ARUP

Scottish Power Energy Networks

Predict4Resilience

Business Case

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Ove Arup & Partners Ltd

8 Fitzroy Street

London

W1T 4BJ

United Kingdom

arup.com

Executive Summary

As society is moving towards Net Zero with higher penetration of intermittent renewables coupled with climate change and the associated severe weather events, the resilience of the electricity network is facing unprecedented challenges.

Predict4Resilience (P4R) is an innovation project led by Scottish Power Energy Networks in collaboration with Arup, the Met Office and the University of Glasgow, and is sponsored by the Strategic Innovation Fund in response to the UK Government's National Resilience Strategy and the National Infrastructure Commission's Resilience Framework.

Predicting potential short-term adverse weather impacts and resultant faults on the network, the P4R Weather Fault System (WFS) can help Distribution Network Operators (DNOs) improve preparedness against adverse weather impacts, improve customer services by reducing the impact of disruptions to supply, and improve resource planning by sharing actionable outcomes from the control room.

With our high-level assumptions in Discovery phase, the WFS benefit/cost ratio for a 10-year assessment period is 1.76x. The WFS will require 6 years to recover its initial development cost and provide c.£430k of Net Present Value (discount at 3.5%) to all DNOs across a 10-year timeframe by the savings expected in the Customer Minutes Lost cost.

With innovation, state-of-the-art forecast modelling and the open data Application Programming Interface (API) that this project provides, it could open additional possibilities to benefit not only the DNOs and customers but the wider community and society. For example, other third parties (e.g., any sector dependent on electricity) can take advantage of the WFS via the open data API to enhance their preparedness against adverse weather events such as through better allocating resources.

After the Discovery phase, the project team will design the User Interface and build a forecast model prototype for the WFS in Alpha phase based on the functional specification and appoint a Design, Build and Operate supplier for the WFS. In Beta phase, we will build the WFS product and the data API as needed. We will also ensure the success of the project via continuous engagement with various potential users and stakeholders including the other DNOs and their Control Room Operators. In accordance with the UK Government Digital Service's Service Toolkit, the Live phase of the WFS will need onboarding, training, whilst the support and maintenance should also focus on continually improving the WFS.

Abbreviations & Acronyms

The following abbreviations and acronyms are used in this document:

API	Application Programming Interface
CHL	Customer Hours Lost
CI	Customer Interruption
CML	Customer Minutes Lost
DBO	Design, Build Operate
DNO	Distribution Network Operator
ESRI GIS	ESRI Geographic Information System
FFE	Fault Forecasting Engine
MVP	Minimal Viable Product
NIC	National Infrastructure Commission
P4R	Predict4Resilience
PRAE	Predictive Analytics of Energy
RASCI	Project Management RASCI Matrix
SIF	Strategic Innovation Fund
SPD	Scottish Power Distribution
SPEN	Scottish Power Energy Networks
SPM	Scottish Power Manweb
UI	User Interface
WFS	Weather Fault System

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1. Introduction

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1.1. Context

The importance of energy to society and the resilience of the electricity network to disruption has never been greater. Energy infrastructure is under growing pressure from a number of social, environmental, ecological and political factors which bring increasingly unpredictable risks that push networks to their limits.

Climate change and associated adverse weather conditions are one such factor which significantly impacts the electricity network, resulting in widespread network outages for extended periods of time. Evidence is showing that climate change is contributing to longer and hotter heatwaves, more persistent droughts, more frequent wildfires and more extreme rainfalls.

A resilience approach to understanding uncertainties helps critical infrastructure to continue to provide the essential services on which society depends. In 2020, the National Infrastructure Commission (NIC) recommended a framework for resilience which anticipates future shocks and stresses; improves actions to resist, absorb and recover from them by testing for vulnerabilities; values resilience properly; and drives adaptation before it is too late.

Storm Arwen, November 2021

Extreme wind speeds and cold temperatures caused loss of power to 1M+ households, and 100K+ were without power for several days. 13 of the 14 network licence areas were impacted, with the most severe damage to SSE Power Distribution, SPEN, Northern Powergrid and Electricity Northwest networks.

Storm Eunice, February 2022

Strong winds brought down trees on power lines causing 1M+ households to lose power, with succeeding storms' Dudley and Franklin resulting in ongoing power cuts lasting several days. These impacts were felt right across the UK electricity network.

The Opportunity

As society becomes more dependent on electricity, the consequence of a lack of resilience becomes more significant. It is vital that electricity Distribution Network Operators (DNOs) are well prepared for and able to rapidly respond to and recover from adverse weather events.

Currently, control room operations are dependant on weather forecast data only for predicting network faults. Predicting and decision-making regarding faults comes from tacit knowledge of experienced personnel.

This presents an opportunity to transform operational practices through the use of a data driven approach to fault prediction. This would make it possible to predict weather events more accurately with longer visibility and identify its impact in order to protect supply.

The Solution

The Predict4Resilience (P4R) project, led by Scottish Power Energy Networks (SPEN) in collaboration with Arup, the Met Office and the University of Glasgow, is an innovation project sponsored by the Strategic Innovation Fund (SIF).

The P4R project aims to use advances in supercomputing and numerical weather prediction to combine state-of-the-art weather forecasting and novel statistical post-processing to better predict short-term adverse weather impacts and resultant faults on the network.

This Weather Fault System (WFS) will assist engineers to make more informed decisions based on actionable fault and risk predictions, leading to better preparedness against adverse weather events and increased operational efficiency. The WFS can also support SPEN's general strategy for infrastructure resilience.

The Business Case

This document presents the Business Case for the WFS produced during Discovery, comparing the costs and benefits of the proposed solution against current practices to demonstrate the viability of implementing the WFS.

1.2. Vision & Objectives

The WFS will enable control room, district managers, and all relevant engineers to make earlier, faster and better decisions informed by probabilistic forecasts of weather-related faults up to 7-to-14 days ahead. More specifically, the WFS is expected to:

- Increase efficient and effective operational practices with a data driven approach to fault forecasts;
- Reduce Customer Minutes Lost (CML) (e.g., the average number of minutes that supply is interrupted), through early access to credible fault data, enabling timely and effective distribution of resources and equipment;
- Reduce costs associated with cancelling planned outages when necessary and if appropriate in weather impacted districts;
- Improve the ability of control room engineers and asset manager to protect network assets; and
- Reduce the carbon footprint of the business by avoiding unnecessary travel of response teams enacting plans where events do not occur.

Any improvement in the response to and/or restoration of outages would increase the social and economic return to rural communities and vulnerable customers who are at higher risk of severe impact from a power outage.

Additional benefits include:

- Contribution towards Government objectives, such as the National Resilience Strategy;
- Learning embedded in the continuous development of SPEN’s Control Room and Resource Dispatch (transferrable to T&D Asset Owners, and the Oil and Gas industry);
- Similar services can be provided to other utilities operators or cross-sector infrastructure operators;
- Potential reduction of H&S incidents and staff exposure to extreme weather hazards; and
- More resilient operations through digitalisation and the use of data to ensure information is available and preserved independently of changes in personnel.

Strategic alignment

The P4R WFS is strongly aligned with societal trends and government policy regarding the future of UK energy infrastructure.

In particular, it is closely aligned with three of the NIC’s Resilience Framework recommendations. More accurate fault predictions further in advance will enable Control Room Engineers to better **anticipate** shocks to the network. This will assist Control Room Engineers to develop more informed response plans for swift and efficient **recovery**. These decisions can be logged and stored, facilitating lessons learnt to **adapt** and **transform** systems.

In addition, the WFS may contribute to reduction of CO_2 emissions by reducing unnecessary personnel and equipment logistics due to non-utilisation of response teams and the need for backup generators.

The WFS may also support a low carbon and stable network by improving understanding of weather-related impacts on assets and extending asset lifespan, thus reducing carbon associated with purchasing new equipment.

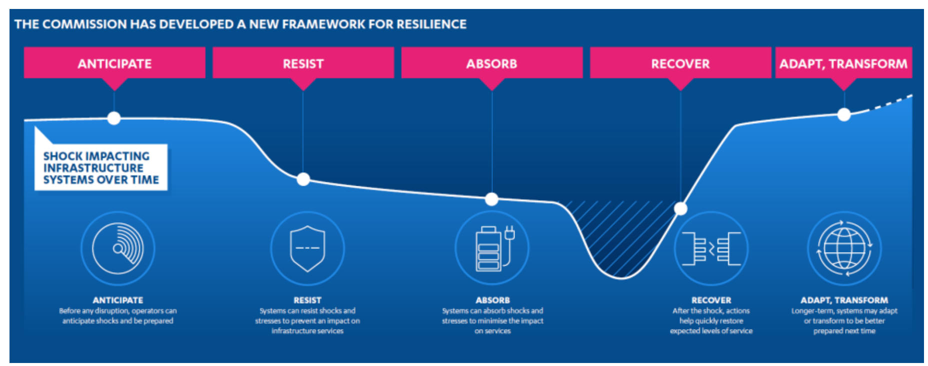

Figure 1. NIC Resilience Framework recommendations

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2. The Solution

2.1. P4R Weather Fault System

The WFS shall be developed for initial use by SPEN's control room engineers and will be piloted in an operational environment during the Beta phase. Following the success of the pilot, the WFS can be brought into full service and offered to other DNOs. In addition, the WFS will include an open data Application Programming Interface (API), providing weather fault data to third party organisations such as local government and energy consumers.

Technical components

User Interface (UI)

The UI will expose application functionality to end users. The UI may be a commercial-off-the-shelf application (such as ESRI Geographic Information System (GIS)) or a bespoke application (such as SPEN's Predictive Analytics of Energy (PRAE) application) which could be further developed to realise the required functionality. A suitability assessment of UI options will be undertaken during the Alpha phase, including evaluation of options capable of integrating with other DNO systems to provide additional data to assist with response planning.

Fault Forecasting Engine (FFE)

The FFE is the core processing element of the WFS utilising statistical analysis techniques to predict network faults given weather forecast data. A knowledge base shall be maintained to track the accuracy of the WFS which can be used to develop and train Control Room Engineers. Reporting and alerting functionality will provide automated alerts when fault predictions exceed agreed thresholds.

Data Store

The data store shall provide a centrally available store of weather and fault data for the WFS – capable of elastic scaling to support growth of the WFS across national and international DNOs. Relevant datasets are expected to include: weather forecast data, network fault data, satellite imagery and Lidar data (as required by the forecast model development).

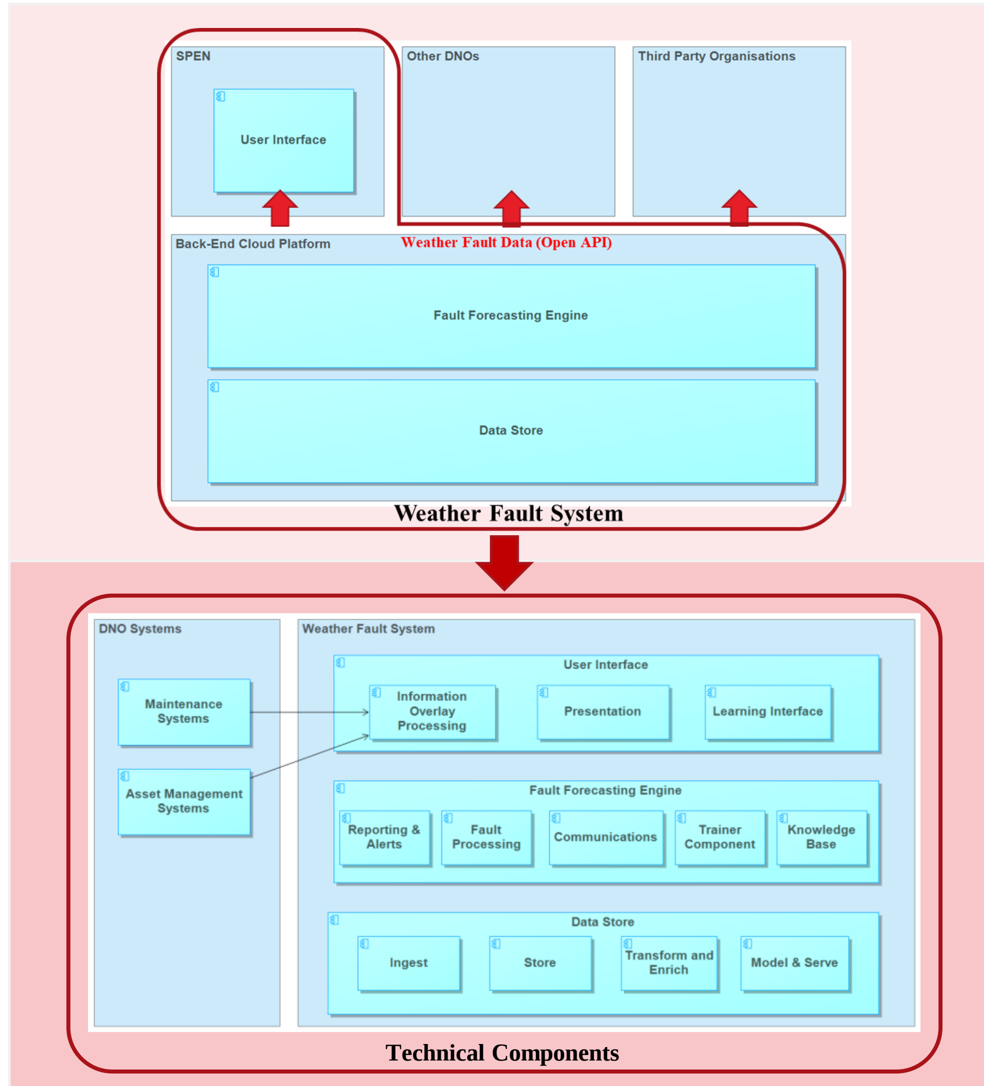

Figure 2. Building blocks and technical components of the P4R WFS

2.2. Development Approach

Collaboration Partners

P4R is formed of a consortium of collaborators, led by SPEN for the Discovery phase, including:

- SPEN – Regulated DNO leading the SIF collaboration.
- University of Glasgow – Leading a preliminary proof of concept for the fault forecast and survey data requirements and availability.
- MET Office – Subject-Matter Expert supporting on weather forecast data and methodologies.
- Arup – Engineering support on fault data analysis and processing, leading the production of a high-level functional specification and business case.

SPEN Stakeholders

The P4R team have engaged stakeholders from across SPEN, including the Project Sponsor, Control Room Engineers, Customer Interruption (CI)/ CML Officers, and IT services. These discussions have informed the project objectives to improve:

- Preparedness by improving prediction of network conditions;
- Customer services by reducing the impact of disruptions to supply; and
- Planning by sharing actionable outcomes from the control room.

The pathway for realising these objectives is shown in Figure 3 below.

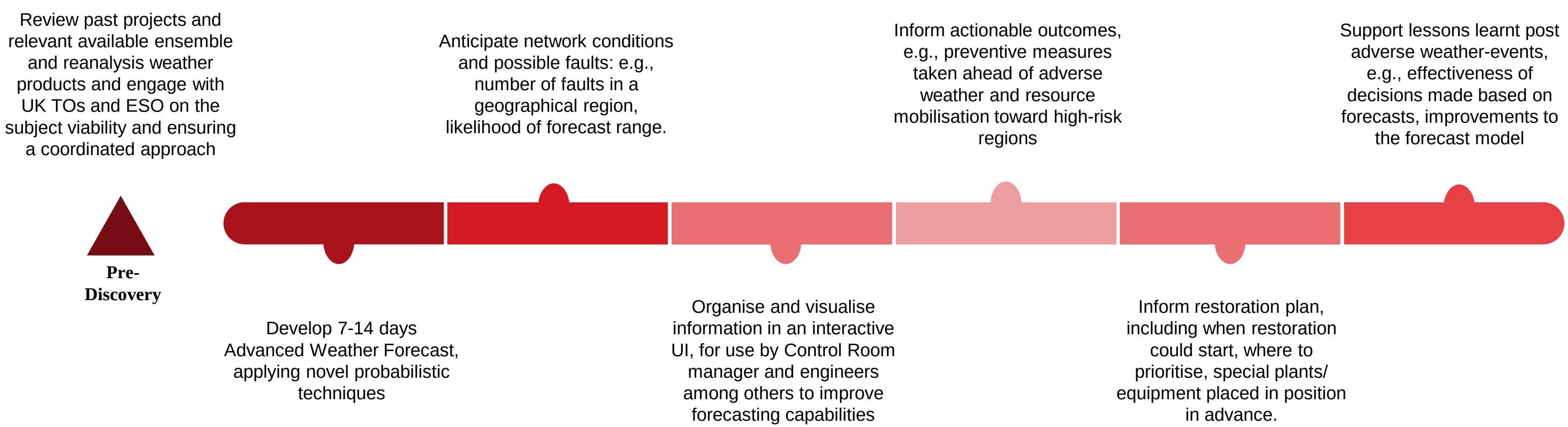

Figure 3. Pathway to realise P4R project objectives

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3. Cost & Benefit Analysis

3.1. Benefits & Assumptions

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Qualitative benefits

Efficiency benefits

The WFS's data driven approach can transform human-centric decision-making practices and improve processes and maintenance decisions.

Integration of the environmental conditions (i.e., weather conditions) to which assets are exposed into asset health information will enable improvements in asset management and allow better asset protection.

Further, users can log and store decisions made on impact forecasts in the WFS to support lessons learnt and knowledge sharing. The WFS also supports embedding data-related skills in SPEN.

Strategic benefits

At a national level, the WFS is aligned with the NIC's resilience framework (further details provided in Section 1.2), and it supports SPEN's resilience strategy and strategic climate resilience studies.

At an organisational level, the WFS aligns with SPEN's data and digitalisation strategy and can also embed learning and development in the day-to-day tasks carried out by control engineers and asset managers.

Quantitative benefits

For detailed calculations, refer to Appendix A1.

Core benefit

Consultation with SPEN's Control Room Engineers flagged savings in the CML cost of network faults caused by "*Wind and Gale (excluding Windborne Material)*" as the key benefit in Discovery. This benefit is achieved by better response planning and resource mobilisation in advance, based on the forecasted location and number of faults.

Assumptions on CML cost savings

The CML cost of a "do nothing" scenario (i.e., the counterfactual where decision-making is based on tacit knowledge of experienced personnel) is estimated based on historical fault data in both Scottish Power Manweb (SPM) and Scottish Power Distribution (SPD) for the 10-year period from 2011 to 2020, excluding those faults covered by exceptional events where penalties do not apply. Specifically, the average of the annual total "CHL (incd)" in the 10-year period, excluding the faults mentioned above, is used to estimate the CML cost of a "do nothing" scenario. The baseline for annual savings is assumed to be 5%.

	SPD	SPM
A: Cost per hour (CHL)	£12.051	£11.859
B: Average of the annual total "CHL (incd)" in hours from 2011-20	66,343	50,767
C=A*B: Annual cost of a "do nothing" scenario	£799,502	£602,049
D=5%*C: Annual baseline cost savings	£39,975	£30,102

Other opportunities for savings

Depending on the type of faults, the WFS may help avoid interruptions to customers and bring CI cost savings by enabling proactive repairs and network management based on the forecasted location of network faults.

Better resource mobilisation and maintenance planning enabled by the WFS, may reduce abortive costs (e.g., cancelling planned works) which would generate savings.

Further, better response planning and improved asset management aided by the WFS may bring a long-term benefit of reducing CO_2 emissions through the avoidance of new equipment, reduced stand-by rotas and less utilisation of fossil-fuel (diesel) generators.

Other considerations

CML cost savings will increase substantially when other weather-related faults are considered, such as those caused by "Snow, Sleet and Blizzard". These savings will be captured as the WFS forecast model is developed further in Alpha phase.

3.2. Costs & Assumptions

Development cost

Assumptions on initial outlay

SPEN currently has a bespoke software application for electricity demand and embedded generation forecast, i.e., the PRAE application, which is considered to be of similar scale of functional and infrastructure requirement in comparison to the WFS. Hence, the initial outlay for the WFS is assumed to be in a similar order as the PRAE's development cost of approximately **£1m**.

Operational cost

Basis for operational costs

The following three key elements form the minimum requirement for the operational cost. These costs are based on the relevant costs incurred by the PRAE application.

Operational cost	p.a.
Weather data supply	£10k
Server hosting & other IT infrastructure	£15k
Support & development costs	£30k

DNO-dependent costs

The operational costs associated with weather data supply, server hosting and other IT infrastructure may increase based on the number of DNOs using the WFS, the amount of data supplied and the capacity required to host it. It is assumed that these two operational costs will multiply in accordance with the number of DNOs using the WFS.

DNO-independent cost

Unlike the operational costs related to the supply of data and infrastructure, it is assumed that the support and development costs, in essence, can be shared amongst the application users. Hence, this operational cost will remain the same regardless of the number of DNOs using the WFS.

Other considerations

During the Discovery engagements, it has been identified that other datasets such as satellite imagery data may be required by the forecast model. Moreover, there are various options for acquiring these datasets as needed by the forecast model. In other words, any cost associated with the supply of these additional datasets will need to be captured once the forecast model is properly developed in Alpha phase.

Similarly, it is also identified in Discovery that the WFS may be able to benefit from the PRAE application's existing infrastructure, which could lead to savings from a development cost's point of view.

Nonetheless, other costs may arise from staff training, integration into other SPEN systems, and incorporation of an open data API for external users, among others. This will depend on the development of the application in Alpha and Beta phases and any further need identified for external users. This will need to be assessed when the relevant needs arise.

3.3. Quantitative Analysis

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For detailed calculations, refer to Appendix A1.

Methodology

The quantitative analysis is based on the baseline investment required for the WFS (i.e., the initial outlay of **£1m** for the application development) and the net savings (i.e., the savings in the CML cost less operating and maintenance costs of the WFS), in order to calculate:

- The benefits / costs ratio;
- The Net Present Value (NPV); and
- The payback period.

As stated in Section 3.1, the baseline benefit is a **5%** savings in the CML cost in comparison to the counterfactual of a "do nothing" scenario (i.e., decision-making based on tacit knowledge of experienced personnel), which is **c.£70k p.a.** for each DNO.

Assumptions on rollout

It is assumed that SPEN will be the initial user of the WFS, and starting from Year 2 of the WFS being live, other DNOs will begin to use the WFS, i.e., rolling out the WFS to the rest 5 DNOs at a pace of 2 new DNOs each year.

The baseline operational cost p.a. will follow the rollout across the DNOs.

Assumptions on timeline

The cost savings (i.e., the benefits) will continue to be generated as long as the WFS is operational. Nonetheless, in order to calculate the "benefits / costs ratio" and "NPV", the timeline for the estimate is assumed to be 10 years, and a discount rate of 3.5% is applied where needed, to be in lined with the HM Treasury Green Book discount rate.

Inflation is excluded from the analysis to avoid unnecessary complexity and provide a simple and transparent estimate.

Baseline financial metrics

Using a 10-year assessment period, the benefit/cost ratio is **1.76x**.

Using a 10-year assessment period and 3.5% discount rate, the NPV is **c.£430k**.

With the Base Case assumptions, the payback period is **6 years** in order to recover the initial investment, as seen in Figure 4 below.

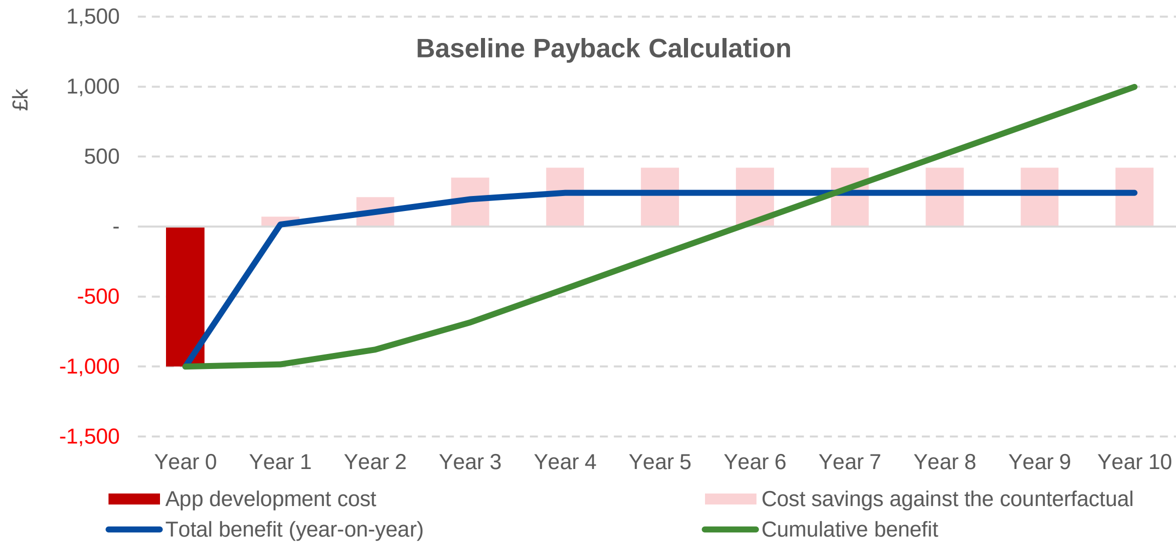

Figure 4. Baseline payback calculation

3.3. Quantitative Analysis *continued*

Sensitivity

The graphs below show the payback period and NPV sensitivities on the benefits, Capex and Opex.

As seen in the graph, the project is less sensitive on both Capex and Opex, but relatively sensitive to the benefit of the WFS, i.e., the cost savings. A 1% improvement in the benefits could reduce the payback period by 1 year. It also increases the NPV by c.£503k and 1% reduction in benefits also reduces the NPV by c.£503k.

On capex, a movement of +/-10% has a limited impact on the payback period. In order to have 1 year reduction in the payback period, the initial capex will have to be reduced by c.30%. Regarding impact on NPV, +/-10% on Capex translates to c.+/-£97k.

On opex, it has a limited impact on the payback period. On NPV, a +/-10% in opex translates to +/-c.£112k.

These sensitivity results show that the successful cost savings delivered by the WFS is paramount to the success of the project.

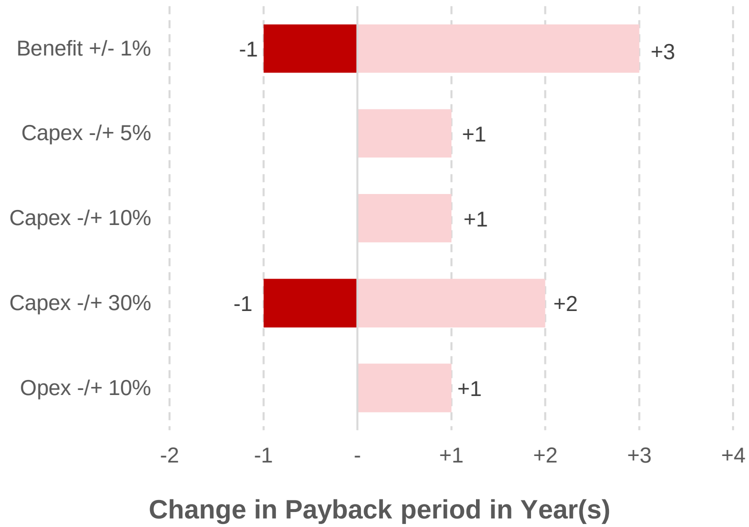

Figure 5. Change in payback period in year(s)

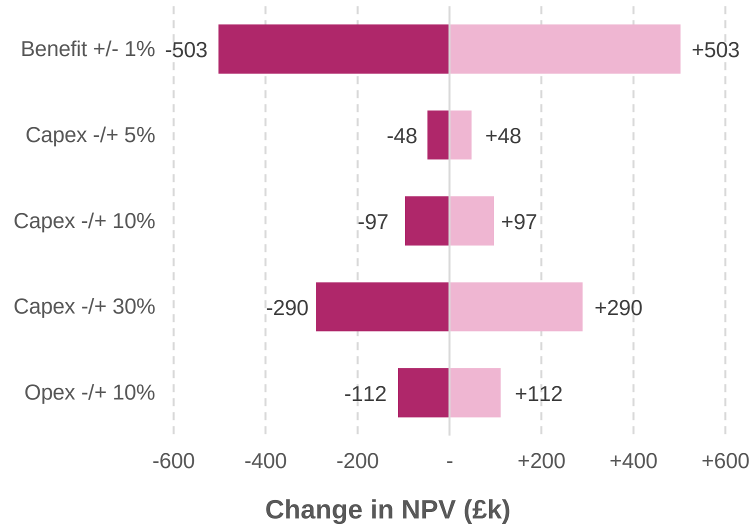

Figure 6. Change in NPV (£k)

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4. Conclusion & Next Steps

4.1. Conclusion & Next Steps

Conclusion

Energy infrastructure is under pressure from a range increasingly unpredictable extreme weather events that have the potential to push systems to their breaking points. It is therefore critical that DNOs proactively seek opportunities to enhance the resilience of their operations and assets to ensure they are well prepared for, and able to rapidly respond to and recover from, unknown shocks and stresses.

The P4R project aims to innovate operational weather forecasting and fault prediction to improve control room capability for predicting and responding to faults caused by adverse weather events. Through the use of advanced super-computing and numerical weather prediction, combining state-of-the-art weather forecasting and novel statistical post-processing, the WFS aims to better predict short-term adverse weather impacts and resultant faults on the network.

The WFS predictions will enable Control Room Engineers to make more informed decisions in their response planning and deployment of resources and equipment, ultimately reducing response and repair times. This innovation to operational practices will not only bring cost reduction benefits to DNOs, but it will also bring cost and experiential benefits to energy consumers.

Based on high-level preliminary assumptions, the WFS benefit/cost ratio for a 10-year assessment period is 1.76x. The WFS will require 6 years to recover its investment and provide c.£430k of NPV (discount at 3.5%) to all DNOs across a 10-year timeframe by savings in Customer Minutes Lost.

Furthermore, the combination of the knowledge capturing component which allows users to log decisions made based on predictions, and the open data API that provides access to a centrally available store of weather and fault data, will enhance DNOs' knowledge sharing and lessons learnt capabilities; supporting continuous adaptation and transformation of the network.

The open data API has the potential to benefit not only DNOs and customers' but also the wider community and society. Other third parties can utilise the open data API to enhance the resilience of their own organisations to the impacts of severe weather events.

In this way the WFS has the potential to make a significant contribution to broader national objectives to bolster the resilience of UK energy infrastructure and ensure networks can continue to provide the critical services on which society depends.

Next Steps

Having demonstrated the technical and commercial viability of the WFS concept in the Discovery phase, the P4R team will develop a MVP in the Continuity and Alpha phases. The key objective will be to design the UI, build a prototype for the WFS and demonstrate that the fault forecasting model is sufficiently accurate.

In addition, the Alpha phase will also include exploration of the wider economic benefits of the WFS as part of refining the Business Case.

Once the MVP is established, the WFS and the back-end platform that provides the data API will be developed for initial use by SPEN's control room engineers and will be piloted in an operational environment during the Beta phase.

Following the success of the pilot, the WFS can be brought into full service and offered to other DNOs and the open data API can be made available to other third parties.

Organisations from across multiple sectors can access the WFS to improve the efficiency of their current practices, generate cost savings and benefits, and build the capabilities required to move beyond coping with challenges towards thriving, learning and adapting.

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Appendices

A1. Cost Benefit Analysis Model

Ove Arup & Partners Ltd
8 Fitzroy Street
London
W1T 4BJ
United Kingdom
arup.com