net Zero" and is expected to attract leading figures from across the energy industry. P4R will be presented within the event's agenda with a demonstration of P4R at the SPEN Stand throughout the event.

The Energy Innovation Summit will provide a platform for over 100 innovation projects led by energy networks to be showcased, making it a key opportunity for P4R to demonstrate its cutting-edge solutions to a wide audience. By presenting at this event, P4R will continue to engage with key stakeholders, network decision-makers, and innovators.

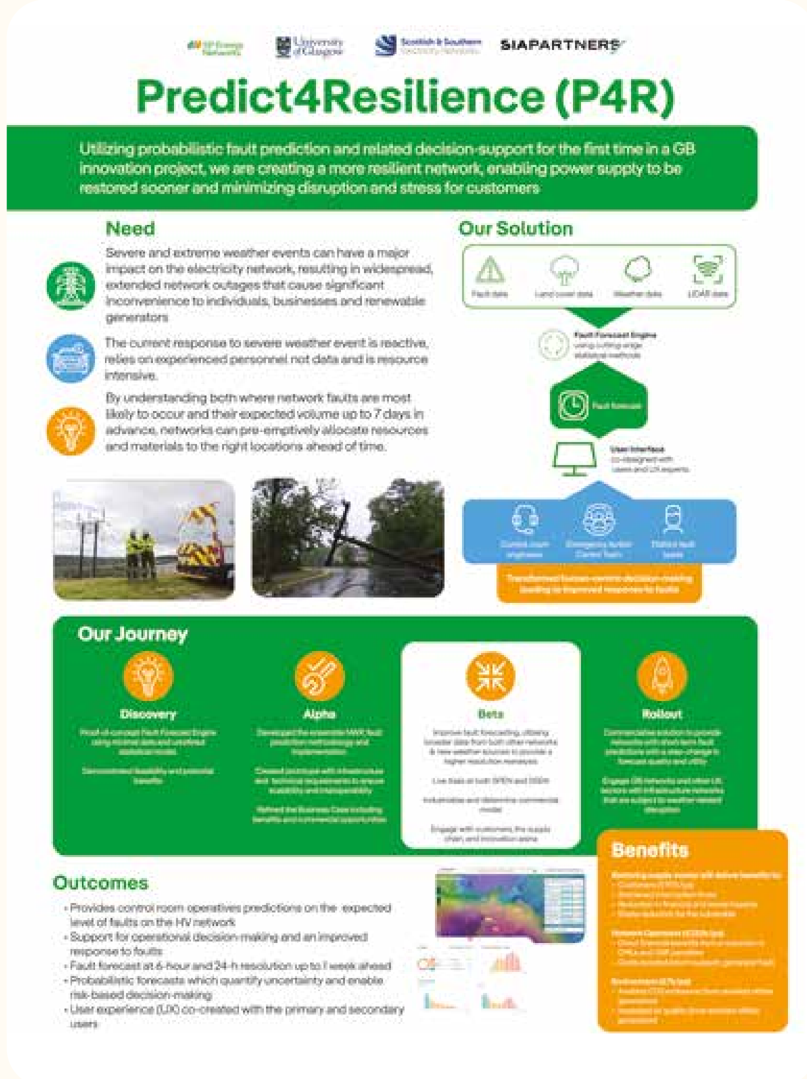

FIGURE 16: POSTER SESSION ENGAGEMENT AT THE ENERGY INNOVATION SUMMIT, 2023

Sharing Learnings and Preventing Duplication

One of the key goals of the P4R project is to ensure that lessons learned are effectively shared across the industry to avoid duplicative efforts and streamline progress on related initiatives. P4R has focused on sharing its findings widely. This approach allows the energy sector to innovate more rapidly and efficiently.

One of the key future collaborations being developed is with CReDo+, another SIF-funded project that focuses on mitigating risks of electricity supply disruption due to climate change. CReDo+ is particularly interested in how P4R's use of weather data and fault prediction models can support its mission. Preliminary discussions have already taken place, and the collaboration will begin in earnest in January 2025. This partnership will allow both projects to share insights on climate impacts, ensuring that they build upon each other's findings and avoid repeating efforts in predictive modelling and fault management.

Similarly, P4R is also partnering with the Predictive Safety Interventions (PSI) project, which aims to improve safety in the utilities sector by leveraging advanced AI technology for real-time safety assessments. PSI has already seen significant success, achieving a 20% reduction in safety events through AI-driven video risk assessments. The two projects will commence joint "Lessons Learned" knowledge-sharing sessions this autumn. These sessions will focus on fostering continuous improvement by sharing insights on AI-driven data analysis, ensuring both projects can evolve without duplicating past work. The collaboration between P4R and PSI will provide valuable cross-sector learnings, particularly around the safe deployment of AI technologies in field operations.

Moreover, to avoid duplicating efforts across the DNO ecosystem, P4R has actively collaborated with key stakeholders and project partners, SPEN, SSEN, along with and other GB DNOs, to ensure that the solution is informed by real-world operational needs. The feedback loop established through live trials and stakeholder engagement has not only refined the P4R platform but also provided a framework for integrating new use cases and insights from across the sector. This approach mitigates the risk of redundancy by incorporating the lessons learned from other DNOs and adjacent sectors.

By fostering these collaborations and actively sharing findings, P4R ensures that new developments in fault prediction and network resilience are complementary rather than repetitive.

International Stakeholder Engagement

The project has also engaged with international stakeholders, including Horizon Power in Australia, where demonstrations of the platform showcased its capabilities to a wider audience. This international outreach has strengthened P4R's position as a leader in fault prediction and network resilience while fostering valuable collaboration across the energy sector.

Lessons Learned

7. **Early and Continuous Engagement**
   Actively involving stakeholders from the beginning of the project ensures that their insights and needs are considered throughout the development process. This practice enables timely adjustments to project strategies based on real-time feedback and changing circumstances. Implementing regular check-ins and interactive workshops can further enhance this engagement.

8. **Champion-Led Integration** Designating Champions to oversee the transition to BAU operations has proven effective. These Champions help facilitate smoother integration of the solution into existing processes and can advocate for the project, gather internal support, and provide crucial insights into operational challenges.

9. **Transparency and Collaboration**
   Maintaining open lines of communication and collaboration with technical experts and stakeholders is vital for continuous platform refinement. This approach allows for the sharing of best practices, challenges, and innovations across the project landscape. Establishing dedicated forums or platforms for stakeholders to share experiences and insights can enhance collective knowledge and drive continuous improvements.

10. **Structured Learning Framework**
    Creating a structured framework for capturing learnings during live trials is essential. This framework should include methodologies for documenting insights, challenges encountered, and successful strategies employed. By formalising the process of knowledge sharing, future projects can benefit from a comprehensive repository of lessons learned, which can inform decision-making and enhance overall project resilience.

Section 12: Costs and Value for Money

The P4R Beta application was submitted in May 2023, with the project originally planned to start in July 2023. However, delays in contract signings between partners pushed the official start date to November 2023. This resulted in a review of the budget and forecasted costs at the beginning of the operational start of the Project in November 2023.

By the end of Q4 2023, the project was under budget by 5%, primarily due to the delayed start and adjustments in resource planning. The focus during this period was on setting up the program, mobilising teams, confirming the design with SPEN operational users, and beginning development on the technical infrastructure and data upload.

In Q1 2024, as resources ramped up, the project returned to its expected budget. A key development in Q2 2024 was the approval of a Change Request, reallocating **£122,275** from contingency funds to ensure the necessary resources were allocated to the development of the P4R solution to make it available in time for upcoming trials. The focus shifted to two areas: improving post-processing and model performance and enhancing the interactive map for better user experience. Significant progress was made in automatic fault forecasting, UX refinement, and building an improved version of the interactive map.

By Q3 2024, efforts were concentrated on finalising the platform ahead of the Business Live Trials starting in October 2024. This involved connecting the front-end to key data sources, improving forecast efficiency, training users, and preparing the Annual Report for submission.

Total Project Expenditure

The project expenditure has been adjusted since the Beta application. As of October 2024, it reflects the material changes (see Section 14: Material Changes). The updated project expenditure is detailed as follows:

Project Partner Name	SIF Funding Requested	Total Project Cost	Total Project Contribution
SP Transmission plc	£360,000	£400,000	£40,000
Scottish Hydro Electric Power Distribution plc	£329,152	£365,725	£36,572
University of Glasgow	£463,060	£514,511	£51,451
Sia Partners UK plc	£2,781,225	£3,090,250	£309,025
SP Distribution plc	£584,887	£649,875	£64,987
Total expenditure	**£4,518,324**	**£5,020,361**	**£502,035**

TABLE 1 - FINAL PROJECT EXPENDITURE PER PARTNER

Forecasted versus Actual Spend

Overall, there have been no significant variations between the planned and actual spend during the first year of the Beta phase at project level. The project has seen an underspend of **£65,672**, which corresponds to 2.7% of the budget for the first year. Over the first year, the effort has focused on developing the solution to high standards and make this available to Business users for the start of the Business Live Trials in October 2024. The budget was reflective of those activities.

-£65,672

Project Underspend in the First Year of The Beta Phase at project level

At partner level, SP Transmission recorded an underspend of **£23,959** against its forecast, largely due to a longer than expected absence from a staff member. In their absence activity has been covered by other resources at SP Transmission and by resources at Sia Partners.

SP Distribution recorded an underspend of **£53,286** compared to its forecast, but the collaborative efforts between Business and Technical teams led to the successful development and deployment of a robust solution. While User Acceptance Testing was accelerated, the Business Live Trials were postponed from September to early October. As key users begin engaging in the Live Trials of P4R, activity is expected to increase. Once initial results are available, SPEN's internal stakeholders will review performance and initiate commercial discussions. Additionally, upcoming knowledge dissemination events and meetings with other SIF projects will further drive engagement.

SSEN recorded an underspend of **£14,160** against its forecast. This is in line with the budget reforecast and the delay of scoping SSEN-specific features for P4R. Delivering a fully useable, stable version of P4R available for the Live Trials in October 2024 was prioritised by the project Steering Committee. The plans for SSEN to be onboarded have not been impacted by this decision and the project expects to be back on budget over the next period.

The University of Glasgow is in line with its revised budget following the arrival of new resources to strengthen the existing team of Senior researchers.

In contrast, Sia Partners has recorded an overspend of **£24,144**. This represents ~1.2% of overspend over the first 12 months of the project. The first year also represents 2/3 of Sia Partners' total budget which focuses largely on Solution development. As the project progresses, this variance will be corrected, and the project team will ensure that spending remains on track and manageable within the broader project budget, while delivering all expected activities.

Project Partner Name	Total Forecast Project Spend to Date	Total Actual Project Spend to Date	Variance in Project Spend to Date
SP Transmission PLC	£110,530	£86,571	-£23,959
Scottish Hydro Electric Power Distribution PLC	£31,876	£17,716	-£14,160
University of Glasgow	£102,764	£104,352	£1,589
Sia Partners UK p/c	£2,061,033	£2,085,177	£24,144
SP Distribution PLC	£111,555	£52,385	-£59,171
Total expenditure	**£2,417,758**	**£2,346,201**	**-£71,557**

TABLE 2 - FORECASTED AND ACTUAL SPEND TO DATE PER PARTNER

Section 13: Special Conditions

In this section, a summary has been made on the fulfilment of the special conditions.

Condition 1
The funding party, Scottish Power Transmission PLC (SPT), did not spend any SIF funding rewarded for this project before the contract signing in November 2023.

Condition 2
Financial Contribution: SPT has reported the financial contributions made to the project as set out in the Beta application.

Condition 3
Meeting Arrangements: SPT and the project consortium have participated in all meetings related to the Project that they are invited to by Ofgem/UKRI/DESNZ during the Beta Phase.

Condition 4
Stage Gate Scoping: SPT and the project partners, with the support from UKRI/Ofgem, has passed the project's first stage gate on 7th August 2024 with an unconditional pass which is the highest rating in the grading framework. For the next stage gate planned before Summer 2026, the project team will continue to work with UKRI/Ofgem to establish the success criteria in order to fulfil all the requirements to pass the final stage gate.

Condition 5
Impact Monitoring: SPT and project partners will produce a Project Impact Monitoring and Evaluation Plan, as part of the end of Project Phase report. The project team will put in place a plan for conducting this work once UKRI/Ofgem issues guidance on this.

Condition 6
SIF Community Forums: SPT representatives and project partners attended the SIF Community Forum on 8th February 2024 in Newcastle. The project team will continue to participate in future community forums throughout the duration of the project.

Condition 7
Policy, Regulatory and Standards Barriers: SPT and the project partners haven't identified any policy, regulatory or standards barriers. The project team will update UKRI/Ofgem on any regulatory, policy and standards barriers and any change requirements which may impact delivery of the Beta Phase activities. Please refer Section 7 in this report regarding this condition.

Condition 8
Updated 60–Seconds Video: SPT, with the support of the project partners, have submitted an updated 60-seconds video at the beginning of Beta Phase of P4R in 2023. Because the project duration is longer than 24 months, the project team will provide another updated 60-seconds video at the project's mid-point meeting. As a part of the end of phase report, the project team will also provide the final updated 60-seconds video.

Condition 9
Post – Beta Phase Roadmap: SPT and the project partners have provided the Monitoring Officer a Post-Beta Phase roadmap within six months of the contract signing. SPT will provide an update on this to the Monitoring Officer every six months at the Quarterly Monitoring Meetings. A final updated version of this roadmap will be submitted as an attachment to the end of phase report.

Condition 10
Commercialisation Strategy: A draft Commercialisation Strategy has been submitted by the project team in July 2024. SPT and the project partners will update the Monitoring Officer on the Commercialisation Strategy every six months at the Quarterly Monitoring Meeting. SPT will include a final update of the Commercialisation Strategy as an attachment to the end of phase report.

Condition 11
Data Best Practice and Digital Strategy and Action Plan Guidance Alignment: SPT and the project partners have provided a response on Data Best Practice and Digital Strategy and Action Plan Guidance alignment in the slides presented at the second Quarterly Monitoring Meeting. Please refer to Section 5 of this report on the Data Access Details.

Condition 12
The **'WARN'** Project was not selected to receive SIF Funding at the Alpha Phase, therefore the P4R project team didn't engage with the team behind the **'Warn'** Project.

SP Energy Networks

Section 14: Material Changes

Material Change Requested

During the Beta Phase of the project, a material change request was submitted and approved. The request involved transferring some of SPEN project management activities and SIF requested funding to the University of Glasgow and Sia Partners, as follows:

Increase project cost for the University of Glasgow from:

£488,537 to £514,812

With SIF funding increasing from **£439,683** to **£463,330.73**

Increase project cost for Sia Partners from:

£2,994,250 to £3,090,250

With SIF funding increasing from **£2,694,825** to **£2,781,225**

Reduce project cost for SPEN Transmission from:

£522,275 to £400,000

Reducing project partner contribution from **£52,227.50** to **£39,999.97**

Rationale for Change Request

This change request was necessary to ensure the project could deliver a working solution in time for the Live Trials scheduled for Autumn 2024. These trials are crucial for testing the solution in a live Control Room environment within SPEN, a key step before transitioning to Business As Usual. Missing this crucial winter season could mean that it is either not possible to fully test the solution over two winter seasons as planned or that an additional trial phase is added at the end of the project, adding costs and delaying the transition into BAU.

Lessons Learned

1. **Importance of Simplifying Contract Signing**
   Ensuring prompt contract approval is essential for maintaining project momentum and avoiding setback in critical phases.
2. **Complexity Management**
   Sufficient time and resources should be allocated for complex components (e.g. Interactive Map) to prevent schedule overruns.
3. **Enhanced Collaboration**
   Cross-functional teamwork can lead to better problem-solving and innovative solutions (Sia Partner's Data Scientist joining the Enhancement team).

However, significant delays occurred, largely due to a 4-month delay in signing contracts. This had an impact on the project in general but specifically led to an 8-month delay in hiring the University of Glasgow Research Assistant, as recruitment could not commence without signed contracts. This delay had a considerable impact on the delivery of the enhancement work package. Additionally, the complexity of developing the interactive weather map exceeded initial expectations and the project team also identified an opportunity to create new functionalities that would significantly improve the User Experience. However, completing these changes to the interactive map delivery plan risked the solution not being ready for the trials.

Recognising the potential impact on the Live Trials from either a delay to project start or any unforeseen challenges within the solution, the original plan and costs within the Beta Phase Submission included **£150,000** of contingency budget (**£135k** of funding and **£15k** of partner contributions) for additional resources to expedite the solution development should the project not be on track for September 2024.

The project plan was recut in November 2023 to ensure there was a clear strategy and pathway to make up for the delayed start, with additional resources (and time) allocated to ramp up workload. However, some sequences cannot be parallelised so doubling the workforce does not necessarily result in the work being done in half the time. Therefore, in Summer 2024, the P4R Steering Committee took the decision to utilise some of it reserved contingency to ensure there were sufficient resources available so that the project could deliver the solution on time.

The change request sought to allocate **£122,275** from this contingency to secure additional resources and keep the project on track for the September 2024 deadline.

Outcomes of Material Change

The change request was approved by UKRI in May 2024, allowing for a reallocation of resources, increasing the University of Glasgow team's capacity and enabling the secondment of a Sia Partners Data Scientist to the Enhancement team.

Additionally, Sia Partners was able to provide more UX Designers and Front-End Developers to improve the User Interface. As a result, the interactive map and timeline were redesigned to offer hourly weather forecasts, rather than the previously planned 6-hour intervals. This, along with research improvements on weather layer displays, significantly enhanced the user experience. The map was completed and fully functional on time for the trials, successfully integrating ECMWF weather forecasts updated four times daily. Moreover, the additional budget supported the development of an algorithm to address delayed reporting, and investigations into wind direction and precipitation led to further optimisations. A new feature for addressing lightning risks will be introduced during the Live Trials. Finally, the development of data pipelines streamlined key processes, allowing for more detailed analysis and efficient sharing of results, data, and models.

The decision to utilise some of the available contingency was instrumental in enabling the project team to complete the necessary work in time, ensuring the solution was ready in time for the Business Live Trials and therefore able to pass through the first Stage Gate.

Appendix

Addendum A - Lessons Learned

1. **Efficient Data Management:** Transitioning to the Zarr format improved handling of large datasets, reducing memory and processing demands while enhancing scalability through cloud integration and parallel I/O.
2. **Streamlined Data Processing:** Integrating Zarr with Xarray allowed for more efficient workflows by enabling large datasets to be processed without being fully loaded into memory, improving scalability and performance.
3. **Optimised Data Collection:** A data optimisation study reduced the number of collection points significantly, cutting costs while maintaining effective coverage through advanced optimisation techniques.
4. **Adapting to Delayed Fault Reporting Post-Storm:** One of the key operational challenges identified during the Alpha phase was the delay in fault reporting after extreme weather events. The Project Team learned that predictive models need to account for these delayed fault reports in resource planning, ensuring that teams are prepared for post-storm fault backlogs.
5. **Continuous User-Centric Development:** One of the primary takeaways from the Beta phase has been the importance of a continuous, iterative user-centric approach. The feedback loop established through direct engagements has been crucial in ensuring that the platform meets the specific operational needs of all user types.
6. **Flexible User Roles and Permissions Enhance Operational Efficiency:** Feedback from various user types highlighted the importance of flexible user roles and permissions. This insight led to the refinement of distinct roles in the Beta Phase, ensuring that each group had the appropriate level of access and control over the platform.
7. **Early and Continuous Engagement:** Actively involving stakeholders from the beginning of the project ensures that their insights and needs are considered throughout the development process. This practice enables timely adjustments to project strategies based on real-time feedback and changing circumstances. Implementing regular check-ins and interactive workshops can further enhance this engagement.
8. **Champion-Led Integration:** Designating champions to oversee the transition to BAU operations has proven effective. These champions help facilitate smoother integration of the solution into existing processes and can advocate for the project, gather internal support, and provide crucial insights into operational challenges.
9. **Transparency and Collaboration:** Maintaining open lines of communication and collaboration with technical experts and stakeholders is vital for continuous platform refinement. This approach allows for the sharing of best practices, challenges, and innovations across the project landscape. Establishing dedicated forums or platforms for stakeholders to share experiences and insights can enhance collective knowledge and drive continuous improvements.
10. **Structured Learning Framework:** Creating a structured framework for capturing learnings during live trials is essential. This framework should include methodologies for documenting insights, challenges encountered, and successful strategies employed. By formalising the process of knowledge sharing, future projects can benefit from a comprehensive repository of lessons learned, which can inform decision-making and enhance overall project resilience.
11. **Importance of Simplifying Contract Signing:** Ensuring prompt contract approval is essential for maintaining project momentum and avoiding setbacks in critical phases.
12. **Complexity Management:** Sufficient time and resources should be allocated for complex components (e.g., Interactive Map) to prevent schedule overruns.
13. **Enhanced Collaboration:** Cross-functional teamwork can lead to better problem-solving and innovative solutions (e.g., Sia Partners' Data Scientist joining the Enhancement team).

Addendum B - P4R Video

See Appendix Attachments Folder.

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