



FINAL DRAFT



Quantum-inspired optimisation applications for future of gas networks

Discovery Phase – Technical Report
May 2026

Bringing Ingenuity to Life.
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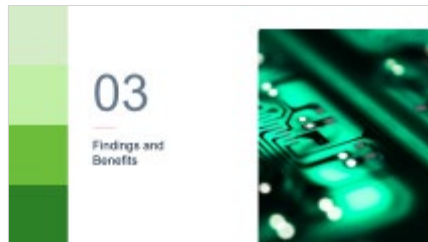
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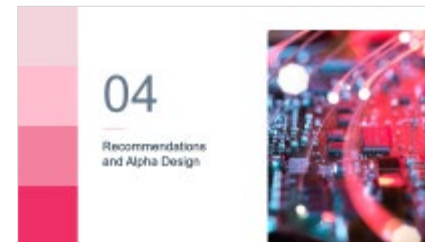
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01

Executive Summary



Executive Summary

The UK energy system is rapidly evolving into a complex, multi-vector network integrating gas, hydrogen, CO₂ and electricity. This is driving a step-change in planning complexity, uncertainty, and interdependencies. Current planning tools and processes are reaching their limits—constrained by slow run-times, fragmented tooling, and heavy reliance on manual, experience-led workflows. This limits scenario exploration, reduces decision quality, and increases operational and system risk.

This “SIF Discovery” project explores if and how rapid advances in technology, specifically leveraging novel quantum-enabled optimisation, can improve and accelerate modelling of future gas transmission configurations, multi-vector decarbonisation and whole-systems planning (Innovation Challenge 7).

A structured discovery approach was undertaken, identified 44 pain points and 100+ insights through interviews and workshops across stakeholders in 5 National Gas Transmission teams and two NESO teams. 14 use cases were defined, and assessed against value at stake for the energy system, ease of implementation, and technical suitability before down-selecting into three priority use cases: multi-year optioneering to support long-term asset investment and outage planning, optimising annual outage planning, rapid and dynamic in-year outage re-planning.

Together, optimisation solutions that span these three use cases would enable a shift from manual, scenario-limited planning to systematic, data-driven optimised planning. Quantum-annealing enabled optimisation is considered to offer a credible route to provide a step-change in capability as it is extremely well suited to highly complex

combinatorial optimisation problems with the ability to provide answers in near-real time, whilst avoiding significant hardware investment for example in computing.

An initial conservative estimation of benefits, using only National Gas as an exemplar, indicates annual benefits could deliver between [REDACTED] delivered through reducing network and customer risk, increasing planning efficiency and capacity, improved transparency and decision confidence, and providing system-wide benefits across stakeholders such as capacity constrained supply chains.

Industry research confirms that (outage) planning is an increasingly urgent challenge across the energy system, driven by speed, scale and complexity of investment decisions growing. Further, the energy system as a whole will become more complex due to the need to create new interfaces. Many current in-flight innovation projects seek to further capability, none are currently considering novel optimisation technology.

It is recommended to move to and deliver an Alpha phase with the objective to design and build a prototype solution for a single priority use case, validate the system-wide benefits, and of successful develop a clear plan to a Beta Phase.

It is proposed this Alpha is a collaboration project, involving interested parties including NESO, distribution and transmission operators in Gas and Electricity, to explore, confirm and establish to what extent the preferred solution, or part of the technology used for the solution can be transferable to other energy system operators or its use expanded to unlock the expected system-wide benefits.



02

Objectives and Methodology



Net zero offers unprecedented opportunities, with advanced optimisation methods key to overcoming the associated challenges

National Gas is transforming its infrastructure to support three types of gases: natural gas/biomethane, hydrogen (H₂), and carbon dioxide (CO₂). This transition involves both the construction of new assets and the repurposing of existing ones on a scale not seen in over a decade.

While this new infrastructure presents exciting opportunities, it also brings substantial challenges. For example, determining the optimal size of the hydrogen network is a complicated task that requires balancing the risk of oversizing against considerable uncertainty in both supply (identifying reliable hydrogen providers) and demand (assessing which customers will be able to transition to hydrogen). In addition, as renewable energy sources become increasingly important in the energy mix, accurately forecasting renewable generation (particularly wind) over the medium term for planning purposes remains difficult. These are just a few of the immediate challenges that National Gas is currently facing.

These types of challenges are growing increasingly complex, as they require integrating natural gas, hydrogen, CO₂ transport, and electricity into existing modelling capabilities, which currently lack the necessary functionality, speed, and scenario coverage needed for effective whole-system planning.

Advanced optimization techniques, such as **quantum annealing**, present a promising opportunity to address these challenges. Quantum annealing is uniquely suited to handle complex problems involving a vast number of variables, enabling solutions to be found much more quickly than traditional methods.



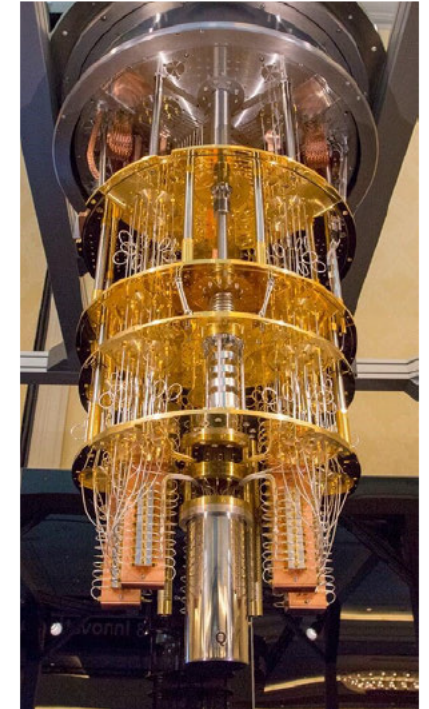
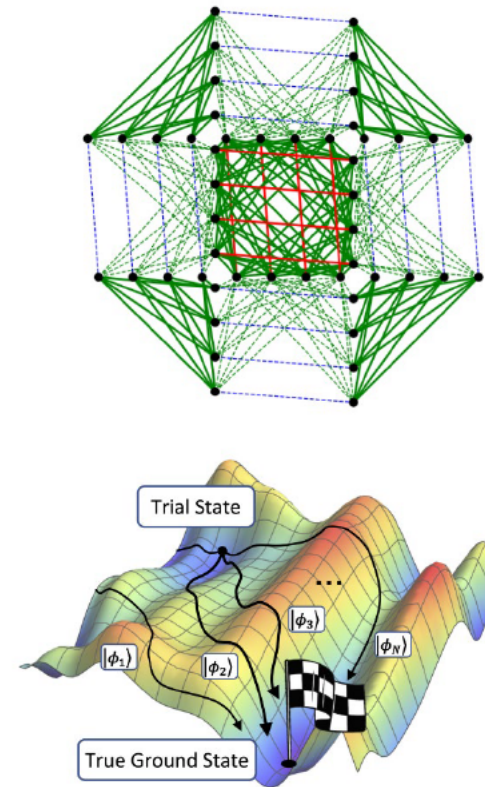
Emerging Quantum technology presents a significant opportunity in computational run time for certain types of optimisation

Quantum Information Processing is very suited to certain types of optimisation problems. Specifically, large combinatorial optimisation problems. Digital Annealing hardware is becoming cheaper and more available, and the software/algorithms are proven to work and perform faster and better.

Quantum annealing is best suited to tasks which are:

- Highly complex, combinatorial optimisation problems
- Large-scale systems with many interacting variables and competing objectives
- Scenarios involving uncertainty or dynamic changes
- Time-critical environments requiring near real-time decision making
- Problems expressible as QUBO/Ising formulations

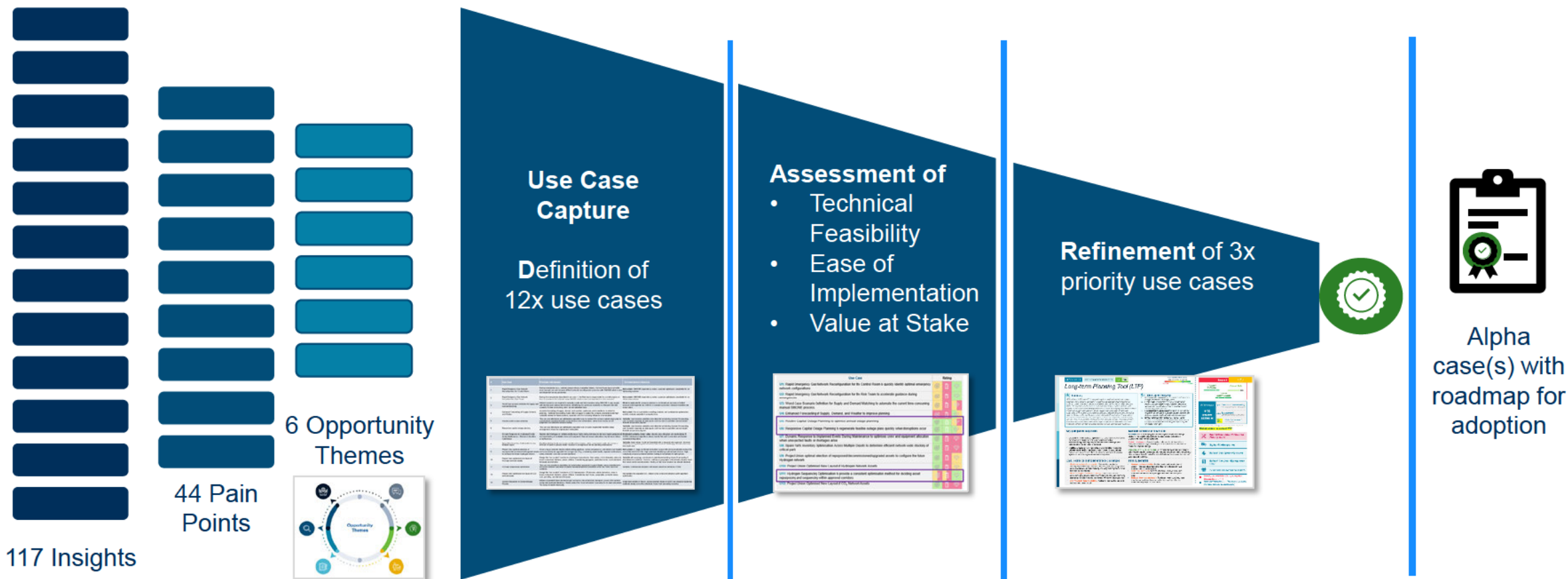
Common use cases: scheduling, resource allocation, network optimisation, routing, knapsack-type selection problems.



Our project journey has uncovered 100+ insights, pain points and opportunity areas to allow us to prioritise 3x Use Cases

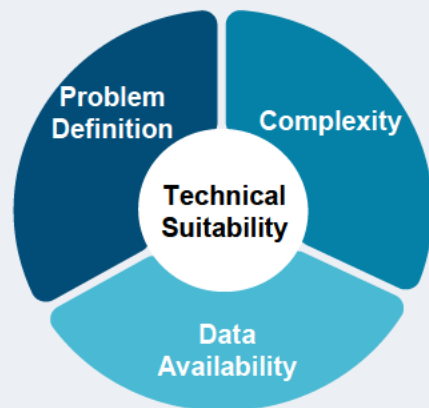
Research: Identify pain points and opportunities for optimisation

Prioritise: Identify the highest value use cases for an Alpha

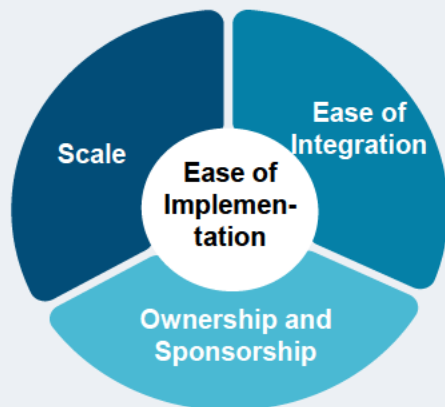


We have evaluated the long-listed use cases against three criteria: Technical Suitability, Ease of Implementation and Value at Stake

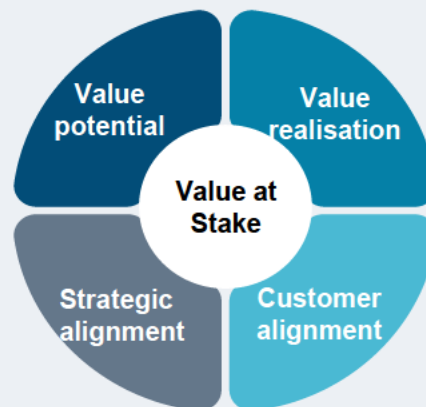
Prioritisation Criteria



- **Problem Definition:** Evaluates the clarity of defining a quantitative objective function and its required variables.
- **Complexity:** Assesses the use case's technical and combinatorial nature to determine its suitability for quantum annealing.
- **Data Availability:** Gauges the reliability of datasets needed to quantify variable interactions and solve the problem.



- **Scale:** Evaluates the overall dimension of the problem and total potential solution space.
- **Ownership and Sponsorship:** Assesses the clarity of alignment and commitment to a defined solution sponsor or business owner.
- **Ease of Integration:** Measures the ease of integrating the solution into critical business processes or daily operations.



- **Value potential:** Extent of value created
- **Value realisation:** Ease of measuring value and rate at which value is realized.
- **Strategic alignment:** Alignment with NG's overall strategic direction, including Net Zero objectives.
- **Customer alignment:** Support for current and future customer needs, expectations, and value drivers

Technical Considerations

Custom Build

Algorithm or optimisation solution will likely require a full custom build, ie no existing technical solution exists / is in use.

Hybrid Solution

Optimisation solution may be built in conjunction / integrated with existing software or tooling in a hybrid manner

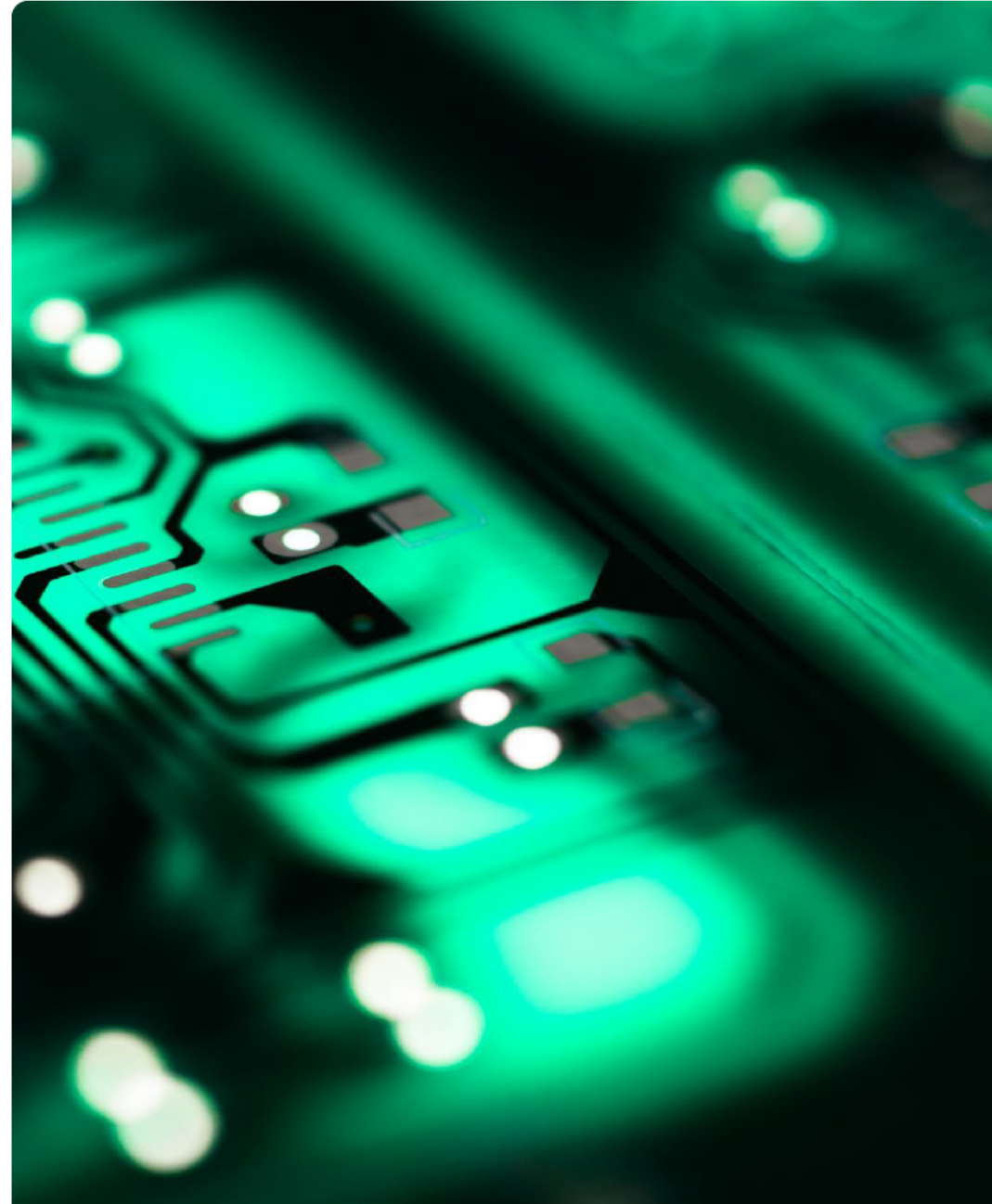
Off the shelf

Commercial Off-the-Shelf software with optimisation features exist that may be exploited or enhanced with quantum annealing capability

Not used in use case evaluation / prioritisation, provided for additional context and information only.

03

Findings and Benefits



We identified over 30 pain points across different areas of the business through 10 in-depth interviews and two group workshops

Stakeholder Group	Main Pain Points
Data Sciences and forecast team	<ul style="list-style-type: none"> Manual configuration of models remains time-consuming and limits automation. Organisational communication and adoption of advanced analytics Implementation and productisation bottlenecks Misalignment and gaps in technical resources (data engineering, architecture) Rising complexity and uncertainty in forecasting (especially with renewables) Probabilistic forecasting is hard to operationalise at scale
Network Operations	<ul style="list-style-type: none"> Manual configuration of models network tools and models remains time-consuming and limits automation. Manual, experience-driven configuration in SINT/network tools Critical within-day power station demand forecasting gap Manual, multi-team weekly planning process Limited ability to run and compare many scenarios efficiently
Network Development	<ul style="list-style-type: none"> Manual, error-prone workflow and unstable input data Limited ability to run and compare many scenarios efficiently Long-term risk modelling is a bit simplistic and less robust Difficulty finding optimal solutions among many feasible ones Tool and data fragmentation across SIMONE, Excel, and legacy tools
Project Union	<ul style="list-style-type: none"> Deep uncertainty in hydrogen demand/supply projections ██ Premature asset design lock-in by external or internal stakeholders Confidentiality restrictions limit collaborative and automated analysis ██ Unclear regulatory risk and accountability undermines planning
Planning	<ul style="list-style-type: none"> Plans are highly reactive and disrupted by frequent changes. Limited capacity to test outage scenarios. Over-reliance on tacit knowledge rather than formal, data-driven process. The planning workflow is fragmented and slows cross-team alignment. Disconnect between project selection and work scheduling. Optimisation heavily driven by qualitative or subjective judgment.



- The different areas of the business are highly interconnected, with the work of some teams having a direct impact on others
- These close relationships result in certain pain points being shared across different areas, particularly in processes involving SIMONE, the simulation and optimisation tool for gas transport and distribution. SIMONE's inability to rapidly simulate multiple scenarios often is perceived as a bottleneck.
- Accurately forecasting supply and demand remains a significant challenge, particularly for mid-to-long-term network development initiatives like Project Union. This is especially critical when projecting renewable energy generation
- The current tooling landscape is fragmented and difficult to scale. This is particularly evident in Maintenance Planning, where the high volume of evolving projects exceeds the existing system's capacity to effectively update and reschedule tasks

Stakeholder engagement identified six themes relating to increasing complexity in network planning and operational decision making

1. Forecasting is becoming increasingly complex:

Everything related to the increasing difficulty, uncertainty, and operational criticality of forecasting (especially with renewables, weather and power stations).

2. Manual work still heavily embedded in critical processes:

Forecasts, models, and scenario configurations require significant manual intervention, making the workflow both time-consuming and prone to errors.

3. The tooling landscape is fragmented and hard to scale:

Modelling, scenario creation, and legacy tools sit across different platforms, which adds integration effort and makes it harder to maintain a smooth, traceable end-to-end process.

4. Scenario exploration and optimisation are constrained:

Number of scenarios that can be run are limited and is focused on finding a solution that meets requirements (one that works) rather than the best solution.

5. Full breath of risk drivers not embedded into decision-making:

Current models and metrics use relatively simple representations of risk, e.g., asset health data.

6. Energy System Planning needs scale exponentially in complexity

Evolution of future energy ecosystem brings huge planning uncertainty, limited historical data. Current modelling & planning capability not currently fit to manage exponential increase in complexity



14 use cases for optimisation were identified based on pain points and opportunity themes through the research and stakeholder engagement

#	Use Case Goal	Value
U1	Optimise Network Ops in emergency response for control room	More optimal decision making, reduced risk of network failures, lower system cost, faster decisions and more resilience, tighter management of quantifiable risk
U2	Optimise Network Ops in emergency response for short-term risk team	Allows the risk team to quickly assess and compare reconfiguration options for faster problem isolation, optimal gas flow, and continued supply.
U3	Optimise long-term capacity planning scenario design	Faster evaluation of all possible supply/demand options, ability to find optimum and evaluate extremes faster, e.g. to find the worst-case planning scenario.
U4	Enhanced Forecasting of Supply, Demand, and Weather	More accurate forecasts would reduce planning modelling complexity and problem size, improve speed and optimised plans across all time horizons
U5	Optimising annual capital outage planning process (Annual Planning Tool – ATP)	A systematic optimisation of the planning process would enable integration of more accurate and recent data (e.g. asset condition data), remove capacity bottlenecks (driven by limited number of experienced experts) and provide future-proof solution for increasingly complex process
U6	Optimise adjustments to capital plans in-year (Dynamic in-year Planning Tool – DPT)	Rapidly develop optimal adjustments to capital / maintenance plan, reduce risk, automation of heavily manual simplified approach
U7	Optimise resource deployment for reactive maintenance	Ensures the fastest possible restoration of affected assets, optimises crew deployment, minimizes downtime, and enhances workforce safety and efficiency.

#	Use Case Goal	Value
U8	Inventory optimiser	Lower inventory costs, reduced risk of deferred maintenance due to stockouts, better use of working capital.
U9	Optimise planning for multi-molecule NTS for Project Union	Enhance NG's investment bid to HTBM with a model to optimise the approach to support faster, more comprehensive and more consistent appraisal of pipeline repurposing/deferral/retention decisions.
U10	Optimise H2 network design for Project Union	A model that can optimise the design (pipeline & asset repurposing / deferral / retention) for the new H2 East Coast corridor to make it the most cost-effective transition to the new network.
U11	Optimise Sequencing of H2 investment planning	Faster, more comprehensive and more consistent appraisal of investment plans (build/ repurposing/ retain) within the H2 FEED-approved corridors
U12	Optimise planning for CO2 network for Project Union	Reduces total build cost, balances resilience and flexibility, and accelerates front-end design for permits and public consultation.
U13	Capacity Options Explorer (COE)	System Capacity scenario development and optimisation, to support higher confidence and faster plan generation, and enable better use of PLEXOS system
U14	Long-term Planning Tool (LTP) for Capital Outage & Major Projects	Extension of ATP/DTP to multi-year capital and outage planning for central and regional teams 5yr+ horizons, cover increased planning complexity e.g. increased inter-dependencies for multi-molecule strategy, regional plan alignment and integration of asset condition data

U5, U6, and U14 have emerged as the strongest candidates

Recommendation based on scoring in



Technical Suitability



Ease of Implementation



Value at Stake

Use Case	Rating		
U1: Optimise Network Ops in emergency response for control room			
U2: Optimise Network Ops in emergency response for short-term risk team			
U3: Optimise long-term capacity planning scenario design			
U4: Enhanced Forecasting of Supply, Demand, and Weather			
U5: Annual Planning Tool (APT)			
U6: Dynamic (in-year) Planning Tool (DPT)			
U7: Optimise resource deployment for reactive maintenance			
U8: Inventory optimiser			
U9: Optimise planning for multi-molecule NTS for Project Union			
U10: Optimise H2 network design for Project Union			
U11: Optimise Sequencing of H2 investment planning			
U12: Optimise planning for CO2 network for Project Union			
U13: NESO Capacity Options Explorer (COE)			
U14: Long-term Planning tool (LPT)			

Recommendation Rationale

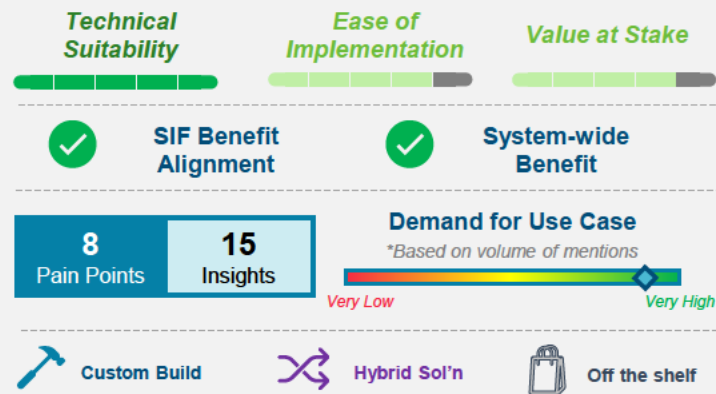
- Quantum-Annealing must be a viable and feasible solution for the problem:** use cases where the problem definition is inherently an optimisation problem that has high match with quantum-annealable solutions are prioritised. Where no existing alternative market solutions exist or traditional optimisation does not address the scale/scope of the challenge, a higher score is given.
- Solution must be implementable:** solutions where ease of implementation is rated low are likely dependent on existing third-party solutions (e.g. SIMONE) with high barrier to customise, or develop additional optimisation capability on top of existing solutions
- Value-at-stake must be clearly identifiable, material and it must address multiple SIF benefit criteria.**

Note: Other technically feasible solutions that can be supported by quantum annealing may be considered for internal implementation by NG/NESO, even though they are not proposed for Alpha as part of this Innovation project.

Three applications that can transform planning and modelling for the future of energy and gas networks

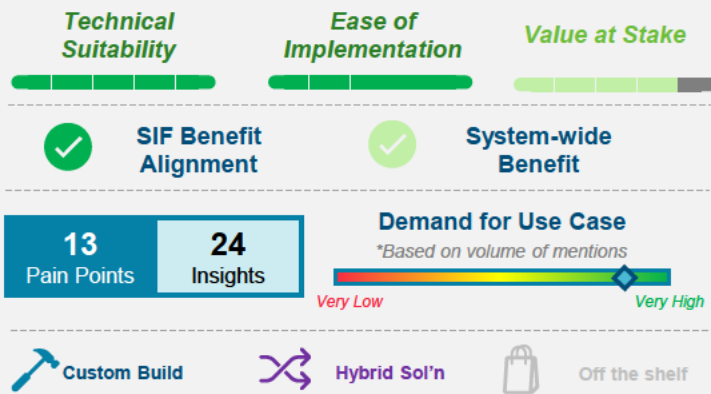
U14. Long-term Planning Tool (LTP)

- Concept is extended to **multi-year capital and outage planning** for central and regional teams
- Solution allows **optioneering**, what-if analysis for **T3 and T4 planning (5yr+)**
- Add functionality to cater for **increased planning complexity through portfolio growth**, increased **inter-dependencies** (e.g. multi-molecule, regional planning), integration of **asset condition data**.
- Exploits QA-suitability for **portfolio optimisation**
- Possible inputs incl: strategic interventions from business plans; Capital and Major projects; asset health; major future outages; capacities by region; national and regulatory constraints etc



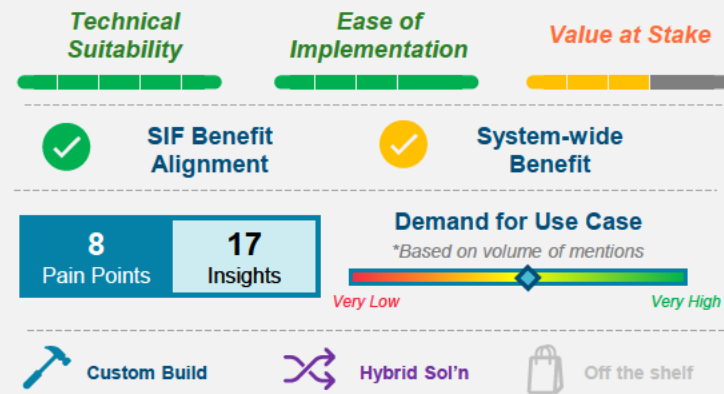
U5. Annual Planning Tool (APT)

- Uses the same optimisation logic as DPT, applied for regular annual planning to support **building seasonal plan(s)** from hundreds of interventions
- Focus shifts from recovery to **plan design**, enabling **systematic optimisation** of many feasible annual **plan options**, include **additional data sources**, establishing **optimal options** to iterate more **quickly**
- Exploits QA-suitability for **portfolio optimisation**
- Possible inputs incl: candidate interventions; network and resource dependencies; customer windows; seasonal demand assumptions; operational, network and contractual constraints



U6. Dynamic (in-year) Planning Tool (DPT)

- Tool to enable **rapid scenario modelling for central (and regional) Capital Outage planning**, focussed on **in-year re-planning** when the live delivery plan is disrupted.
- The tool explores **alternative adjustments under fixed constraints**, compares recovery options and provides evidence base
- Exploits QA-suitability for **rapid, frequent re-optimisation** of scheduling problems
- Possible inputs incl: existing outage plan; fixed outages and commitments; known activity and network dependencies; live change events (slippage, failures, new demands)



The three planning use cases identified may use similar technology and optimisation building blocks, unlocking different value drives across three time horizons

U6. Dynamic (in-year) Planning Tool (DPT)

Focus is on rapid in-year re-planning and recovery, testing scenarios and identifying the best adjustments under fixed constraints when disruptions occur.

U5. Annual Planning Tool (APT)

Focus is on sequencing interventions to minimise downstream rework and reduce the need for in-year replanning.

U14. Long-term Planning Tool (LTP)

Focus is on comparing different long-term strategies and understanding trade-offs, rather than committing early to a single plan.

Increasing value at stake, because the scope, time horizon and decisions being influenced expand.



Live plan execution; subset of interventions impacted by disruption

Full seasonal portfolio (hundreds of interventions across regions/resources)

Whole portfolio across assets, regions, and programmes (incl. future investments)

Days to weeks (in-year)

6 to 12 months

Multi-year (5+ years)

Rapid Tactical adjustment – schedule change management, re-sequence work, choose best mitigation under constraints and time pressure

Plan design – sequence interventions, allocate resources, build a robust plan that minimises in-year rework

Strategic optioneering – compare investment pathways, timing of major works, and trade-offs across cost, risk, and performance

Long-term Planning Tool (LTP)



Summary

LTP builds on DPT and APT to support long-term regional capital and outage planning, where growing uncertainty, portfolio size and inter-dependencies are pushing current tools and manual optioneering approaches beyond their practical limits. The tool enables planners to systematically design, explore and evaluate regional interventions over multi-year horizons, rather than relying on a small number of manually constructed baseline plans. Given a set of strategic drivers and constraints, LTP generates and ranks a portfolio of feasible plan options, providing clear justification of trade-offs around risk, deliverability and value. These options form a structured evidence base for expert review and integration across regions, with the ability to re-optimize iteratively as assumptions change, resulting in faster, more transparent and more defensible long-term plans with reduced rework and increased delivery confidence across regions, central planning and regulators.

High Level Features

- Multi-year plan generation:** Long-term optioneering of regional capital and outage plans.
- Large-scale option exploration:** Systematically explores a much wider range of feasible multi-year regional plan combinations than is possible through manual long-term planning.
- Constraint-led plan evaluation:** Assesses candidate long-term plans against evolving network, asset health, delivery capacity, regional and national constraints
- Evidence-based plan selection:** Supports clear comparison of alternative seasonal plans, providing a transparent rationale for selecting and approving the preferred annual plan.

Key pain points supported

- Capacity-limited strategic optioneering:** Long-term regional plans are developed through expert judgement and iterative sense-checking, meaning only a small number of strategic plan options can be constructed or reviewed
- Inability to explore long-term risk and trade-offs:** Interactions between asset health trajectories, major future outages, delivery capacity and new infrastructure are assessed piecemeal, leaving systemic and cross-regional risks under-explored.

Data, Technical & Implementation Challenges

- Moderate technical complexity:** Optimisation applied to strategically abstracted, multi-year planning problems using limited decision variables, scenario framing and weighted objectives rather than detailed scheduling.
- Moderate Implementation challenges:** Introduces a new decision-shaping layer upstream of existing planning and modelling processes, without replacing established workflows or governance.
- Low-Moderate Data Availability:** Relies on aggregated, uncertain and scenario-based inputs

Example scenario of future use

Scenario: NG is developing a multi-year regional capital and outage strategy, incorporating major future outages, asset replacement programmes and new infrastructure.

Problem Statement: Manual long-term planning limits the ability to compare alternative regional strategies or test how robust plans are as future assumptions change.

Presence of the APT Use Case: LTP systematically evaluates a broader set of feasible multi-year regional plan options across scenarios, providing a clear evidence base for selecting robust strategies to progress into annual planning and modelling.

Primary Benefits

- Strategic option visibility:** Enables systematic exploration of long-term regional strategies rather than committing early to a small number of baseline plans
- Earlier risk discovery:** Reveals structural, cross-regional and multi-year risks before they propagate into annual and in-year plans.
- Reduced downstream rework:** Produces more robust long-term plan choices, reducing iterative re-planning and disruption in annual and in-year (DPT) processes.

Impact



8 Pain points

+15
insights
addressed

++ Consumer Understanding
With increased uptake in participation.

+++ Engagement
With designs tailored to consumers

*Note potential savings are high level estimates, details in appendix

Stakeholders Impacted



National Gas Capital Maintenance
Planning teams



Regional Delivery teams



National Gas System Operators



National Gas Asset Management
teams



Customers connected to the NTS

- Directly Impacted (i.e. Solution provides benefits for the user)
- Indirectly Impacted (i.e. Presence of solution provides benefits to stakeholder)



Annual Planning Tool (APT)

Summary

APT will build on the dynamic planning tool to optimise the annual capital outage planning process. It will provide the planners with a tool to develop plans from 100s of capital interventions rapidly, automatically and with the ability to vary optimisation parameters and criteria. This will form an input into the existing Network Analysis & Modelling (supported through SIMONE). With quantum-annealing at its core the tool will optimise against multiple user-defined constraints and parameters, including operational, network, customer requirements, scheduling, resourcing and asset health / condition. Converting currently held tacit knowledge into a single systemised and robust tool that is custom-designed against planner's needs will significantly increase quality, speed and robustness of planning. The ultimate aim is to reduce annual planning cycle from up to 5 months to less than 2, whilst enabling expansion of scope and complexity of the optimisation to drive network and system-wide benefit.

High Level Features

- Annual plan generation:** Constructs complete annual outage plans from scratch.
- Large-scale option exploration:** Systematically explores a much wider range of feasible annual outage combinations than manual planning
- Constraint-led plan evaluation:** Assesses candidate plans against network, asset, customer, and contractual constraints to identify pinch points and trade-offs
- Evidence-based plan selection:** Supports clear comparison of alternative seasonal plans, providing a transparent rationale for selecting and approving the preferred annual plan.

Key pain points supported

- Manual, resource-intensive plan build:** Annual outage plans require months of spreadsheet-based sequencing, iteration, and sense-checking to construct a feasible whole-system plan.
- Limited exploration of risk and options:** Only a small fraction of feasible outage sequences and timings can be tested manually, leaving cascading system risks under-explored at plan-build stage.
- Slow, negotiation-heavy approval:** Heuristic-driven plans lack a consistent evidence base, potentially leading to extended negotiation before sign-off.

Data, Technical & Implementation Challenges

- Moderate technical complexity:** Custom optimisation using established annealing-based scheduling and constraint methods for seasonal outage planning.
- Moderate Implementation challenges:** Replaces spreadsheet-led plan build with an optimiser-supported approval workflow.
- Moderate Data Availability:** Required data exists but is fragmented, needing structuring and codification for optimiser ingestion.

Example scenario of future use

Scenario: National Gas is developing the Winter capital outage plan, integrating ~200 interventions, customer constraints, and demand uncertainty.

Problem Statement: Manual planning limits comparison of alternative outage sequences, making it difficult to evidence that the proposed Winter plan is the best whole-system outcome.

Presence of the APT Use Case: APT systematically evaluates a far broader range of feasible outage sequences, revealing cascading risks and providing a transparent evidence base for plan selection..

Primary Benefits

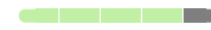
- Less manual effort and rework:** Eliminates large amounts of spreadsheet-based sequencing, iteration, and sense-checking, reducing planning workload during annual plan build.
- Higher confidence earlier:** Gives planners early visibility of how constraints and outages interact across the whole season, reducing late surprises and last-minute plan churn.
- Fewer in-year changes through better plan design:** Allocates contingency at critical network pinch points while avoiding unnecessary slack elsewhere, resulting in more stable plans.

Impact

Technical Suitability



Value at Stake



Ease of Implementation



13 Pain points

+24 insights addressed

++ Consumer Understanding
With increased uptake in participation.

+++ Engagement
With designs tailored to consumers

*Note potential savings are high level estimates, details in appendix

Stakeholders Impacted



National Gas Capital Maintenance Planning teams



Regional Delivery teams



National Gas System Operators



National Gas Asset Management teams



Customers connected to the NTS

- Directly Impacted (i.e. Solution provides benefits for the user)
- Indirectly Impacted (i.e. Presence of solution provides benefits to stakeholder)

Dynamic (in-year) Planning Tool (DPT)



Summary

DPT focuses on improving quality and speed of re-planning of the in-year delivery plan driven by unforeseen changes, such as new demand, changes in customer requirements, unforeseen network outages, delays and slippage. The tool takes the existing baseline plan, additional data sources (such as asset health) and change drivers as input and produces optimised options for updated plans and schedules, accounting for existing or unmoveable constraints. The solution will produce optimised updated plans in hours not days, thus improving plan quality, reduce network risk and unlock delivery capacity. Outage planners will be able to deal with increased complexity, provide faster and better service to customers, and produce more transparency and more confidence in plans for wide range of stakeholders.



High Level Features

- Event-triggered re-planning:** Reacts to unplanned changes by regenerating revised Summer or Winter outage plans.
- Systematic recovery exploration:** Tests alternative outage timings and combinations to reveal knock-on effects beyond obvious fixes.
- Risk and constraint visibility:** Highlights where revised plans could reduce exposure to operational, contractual, asset, or customer risks.
- Clear decision support:** Compares recovery options side-by-side with traceable rationale.

Key pain points supported

- Intensive manual rework:** Unforeseen changes force manual, time-consuming rebuilds of large sections of the seasonal plan.
- Hidden cascading risk:** Time pressure limits option testing, so downstream impacts and higher-risk outage combinations are easily missed.
- Approval friction and delays:** Heuristic-driven revisions lack a common evidence base, increasing time spent negotiating changes.

Data, Technical & Implementation Challenges

- Low technical complexity:** may be custom or hybrid build, combining a bespoke optimisation with existing tooling
- Low implementation challenges:** Designed to slot into existing planning processes, allowing planners to compare optimised recovery options alongside current manual approaches without disrupting established decision routes.
- Moderate Data Availability:** Core data exists (plans, outages, assets, customer windows), but would need to be structured for ingestion into an annealing approach.

Example scenario of future use

Scenario: A Winter capital outage plan is disrupted when a critical compressor outage slips, impacting multiple downstream outages and industrial customers.

Problem Statement: Re-planning is manual and heuristic-led, making it difficult to quickly understand knock-on impacts and leading to extended negotiation over recovery options.

Presence of the DPT use case: DPT rapidly explores alternative outage sequences, highlights risk trade-offs, and provides a shared evidence base to support fast, confident agreement on a revised plan.

Primary Benefits

- Speed and Reduced disruption from plan changes:** National Gas can recover quickly from outages or scope changes, limiting knock-on impacts to customers and delivery schedules
- Lower cost and effort in planning cycles:** Less rework and fewer iteration loops reduce planning effort while increasing confidence in approved plans
- Greater assurance under change:** Revised plans remain credible and defensible even as conditions shift

Impact

Technical Suitability



Value at Stake



Ease of Implementation



8 Pain points

+17 insights addressed

++ Consumer Understanding
With increased uptake in participation.

+++ Engagement
With designs tailored to consumers

*Note potential savings are high level estimates, details in appendix

Stakeholders Impacted



National Gas Capital Maintenance Planning teams



Regional Delivery teams



System Operators



National Gas Asset Management teams



Customers

- Directly Impacted (i.e. Solution provides benefits for the user)
- Indirectly Impacted (i.e. Presence of solution provides benefits to stakeholder)

Features, consequences and benefits of the outage planning use case family seek to address all major opportunity themes

Features of use cases	Consequence	Benefit theme
<ul style="list-style-type: none"> • Constraint-aware optimisation with Systematic option exploration • Integration of more data leading to automated generation of more optimal options • Early risk discovery • Reduced manual re-work as conditions change 	<ul style="list-style-type: none"> • Earlier, more credible visibility of future workloads across suppliers and system partners • Earlier identification of delivery and system conflicts, reducing late change 	Reduced network & customer risk through higher-quality plans
<ul style="list-style-type: none"> • Automated plan option generation • Rapid iteration capability • Handles combinatorial complexity 	<ul style="list-style-type: none"> • Reduced churn and downstream re-work for delivery partners as plans stabilise earlier • Increased delivery confidence through fewer late plan changes 	Greater efficiency, speed and planning capacity
<ul style="list-style-type: none"> • Explicit trade-off articulation • Evidence-based comparison • Scenario-based evaluation 	<ul style="list-style-type: none"> • Greater confidence for suppliers, customers and regulators in chosen plans • Clear justification of decisions, reducing challenge and friction 	Improved transparency and confidence
<ul style="list-style-type: none"> • Scalable planning capability • Consistent assurance narrative • Capacity release for future strategy • Performance incentive support 	<ul style="list-style-type: none"> • Enables consistent regional implementation and wider adoption across gas distribution networks • Supports cross-system coordination (e.g. electricity system planning) and alignment with incentive mechanisms 	System benefits to customers, regulators

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[Redacted]	[Redacted]	[Redacted]	[Redacted]	[Redacted]	REV estimate**
[Redacted]	[Redacted]	[Redacted]	[Redacted]	[Redacted]	[Redacted]
[Redacted]	[Redacted]	[Redacted]	[Redacted]	[Redacted]	[Redacted]
[Redacted]	[Redacted]	[Redacted]	[Redacted]	[Redacted]	[Redacted]
[Redacted]	[Redacted]	[Redacted]	[Redacted]	[Redacted]	[Redacted]

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Outage planning is a known, growing challenge across the energy system driven by speed, scale and complexity of investment and a gap in appropriate tooling

The (outage) planning challenge extends across operators and networks

Operators across electricity and gas networks are hitting the ceiling of their planning capabilities, including the volume of data, speed and quality of outputs they produce to aid timely decision-making

Emerging system interfaces are increasingly complex

Interactions between transmission, distribution, and system planning are growing in scale and complexity. Many of these challenges are still evolving and not fully defined, and no existing market solution fully addresses this end-to-end, system-wide need.

A new approach is required to address a system-wide challenge – and novel optimisation techniques provides an attractive solution pathway

The DPT, APT and LTP tools could provide new capability to help address this gap, by

- Exploring the full planning space, rather than predefined scenarios
- Scaling to complex, system-wide optimisation and support rapid re-planning
- Enabling systematic evaluation and comparison of feasible plans under defined constraints.

The approach to apply Quantum Annealing is unique and novel. Whilst other outage planning innovation projects are in flight some are not optimisation solutions, and none are exploring Quantum Annealing:

Approach / tool	Who uses it	What it does	Insights and outputs	Limitation(s)
NIA-funded OPTIMA – Outage Planning Tool Integrating Machine learning and Analytics [1]	SP Energy Networks Transmission (current NIA project).	Automated decision-support tool for transmission outage planning, using ML and analytics	Recommended outage windows and sequencing based on historical outcomes, forecast conditions, resource availability.	ML-driven and heuristic rather than globally optimal; bounded optimisation scope; relies on quality and representativeness of historical data.
NIA-funded Year-Ahead Outage Optimiser (YAhOO) [2]	SSEN Transmission only, via NIA-funded trials with N-SIDE (technology partner) [3]	Applies heuristic methods to support feasibility testing of year-ahead outage plans.	Faster feasibility checking and decision support for year-ahead outage plans within constraints.	Requires tightly scoped problem formulations to remain tractable.
NIA-funded Optimal Outage Planning System [3]	Developed and trialled by NESO planners, supported by academic partners, but not industry-wide operational tool.	Analyses power system operability impacts (e.g. thermal overloads) of planned outage scenarios.	Quantified operability and risk impacts of outages for proposed scenarios.	Designed for evaluation and risk assessment; does not perform large-scale combinatorial plan search.
Market and system analysis tools (e.g. PLEXOS) [4]	Energy planners, grid operators, utility companies, traders, and government regulators	Simulates integrated gas and electricity system operation for specified plans and assumptions.	Detailed simulation outputs including dispatch, flows, prices, emissions and constraints for.	Computationally intensive; not designed for large-scale plan search.

[1] Energy Networks Association, OPTIMA – Outage Planning Tool Integrating Machine learning and Analytics. Available from: https://smarter.energynetworks.org/projects/nia_spen_0123/ [Accessed on 06/05/2026]

[2] SSEN, YAhOO. Available from: https://smarter.energynetworks.org/projects/nia_shet_0048/ [Accessed on 12/04/2026]

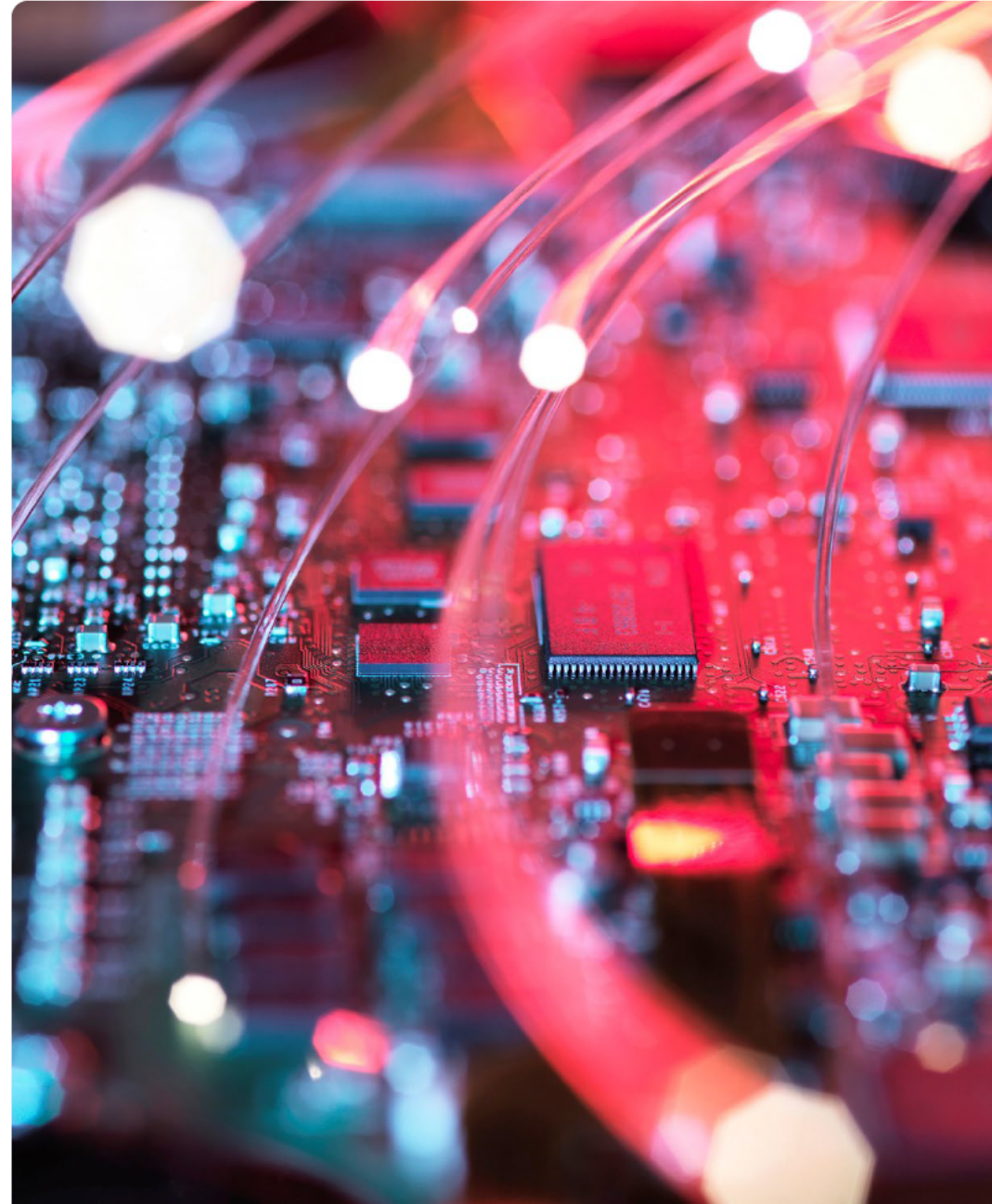
[3] NESO, Optimal Outage Planning System. Available from: https://smarter.energynetworks.org/projects/nia_nqs0037/ [Accessed on 12/04/2026]

[4] Energy Exemplar, Plexos-Logo-RGB-071720-Color-RegMark

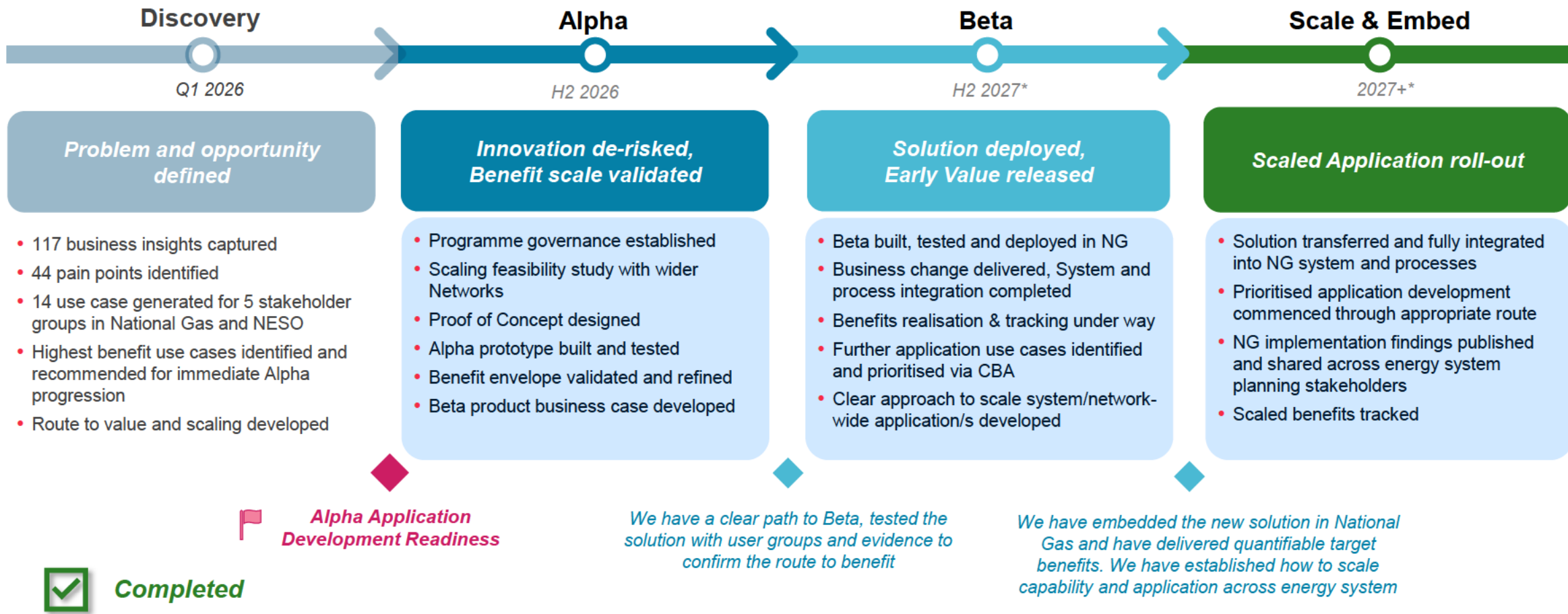
Intelligent Energy Decisions, All in One Platform. Available from: <https://www.energyexemplar.com/plexos> [Accessed on 04/05/2026]

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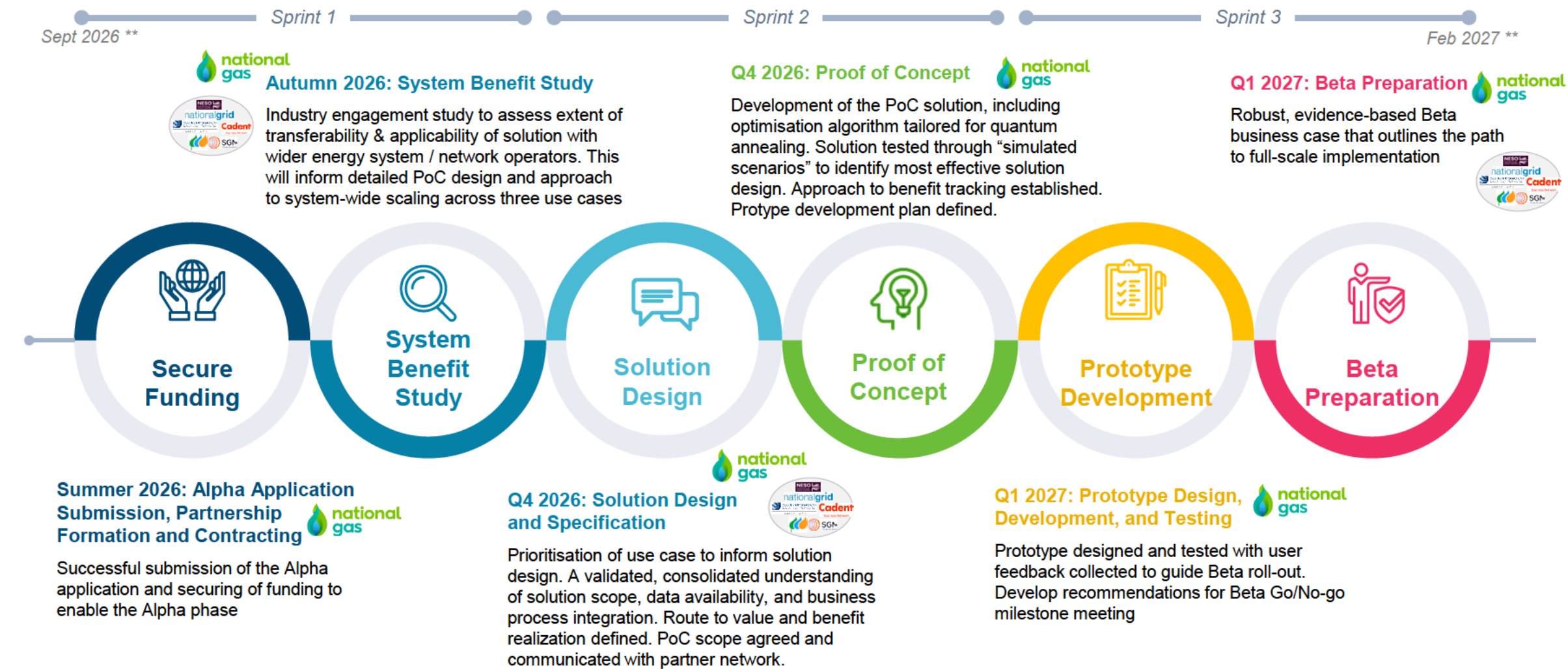
Recommendations and Alpha Design



With discovery complete, the alpha phase bridges the path to building a real-world beta delivery through iterative, user-focused sprints



The Alpha turns vision into action through three sprints that iteratively refine specification, track value and reduce risk factors



* Indication of potential collaborating partners and key engagement stages
 ** Target timelines, to be confirmed



Additional details for Alpha Phase activities, partner roles and outcomes

	Stage	Key activities	Partner roles	Outcomes
Sprint 1	System Benefit Study 	<ul style="list-style-type: none"> Test applicability and transferability of three use cases and high-level solution across wider system / network stakeholders, taking into consideration increasing complexity of future outage planning Assessing benefits, constraints, dependencies, and route to system optimisation value and scaling Confirm ongoing engagement with partner network 	<ul style="list-style-type: none"> NG: Facilitate stakeholder engagement; provide support and input into use case and benefit definitions PA Consulting: Lead engagement study, analysis of findings and design of scaling and partner engagement approach Support partners: Provide input into use case definition, applicability assessment and system benefit identification 	<ul style="list-style-type: none"> Understanding of system-level benefits and solution transferability against use cases Prioritised view of scaling opportunities across application areas by stakeholder and system Revised solution benefit estimate
	Solution Design and Specification 	<ul style="list-style-type: none"> Prioritise use cases and application areas against benefit and deliverability criteria Solution and scope design, supported by stakeholder engagement, process and user journey mapping, data discovery, assumptions, risk and dependency identification Define decision-making system and assess technology approach, including preferred quantum-enabled optimisation solution Define PoC scope, benefit measurement and realisation route 	<ul style="list-style-type: none"> NG: Lead use case evaluation against benefit / success criteria; arbitrate final use case selection; lead stakeholder engagement; provide user engagement; enable data access PA Consulting: Lead solution design and definition; Define technical data needs; design templates; lead technical discovery; collate technical evidence; support scoring and selection rationale Support partners: Support and review solution design; user journey mapping where applicable 	<ul style="list-style-type: none"> Agreed and prioritised use case Solution and PoC design defined Agreed approach to develop PoC and test scaling across wider stakeholders during PoC and Prototype
Sprint 2	Proof of Concept (PoC) 	<ul style="list-style-type: none"> Development of PoC solution, including design and build of optimisation algorithm, testing approach using simplified "simulated scenarios" to inform Prototype definition and development approach Running PoC sprints with iterative small-scale user testing Define approach to benefit tracking and performance measurement Define prototype requirements (incl data, system, functional, non-functional), user engagement and testing, and prototype build plan 	<ul style="list-style-type: none"> NG: Provide user requirement, sign off design spec; provide input into assumptions, readiness, success criteria and benefit measures; approve prototype design; lead partner engagement PA Consulting: Lead problem and solution formulation, algorithm design, lead simulation testing and performance evaluation; document results; support partner engagement; design prototype Support partners: Advise on sector-level applicability 	<ul style="list-style-type: none"> Validated mathematical formulation appropriate for quantum annealing Validated solution benefits evidenced from PoC findings Clarity on approach and plan for prototype development
	Prototype Development 	<ul style="list-style-type: none"> Definition of prototype outcome and success criteria, confirmation of delivery approach and stakeholder / user engagement Design, build and testing of prototype solution Analysis of testing feedback, solution performance and benefit measures against design and success criteria Develop recommendations for Beta Go/No-go milestone meeting 	<ul style="list-style-type: none"> NG: Provide user, data and system access/input; provide user testing support and success measurement; lead go/no-go decision PA Consulting: Lead prototype design, build, and testing; track solution benefit; lead performance analysis; prepare Beta Go/No-Go Support partners: Support testing where applicable, contribute lessons learned. 	<ul style="list-style-type: none"> Tested prototype with user-validated functionality Clear evidence of operational and commercial value Recommendation for Beta
Sprint 3	Beta Preparation 	<ul style="list-style-type: none"> Develop Beta business case, including commercial, delivery and wider system stakeholder engagement approach Identify regulatory and statutory requirements for Beta scale-up Prepare knowledge dissemination materials for sector-wide learning Confirm stakeholder ownership for future development, transfer, embedding and management 	<ul style="list-style-type: none"> NG: Own and sponsor Beta business case; Develop non-technical roadmap plan; lead partnership engagement PA Consulting: Consolidate evidence; support business case development and technical roadmap planning Support partners: Provide input into Beta plan, rollout, and solution transfer 	<ul style="list-style-type: none"> Beta business case Clear and credible path to implementation Plan to transfer, apply, scale across partnership network

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