Final Report

NGED Connection Journeys AI Innovation Project

National Grid Electricity Distribution

November 2025

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Introduction

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Project Overview

In the energy sector, one of the most pressing issues over the past three years has been the growing queue for electricity grid connections. NGED's queue has exceeded 50 GW, encompassing more than twice the generation capacity required for CP30. The most significant challenges arise at the HV and EHV levels, where the queue continues to expand and both generation and demand connections involve complex, multi-team coordination and lengthy processes. The volume of HV and EHV connection applications to UK distribution networks has surged dramatically in recent years and is expected to rise, reflecting the rapid pace of electrification and the push toward net zero. This is likely to require more heads to handle and process these applications which is likely to increase the opex expenditure for distribution networks if more intelligent ways of handling these applications are not identified and embedded.

Currently, there is a limited understanding of how AI can be effectively integrated into the HV and EHV connection workflows, which areas should be prioritised, and the specific obstacles that might hinder the full realisation of AI capabilities.

This project aims to identify potential AI opportunities, determine priorities, and develop one selected opportunity into a demonstrable Proof of Concept (PoC). Baringa is leading the initiative, with EA Technology providing additional support and expertise in power systems engineering.

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Scope and Objectives

Scope

The AI in Connections topic covers a wide range of potential applications across various network connection types. NGED stakeholders have decided to concentrate this project on specific connection categories, selected due to the high volume and complexity of these requests:

- HV (11kV) demand and generation connections and
- EHV (33kV+) demand and generation connections

Objectives

- Identifying challenges and opportunities within the current HV and EHV connection processes and exploring possible solutions, including AI-based approaches.
- Creating and recommending a roadmap to ensure NGED is well-positioned to adopt AI solutions efficiently and in a coordinated way.
- Delivering a Proof-of-Concept AI solution targeting one of the most critical pain points.

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Key learnings from other similar projects

Many projects have explored AI use in networks, but none have focused specifically on its use in Major Connections.

Project	Description	What is the impact on customers?	Learning and relevance for Connection Journeys AI
AImee	• This (ongoing) UKPN project aims to understand where AI (and other solutions) can be used to automate tasks for customer-facing staff. • Value in a self-serve tool to allow customers and third parties to get direct answers to questions from a trusted source.	• The self—service tool will help support vulnerable customers, by providing quick information directly through self-serve (for those able to) or indirectly by freeing up staff resource to concentrate on more complex cases and customers requiring additional support.	• Customer-facing self-serve tools (through AI otherwise) support vulnerable customers by giving direct access to information and freeing up staff resource. • Any customer-facing tool must be trusted by customers. • Automated tools should not completely replace more traditional methods of communication between customer and network operator such as phone calls.
StormAI	• This SSEN project sought to embed an AI solution to improve accuracy of the Estimated Time of Restoration (ETR) provided to customers through SSEN's website. • The solution used AI image recognition and analysis to predict the ETR .	• ETRs were already available on SSEN's website • A limited training data set size restricted the efficacy of the model. • The tool is expected to be integrated into SSEN's online Power Track tool, once the data set has increased sufficiently to improve the model's efficacy.	• The efficacy of the model was restricted by the training set sample size. • It is important when training an AI model to maximise the size of the data set used to train the model.
iDentify	• This SPEN project sought to use AI image recognition to identify network assets (such as cut-outs) and provide this information to installers through a web-app / mobile app.	• App allows installers to self-serve queries which may previously have required conversation with DNO. • This allows for quicker installations for customers.	• Web or mobile apps are an effective means for hosting AI applications for use by installers, having received highly positive feedback in iDentify. • AI image recognition is effective at recognising network assets.
Artificial Intelligence and Machine Learning	• This ENWL project sought to utilise machine learning on data collected by LV monitoring equipment to make recommendations for network investment.	• The project demonstrated the Machine Learning could be used to successfully categorise fault types as joint & terminations or mid-cable, reducing time to restoration in the event of a network fault	• This early project (2018-2021) gave early indication of potential benefits of AI and Machine Learning to network operators. • It showed AI and Machine Learning could be used, in conjunction with network monitoring data to provide insight to network operators about the status of their network.
ConnectDirect	• The ENA's ConnectDirect platform is an AI-powered tool used to improve the application process for connecting domestic LCTs (EVs / Heat Pumps / PV / BESS)	• Since the broad rollout to installers in May 2024, the system has successfully been used to automatically give installers rapid consent to connect LCTs. In more complex cases, these are escalated to planners for resolution.	• AI tools are powerful tools for increasing speed of connection approvals (reducing average processing times for LV LCT connections to 1.5 days). • AI tools usage has a record of rapid scaling. ConnectDirect was used to process over 100,000 applications in its first year of use.

Need for this project:

- The projects described above consistently show benefits to customer through the use of AI in various area of DNO operation, including in LV connections. However, none of the project above reside within the HV / EHV Connections area of DNOs' operation. This project is needed to explore where the benefits of AI could be unlocked for customers and network operators themselves, by addressing pain points, improving operational efficiency and delivering positive impact against NGED's ED2 business plan commitments.

Approach taken

The project was delivered in five distinct phases

1

Project Mobilisation Workshop

The project team engaged with senior NGED stakeholders to ensure alignment with Connections strategic goals.

2

Connections Journey Analysis and AI Opportunity

The project team conducted in-depth analysis of existing HV and EHV connection journeys from pre-application through to offer and acceptance, through three one-day workshop with NGED stakeholders involved in the process (11kV Planner, PND engineers, policy). Pain points in the existing process were identified and solutions (AI and otherwise) ideated.

3

AI Use-Case Prioritisation

The team reviewed the AI use-cases identified and prioritised based on stakeholder feedback, accounting for the value delivered to NGED through improved efficiency and customer satisfaction and the complexity of solution development. The prioritisation process also accounted for dependencies.

4

Roadmap and Backlog

An AI roadmap was developed that outlines NGED's key initiatives over the next decade. It is designed to build a strong foundation for AI capabilities, enhance operational efficiency, and improve customer satisfaction. It also serves as a strategic guide for innovation, detailing the priority projects and their sequencing to ensure smooth integration into business-as-usual operations.

5

Proof of Concept

A Proof of Concept (PoC) was developed based on a stakeholder-prioritised use case, serving as a practical demonstration of the proposed solution's potential. The PoC surfaced key insights and learnings, which informed a set of recommended next steps to guide future development and implementation.

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AI Use Case Identification

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AI opportunity analysis and Stakeholder engagement approach

>50 Stakeholders

Engaged across NGED senior leaders, customer applications, PND, 11kV planners, policy, IT&D

6 Workshops

Held across the end-to-end HV and EHV connections journey incl. prioritisation

~70 Pain Points

Elicited from engagement with NGED stakeholders

9 AI use cases

Identified with potential AI solutions

The project has engaged with numerous **stakeholders** across the end-to-end **connection journeys for HV and EHV** connections within NGED to **elicit over 70 pain points** and identify **nine pain points/ opportunities that can be addressed by implementing AI-based solutions.**

#	Use case Description
1	Use of AI to ensure the integrity of the incoming application
2	Use of AI in searching relevant policies and uniform interpretation of policies for planners and PND engineers
3	Generating Budgetary quotes and Application Factors using AI
4	AI based optimal route selection to the point of connection
5	AI based commodity pricing reporting
6	Use of AI in responding to Customer Enquiries from customer
7	AI based ICP design assessment
8	Use of AI in assisting planner and PND teams to minute customer conversations
9	Use of AI in draft connections agreements

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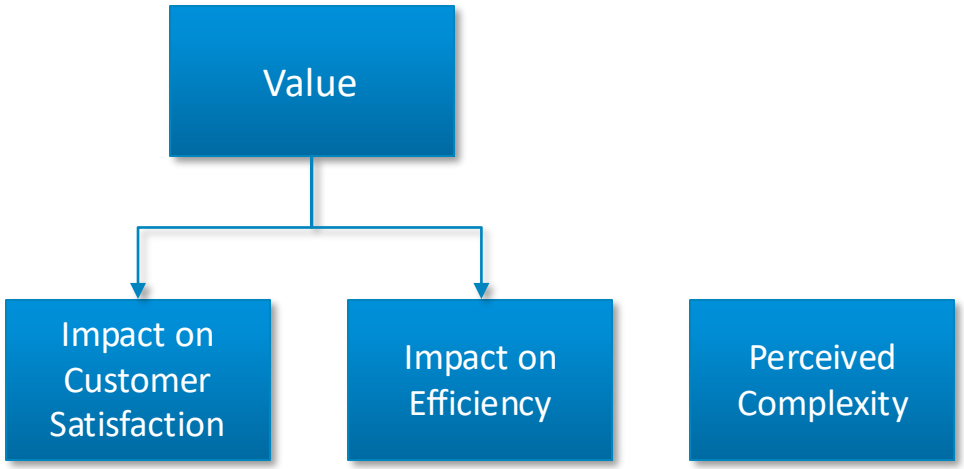
POC Selection Criteria

Each of the 9 use cases identified were subject to a prioritisation exercise to identify the use case to be selected for PoC development



- A prioritisation exercise was conducted to identify which AI solution to develop into POC
- Stakeholder views (PND engineers, 11kV planners, connections policy team) were elicited to understand the value of each solution
  - ► This was reviewed and revised by senior stakeholders, accounting for NGED's strategic objectives
- The complexity of integration was considered based on Baringa's expertise and experience in developing similar AI solutions
  - ► This also accounted for critical dependencies and access to relevant data sources, and deliverability with the project duration
- The combination of value and complexity were used to identify the POC based on optimal combination (highest value delivered with a reasonable complexity given the relative short timescales of this project)

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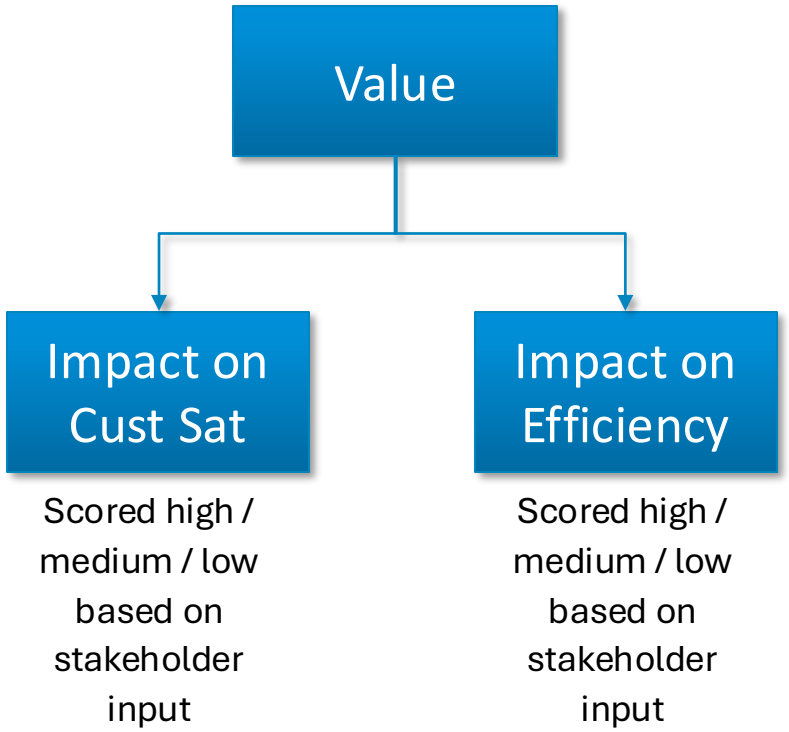
Ranking Framework Used For Guidance

The following ranking framework was used for evaluating AI initiatives based on their impact on efficiency and customer satisfaction. The framework categorises the impact into three levels: high, medium, and low, providing a structured approach to assess the potential benefits of each initiative. The stakeholders used this criterion to rank the solutions that offer the most significant improvements in both operational efficiency and customer experience.



Impact on Customer Satisfaction	Impact on Efficiency
High – Has a significant shift in customer sentiment. i.e. significant improvement in transparency of info and delivers agility in response from NGED	**High** - Implementing an automation system that reduces processing significantly.
Medium – Leads to some noticeable improvement in customer satisfaction. i.e. moderate improvement in transparency of info and delivers agility in response from NGED	**Medium** - The initiative leads to a measurable but moderate increase in efficiency.
Low – Has minimal or no improvement in transparency of info or in agility in response from NGED	**Low** - The initiative yields little or no immediate improvement in efficiency metrics. It may have a negligible effect or only enable future improvements indirectly

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Ranking of AI Use Cases

Each of the 9 AI use cases were ranked against the agreed criteria to identify a use case for PoC Development

#	Use case Description	Impact on Customer Satisfaction	Impact on Efficiency	Perspective on Complexity
1	Use of AI to ensure the integrity of the incoming application	Low	Medium	Medium
2	Use of AI in searching relevant policies and uniform interpretation of policies for planners and PND engineers	High/Medium	Medium/Low	Medium
3	Generating Budgetary quotes and Application Factors using AI	High	High/Medium	Medium/Low
4	AI based optimal route selection to the point of connection	Medium	Medium	High
5	AI based commodity pricing reporting	Medium	Low	High/Medium
6	Use of AI in responding to customer enquiries	High/Medium	High	High/Medium
7	AI based ICP design assessment	High	High/Medium	High
8	Use of AI in assisting planner and PND teams to minute customer conversations	Medium	Medium	Low
9	Use of AI in draft connections agreements	Low	High	Medium

The stakeholders assessed these AI opportunities based on their potential impact on operational efficiency and customer satisfaction. The AI solutions were evaluated on their perceived complexity, and based on this analysis, a use case #3 for proof-of-concept (POC) development was selected.

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AI Use Case Description

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AI Use Case 1: Ensuring Application Integrity

Summary of the issue

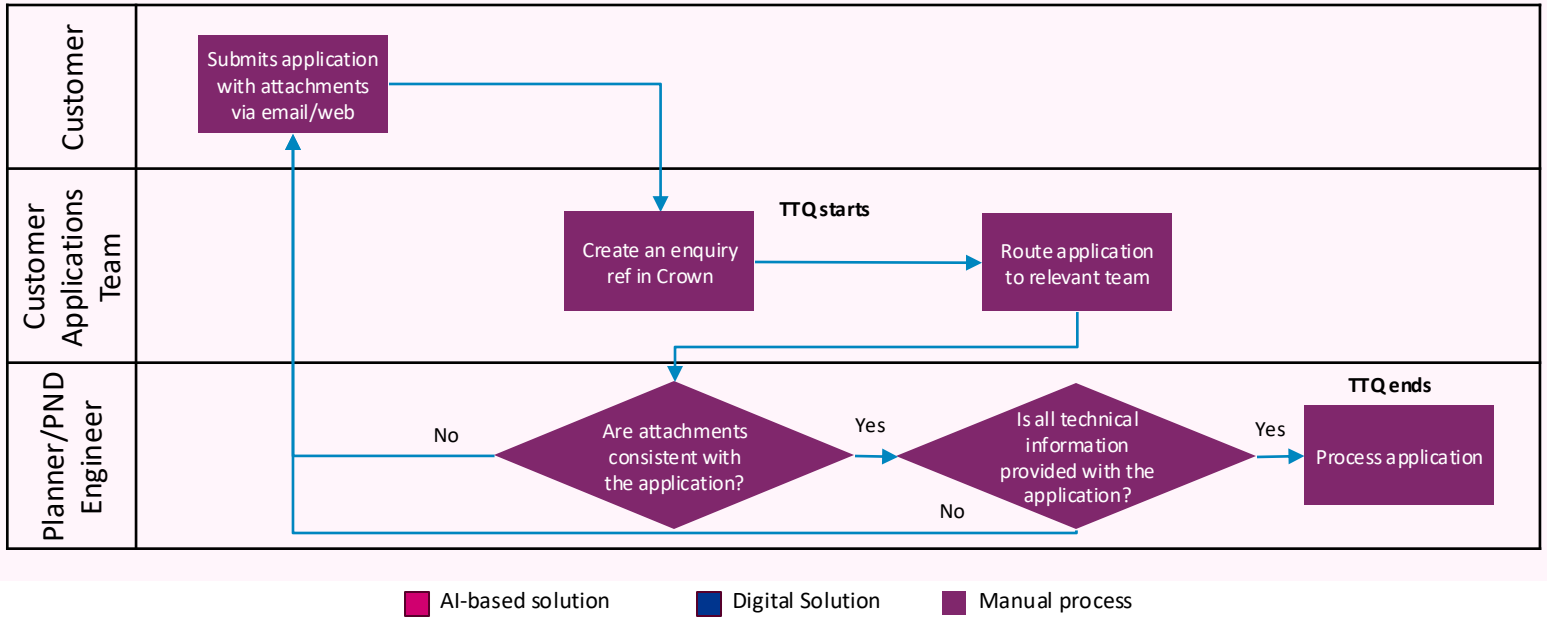
- The Customer Applications Team (CAT) manages a significant volume of enquiries via different sources such as email and online portal, since not all incoming applications are submitted through the online system. The CAT team raises an enquiry reference number in CROWN, and at this point, the Time to Quotation (TTQ) starts getting calculated.
- There is no efficient customer triaging method available online, and as a result, many applications are not triaged effectively before they are sent to planners. Consequently, planners and PND teams frequently need to invest time verifying that applications contain the necessary information and that the details align with the attached documents and request for missing information, whilst trying to minimise the impact of delays on TTQ.

Stakeholders who are impacted

Customer Application Team

Planners and PND Engineers

Current Process



Connections Journey and Process Steps

- Application to Offer: Budgetary quotation and Formal quotation

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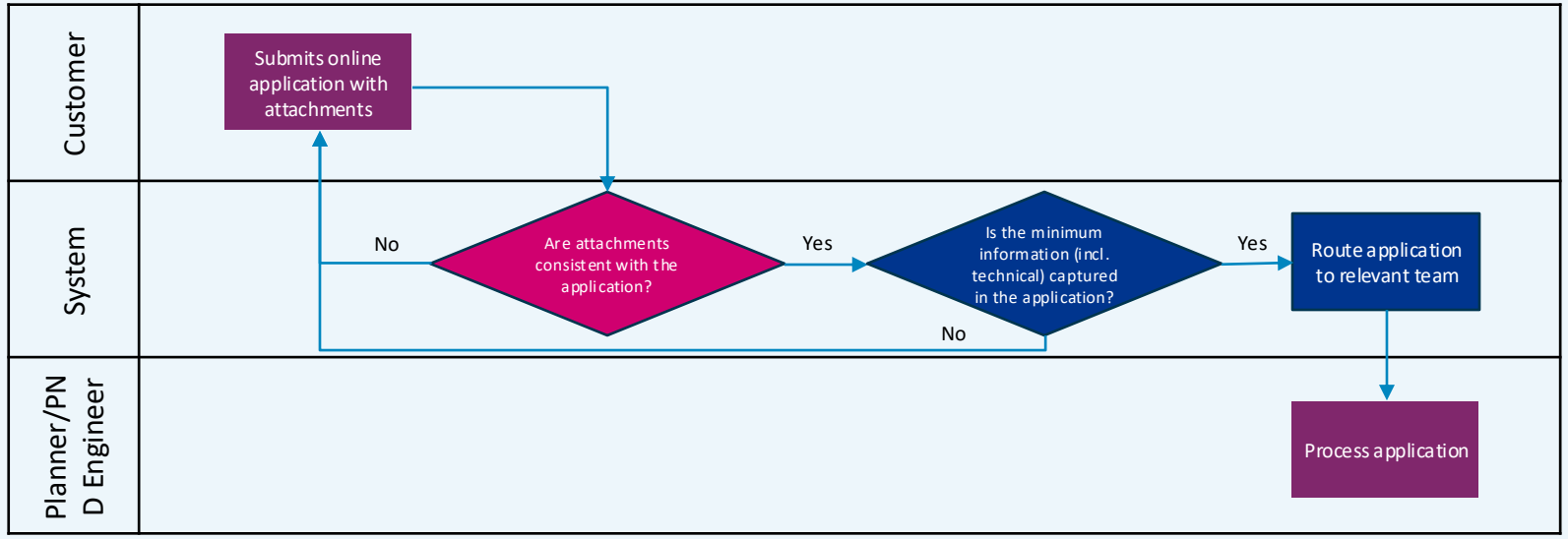
AI Use Case 1: Ensuring Application Integrity

High level overview of the solution

- An AI based system (forms part of a connection application processing solution) that leverages intelligent document processing to ingest and subsequently validate attachments such as Site plans, technical documents and Letter of Authority to indicate readiness and compares then with the information within the application form.
- The AI solution is enabled by Multi-modal Retrieval-Augmented Generation (RAG) process that allows users to input text, documents and images into an LLM-powered system that dynamically compares applications against uploaded attachments.
- Additional context can be provided alongside the attachments in the form of text, and this solution could form part of a more holistic RAG system that also makes use of policies, standards and other datasets. The solution can be developed as an internal tool initially. Then it can be used to respond directly to applicants once it has been robustly tested and inspires sufficient confidence.

High-level process flow with the solution



Impact on NGED Commitments within ED2

High	Medium	Low

- **GM1: Customer Satisfaction**
- **GM2: Awareness of Competition**
- **GM3: Guaranteed Standards of Performance**
- **GM4: Stakeholder Engagement**
- **GM5: Published Information**
- **GM6: MCTTQ/MCTTC**

Impact Description

- This initiative has the potential to enhance operational efficiency by lessening the workload for CAT teams, planners, and PND planners. (GM3, GM6)
- Early detection of gaps in applications can inform customers promptly, allowing them to address these gaps sooner in the process. (GM1, GM6)
- Receiving a complete application will aid in better setting of the GRT clock and contribute to improving the MCTTQ. (GM6)

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Risks, Dependencies, Barriers and Considerations

Risks

- The training dataset should encompass a variety of attachments and documents typically received during the application process. If the AI is trained on restricted, biased, or inaccurate data, it may produce unreliable results.
- The expected advantages may diminish if the Customer Applications Team, planners, or PND engineers do not trust or fully understand the system and decide to disregard the AI outputs.

Mitigation

- Governance and controls must be put in place to monitor the performance of the solution and capture any bias within AI input data. Metrics should be identified and reported to show transparency.
- NGED should audit data sources to detect patterns that could lead to biased results and enhance datasets to ensure balanced representation where disparities exist.
- NGED may use synthetic data to address deficiencies in real-world datasets, aiding in achieving balanced representation, particularly when real data is scarce or sensitive.

Dependencies

- This solution will be integrated into a wider programme aimed at digitising the entire connections process at HV and EHV levels.
- A roadmap for connections initiatives is currently being created to deliver a comprehensive end-to-end solution by ED2.
- The solution will necessitate applications to be submitted in a standardised format, allowing the AI system to evaluate them consistently and supporting uniform connection processes across HV and EHV levels.

Regulatory Barriers and Considerations

Barriers:

- No regulatory obstacles have been identified.

Considerations

- It is important for the digital solution to account for the Guaranteed Response Time (GRT) clock, a regulatory performance metric used in the UK electricity distribution sector, to ensure accurate measurement of performance regarding Time to Quote within the Major Connections Time to Connect Incentive, so that the automated process remains compliant.

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AI Use Case 2: Internal Policy Tool for Planners and PND teams

Summary of the Issue

- Planners and designers spend significant time trawling through relevant connections and engineering policies throughout the connections journey. For example, during the quotation/offer process or when responding to customer queries, time is spent searching for guidance in policy documents or back-and-forth communication with connections policy teams.
- There are inconsistencies in practices followed across the regions. This is due to policy changes often being communicated informally via email, which may not reach all relevant personnel. For example, the internal written policy for submitting works to the Statement of Works team is outdated and therefore not often followed.

Stakeholders who are impacted

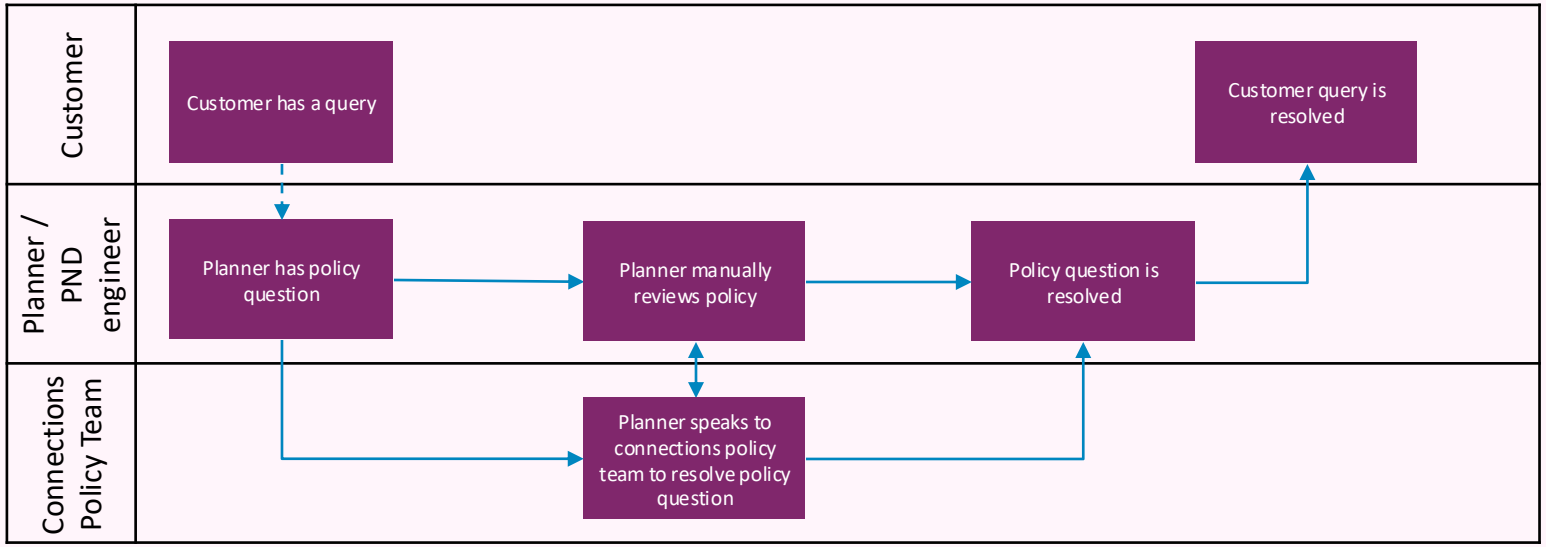
11kV Planners

PND Engineers

Connections Policy Team

Major Projects Team

Current Process



AI-based solution Digital Solution Manual process

Connections Journey and Process Steps

- Pre-Application: Budgetary quotation
- Agreement & Energization: Planning

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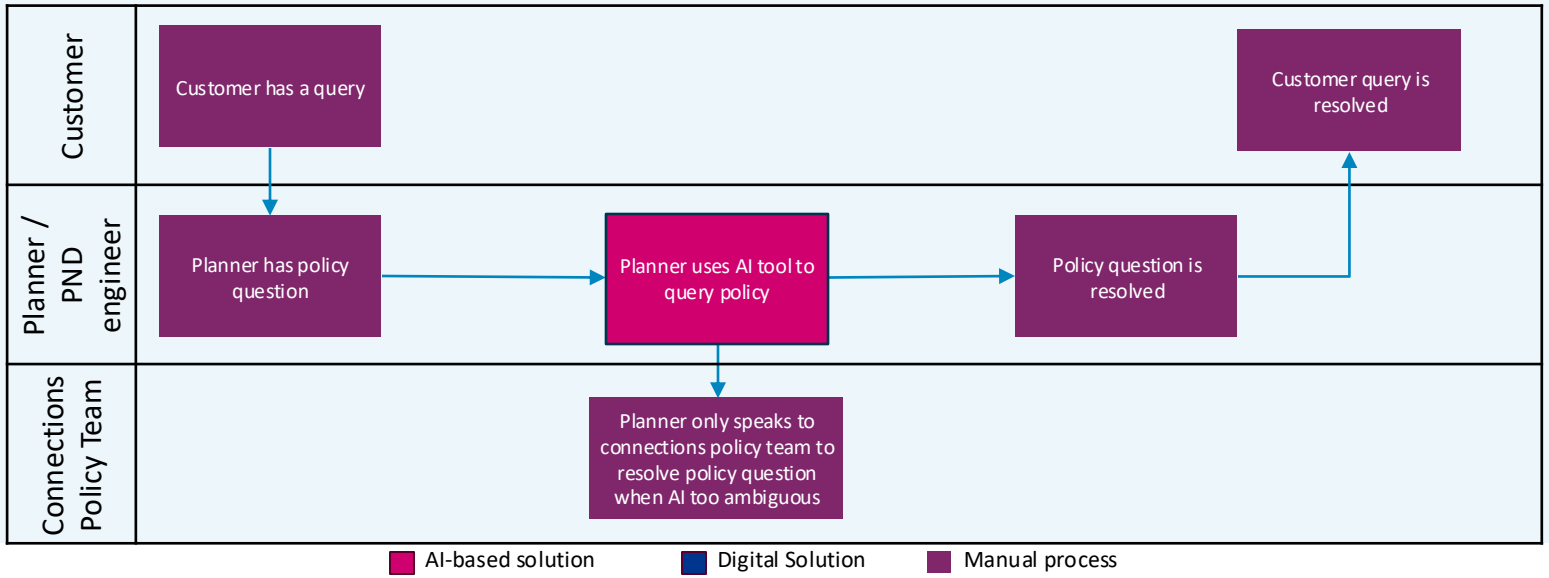
AI Use Case 2: Internal Policy Tool for Planners and PND teams

High level overview of the solution

- An internal policy search tool designed for Planners and PND teams to address policy-related queries using natural language efficiently. This tool will utilise a Retrieval-Augmented Generation (RAG) approach to process requests from Planners and Designers, dynamically locating the pertinent NGED policies and specific sections, and delivering a clear, concise report.
- Additionally, the tool will offer direct references to the original policy documents, enabling planners to verify responses against the source material.
- The system can also be trained to detect possible policy gaps or ambiguities, suggest remedial actions, and compile a backlog of potential policy updates or changes for the connections policy team's consideration.

High level process flow with the solution



Impact on NGED Commitments within ED2

High	Medium	Low

- **GM1: Customer Satisfaction**
- **GM2: Awareness of Competition**
- **GM3: Guaranteed Standards of Performance**
- **GM4: Stakeholder Engagement**
- **GM5: Published Information**
- **GM6: MCTTQ/MCTTC**

Impact Description

- Planners will be able to quickly search policy documentation, minimising the need for repeated interactions with the policy team and reducing the time spent manually reviewing documents. This improvement boosts operational efficiency, shortens the time to quote and connect (enhancing MCTTQ/MCTTC – GM6), and ensures adherence to guaranteed standards (GM3).
- Using a consistent tool will promote more uniform interpretation of policies among different planners.
- This approach will support standardized communication with customers, guaranteeing a consistent level of service across all regions and enhancing customer satisfaction (GM1).

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Risks, Dependencies, Barriers and Considerations

Risks

- AI solutions based on RAG, like the proposed approach, tend to produce fewer hallucinations compared to standard Large Language Models. However, occasional instances of false or inaccurate information may still occur.
- Knowledge Base – If the available policy data is outdated or lacks sufficient high-quality, structured information to effectively support the AI model, the generative output may be misleading. This risk is greater in complex or edge-case scenarios. Additionally, any biases present in the knowledge base are likely to be reflected in the tool's responses.
- The AI tool may become obsolete if newly published or updated policies are not integrated promptly, which could result in inaccurate guidance. Regular updates and reconfiguration may be necessary as policies change.
- If retrieval system contains biased or inconsistent documents, the model may reflect or amplify those biases. Excessive dependence on retrieved content could result in the approval of inaccurate information if the system is left inconsistent.
- Resistance to Adoption – Planners and PND teams might be reluctant to trust AI-generated interpretations over traditional manual reviews or human consultations, potentially limiting the tool's effectiveness and return on investment.

Mitigation

- NGED to hold training for tool users to ensure all users are aware of possible shortfalls of approach, such as hallucinations. The tool will provide source documentation, which tool users should use to verify its responses.
- NGED should conduct a thorough audit of the policies forming the training data, to ensure policies are accurate, high-quality and up-to date. This audit should also ensure the training data is non-biased and achieves a balanced representation. The audit should also ensure all policies in the repository have accurate metadata populated.
- The RAG system should use document scoring (where documents are scored based on recency, trustworthiness and relevance) to ensure responses are reliable.
- Solution architecture must be carefully designed to ensure NGED's policies are kept secure. The solution will be designed to limit sensitive documents based on user roles to those with appropriate access permissions.
- NGED staff to use policies referenced by AI to verify that the tool is returning correct information. Human in the loop practices should be adopted, especially for critical questions.

Dependencies

- A well-curated, structured, and tagged repository of documents (e.g. engineering policies, standards, design templates). Version control and metadata (e.g. voltage level, region, date, applicability) to support accurate retrieval.
- Engineering rules and connection policies must be encoded in a machine-readable format. Ongoing governance to be in place to update rules as standards evolve.
- Access to a reliable Large Language Model, supporting responses grounded in retrieved content from the policy repository (knowledge base).
- An effective training programme should accompany the tool's introduction to ensure it is understood and trusted. Fine-tuning or prompt engineering to align with domain-specific language and safety-critical constraints

Regulatory Barriers and Considerations

Barriers:

- No regulatory obstacles have been identified.

Considerations

- Budget estimates and quotations must comply with the regulatory standards, regardless of the process planners go through to check compliance with policy. Therefore, importance of accurate responses is paramount.

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AI Use Case 3: ML based budgetary quotation

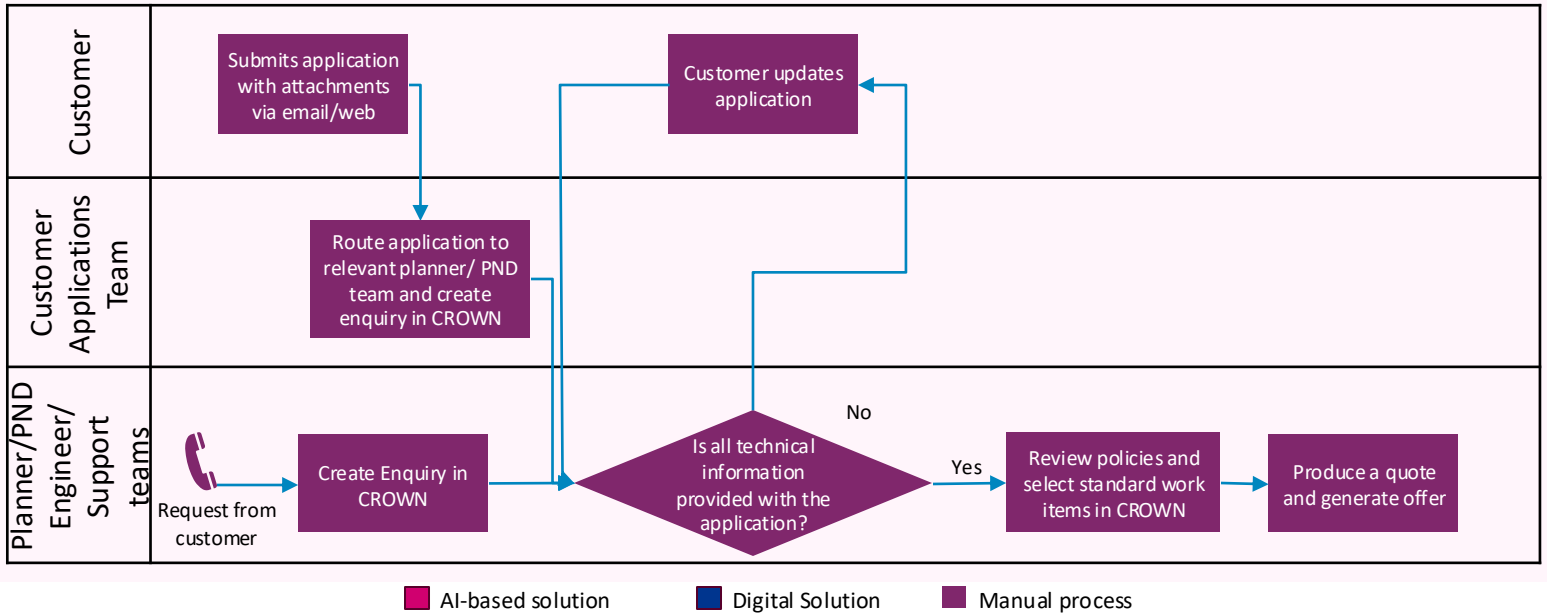
Summary of the issue

- At present, users are unable to generate budget quotations via self-service. Numerous requests for budget quotes have been submitted by applicants, increasing the workload for designers and diverting their attention from more critical and complex formal offers.
- Over the past five years, more than 9,500 applications were received for budgetary quotes at 11 kV or below, while approximately 3,500 applications were submitted for connections at 33 kV and above. Not all budgetary quotes convert into valid connection projects. While planners and PND engineers create high-level budgetary quotes without conducting detailed studies, the volume of budgetary quotes creates a significant demand on planners/PND teams' time.
- Several customers have reported a significant difference between budgetary and formal quotes and expressed dissatisfaction.

Stakeholders who are impacted

Planners and PND Engineers

Current Process



Connections Journey and Process Steps

- Application to Offer: Budgetary quotation and Formal quotation

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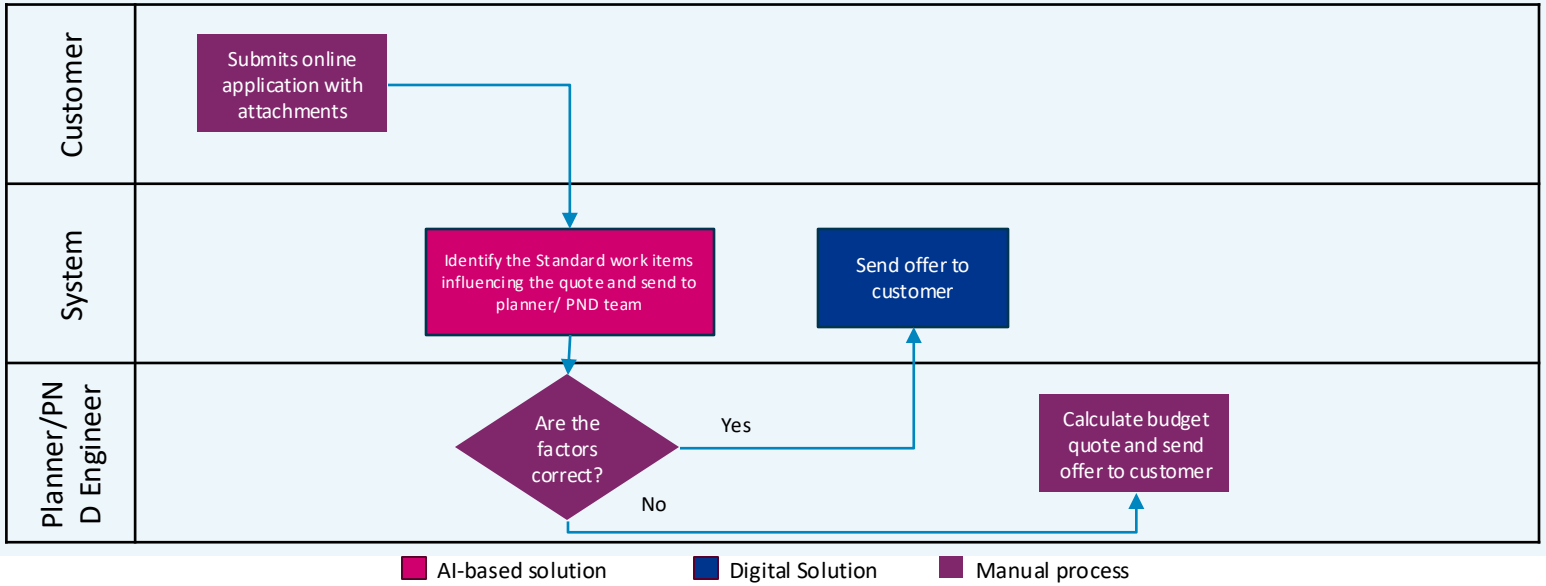
AI Use Case 3: ML based budgetary quotation

High level overview of the solution

- A machine learning approach that will empirically derive the budget prediction and/or the inputting factors leveraging regression and classification techniques, respectively. This model will leverage all available data input into an application, serving as the independent variables, including temporal features that can learn seasonal and other time-dependent variations.
- The dependent variable could leverage final offers for applications and budgetary factors. The solution will involve an analysis of correlations between the dependent and independent variables, which will identify salient features which, via feature engineering, will be curated into a training and test dataset. Competitive testing of various machine learning models will be leveraged, with additional consideration for explainability, to provide NGED with insight into which features most impact the output. A planner or PND engineer can review the budgetary quotes and input factors until they build enough trust and then be exposed to customers through a web portal or other customer-facing interfaces.

High level process flow with the solution



Impact on NGED Commitments within ED2

High	Medium	Low

- **GM1: Customer Satisfaction**
- **GM2: Awareness of Competition**
- **GM3: Guaranteed Standards of Performance**
- **GM4: Stakeholder Engagement**
- **GM5: Published Information**
- **GM6: MCTTQ/MCTTC**

Impact Description

- This approach aims to bridge the gap between the quotes produced at the budget stage and the formal offer stage and will enhance customer satisfaction. (GM1)
- Implementing digital and AI tools to generate speculative budget quotes will increase the efficiency of planners and PND teams, allowing them to concentrate on more complex and time-intensive tasks. (GM1, GM6)
- This efficiency and bandwidth will help in improving GSOP performance and improving the MCTTQ metrics. (GM3 and GM6)

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Risks, Dependencies, Barriers and Considerations

Risks

- Machine Learning models can misfire if not carefully managed. Issues like inaccurate predictions, overfitting to training data, or biased outputs are common technical pitfalls. Poor data quality or concept drift over time further erode model reliability.
- Good models can fail to deliver value if not operationalised well. Challenges in deploying ML into existing systems, scaling it in production, and maintaining it (retraining, monitoring performance) often derail projects. Security and infrastructure gaps add additional operational risk.
- ML applications must respect data privacy laws and ethical norms. Opaque “black-box” algorithms that can’t be explained, or models that inadvertently discriminate, pose legal liabilities and reputational harm. Regulators increasingly demand fairness, transparency, and accountability from AI systems.

Mitigation

- NGED should use cross-validation, hold-out testing, and performance tracking to ensure accuracy, while preventing overfitting with regularisation, model simplification, and early stopping. Regular audits, bias checks, and data validation help control bias and quality, alongside continuous learning to manage drift.
- Operational risks can be managed by involving IT early, aligning models with workflows, implementing strong MLOps, conducting regular reviews, and improving security through encryption, access controls, and adversarial testing.
- Finally, the legal and ethical risks can be addressed by anonymising data, continuing the existing DPIA practices and minimising personal data usage. Accountability should be strengthened by assigning responsible owners and ensuring human oversight for critical decisions

Dependencies

- This solution can be implemented in 2 phases. Within the first phase, the solution can be used to produce budget quotes that a planner will verify. During the second phase, the solution will be exposed to customers as part of a self-service system, whereby customers can generate quotations automatically.
- For the second phase, the solution would need to integrate with a digital connection solution that enables HV and EHV customers to self-serve.

Regulatory Barriers and Considerations

Barriers:

- No regulatory barriers identified

Considerations:

- The solution must consider the stage at which the GRT clock is triggered to measure performance on Time to Quote as part of the Major Connections Time to Connect Incentive

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AI Use Case 4: AI based cable route optimisation

Summary of the issue

- Cable routing for the study is manually handled by planners. The manual process can be time consuming, and may not account for details such as the ground surface material especially when site visits are not possible. This affects the accuracy of the budget estimates produced.
- Offers are frequently generated without an on-site inspection, relying instead on a standard rate, and are subsequently adjusted after the site visit to present a more precise cost to the customer.
- This practice can affect customer satisfaction, as there are often differences between the initial budget estimates and the formal quote.

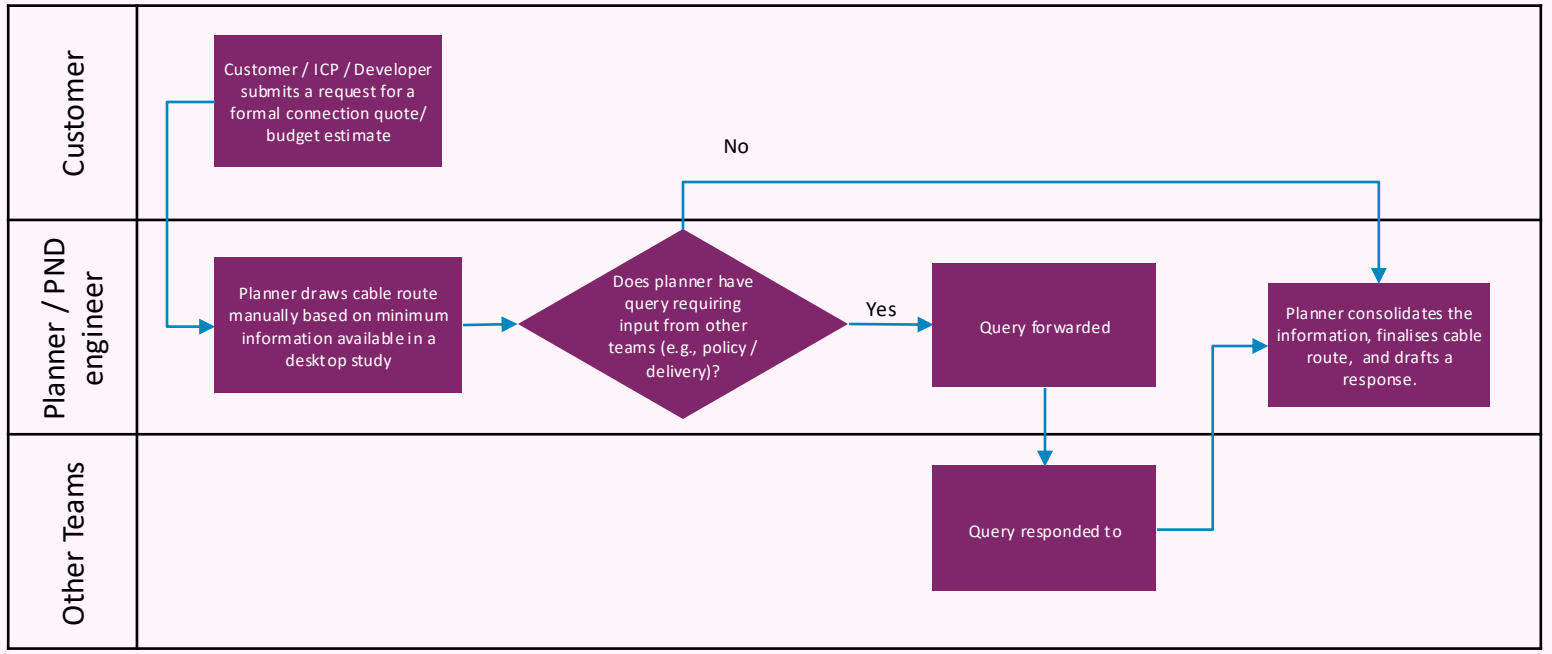
Stakeholders who are impacted

11kV Planners

PND Engineers

Customers/ ICPs/ Developers

Current Process



AI-based solution Digital Solution Manual process

Connections Journey and Process Steps

- Study: Network study, Planning

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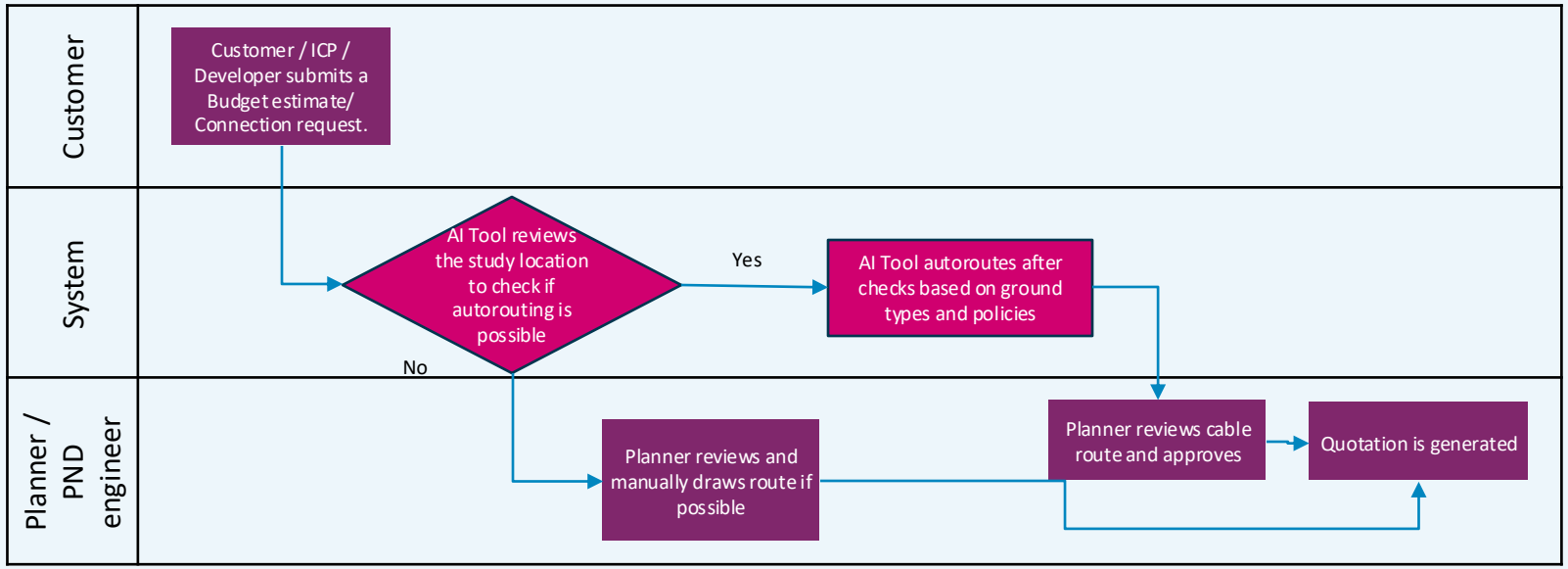
AI Use Case 4: AI based cable route optimisation

High level overview of the solution

- The solution will leverage a combination of AI routing methods and metaheuristics to identify the lowest cost and most realistic routes. The system will leverage AI Image recognition on satellite and/or street view images to leverage surface types, which will serve as an input to a Graph Neural Network (GNN) or similar model, optimised to create the most realistic resulting graph. Metaheuristics can then be leveraged on this resulting graph to optimise for the "shortest" route from point A to B according to the learned graph network. The shortest route here would be defined as the least cost. GNNs are a class of machine learning models that operate on graph-structured data, such as maps. They are designed to learn patterns, relationships, and subsequent attribution to nodes and edges.
- This solution will form part of the connection self-service solution proposed by NGED. It can complement the ML-based quotation generation to produce quotes that are reflective of practical challenges currently only observed during site visits post offer acceptances.

High level process flow with the solution



Impact on NGED Commitments within ED2

High	Medium	Low

- **GM1: Customer Satisfaction**
- **GM2: Awareness of Competition**
- **GM3: Guaranteed Standards of Performance**
- **GM4: Stakeholder Engagement**
- **GM5: Published Information**
- **GM6: MCTTQ/MCTTC**

Impact Description

- Faster route information improves customer satisfaction by allowing information to be provided to customers about the cable route earlier. Automatic cable routing will improve the accuracy of estimates at the budget stage and at full quotation. The discrepancies between estimates and quotes will be reduced, increasing customer satisfaction (GM1)
- Automated cable routing increases planner efficiency by reducing the time for cable routing. This decreases the time to quote, therefore delivering improved TTQ performance drives MCTTQ/MCTTC outcomes (GM6)

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Risks, Dependencies, Barriers and Considerations

Risks

- Poor quality or incomplete map, imagery, or historic cost data may lead to inaccurate route recommendations.
- AI models may suggest routes that are mathematically optimal but impractical due to land access, regulatory, or environmental constraints.
- Suggested routes may not fully comply with planning regulations, safety standards, or environmental requirements.
- Planners and engineers may mistrust AI recommendations if the reasoning is not transparent.
- AI models may degrade over time if not retrained with updated data, leading to outdated or irrelevant outputs.
- Variability in data resolution and coverage across regions may reduce consistency and fairness of route optimisation.
- High computational requirements for graph-based optimisation could impact scalability and performance.

Mitigation

- Validate and cross-check map, imagery, and cost datasets through robust data quality pipelines. Embed compliance checks to ensure suggested routes meet planning and safety requirements.
- Incorporate regulatory, environmental, and land access constraints directly into optimisation logic.
- Provide explainability features (e.g., rationale for route selection) to build user trust.
- Establish and maintain human-in-the-loop review to verify AI outputs, especially for high risk cable routes and/or where confidence in the cable route is low.
- Consider establishing regular retraining cycles using updated map, imagery, and project data.
- Normalise data sources and apply bias audits to reduce inconsistencies across regions. Consider utilising synthetic data where data is incomplete to address data bias and ensure balanced representation.
- Optimise computational requirements by leveraging scalable infrastructure and efficient algorithms.

Dependencies

- Availability of up-to-date input (e.g. OS) map data and high-resolution satellite imagery, both of which require frequent and preferably automated updates.
- Integration with existing planning and design tools used by planners and PND teams.
- Scalable computational infrastructure to run graph-based optimisation efficiently and cost-effectively.
- Access to historical cable routes and cost breakdowns for model training.
- Well-structured and version-controlled repository of engineering and connection policies, consistently populated with metadata.
- Mechanisms for planners and engineers to provide continuous feedback on AI outputs to ensure AI solution is monitored and updated when required.
- Alignment with NGED's digitalisation strategy to ensure long-term adoption and support.

Regulatory barriers

- NGED are under a license obligation to offer the lowest (whole cost) capital cost solution, while obliging to operate economically, efficiently, and resiliently.
- The team must provide confidence that the solution produces the lowest capital cost solution that is feasible.

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AI Use Case 5: AI based commodity pricing reporting

Summary of the issue

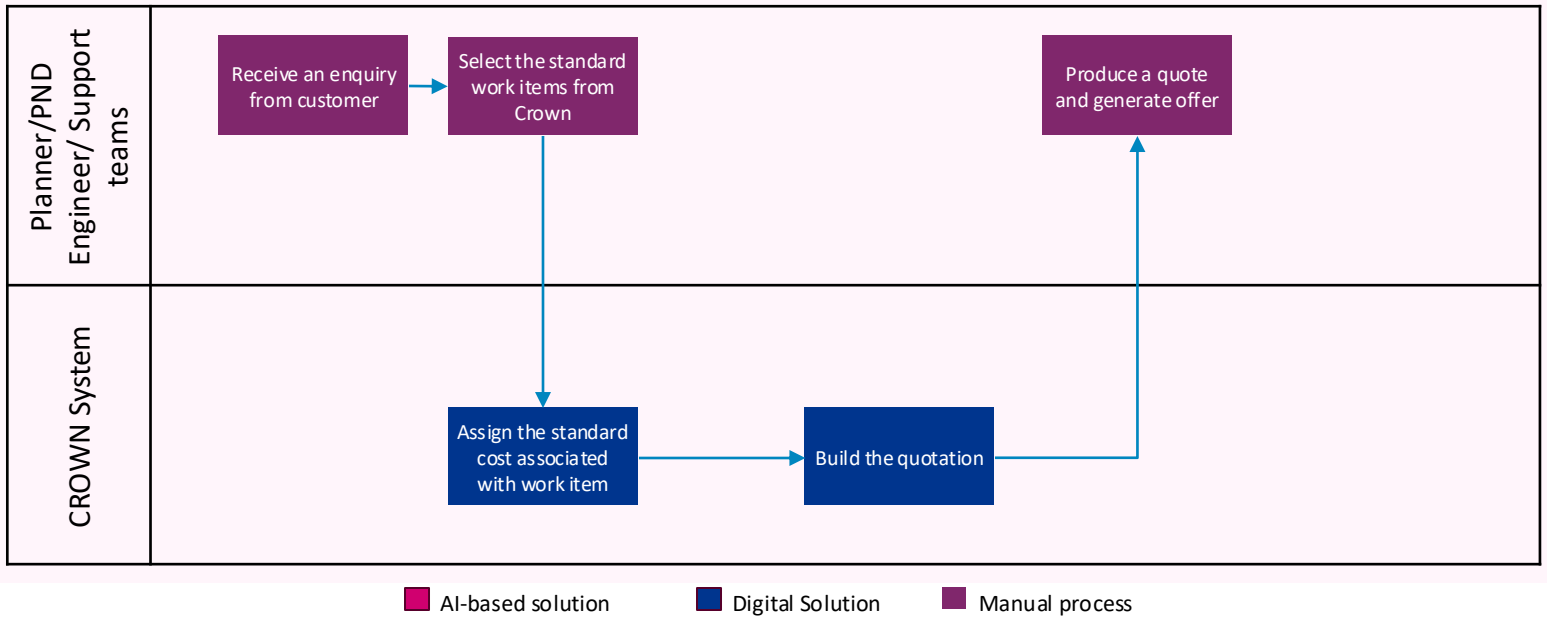
- Material price inflation (copper, steel, etc.) in recent years has made fixed-price offers much less profitable. The offers are made in today's prices, even though the connection date may be more than 5 years away. The prices in Crown are outdated for many components, such as cables, steel and switchgear, and hence the offers may not reflect the dynamism seen in commodity prices experienced outside.
- Whilst the DNOs are permitted to recover any changes in the cost of connections due to price variations as per DCUSA schedule 22, the Common Connection Charging Methodology, these variations may not always be triggered based on changes in the commodity prices.
- As a result, price inflation may need to be absorbed by DNO. This might be more common at 11kV projects due to higher volume and lower average value of the project.

Stakeholders who are impacted

Planners and PND Engineers

Customers/ ICPs/ Developers

Current Process



Connections Journey and Process Steps

- Application to Offer: Budgetary quotation and Formal quotation

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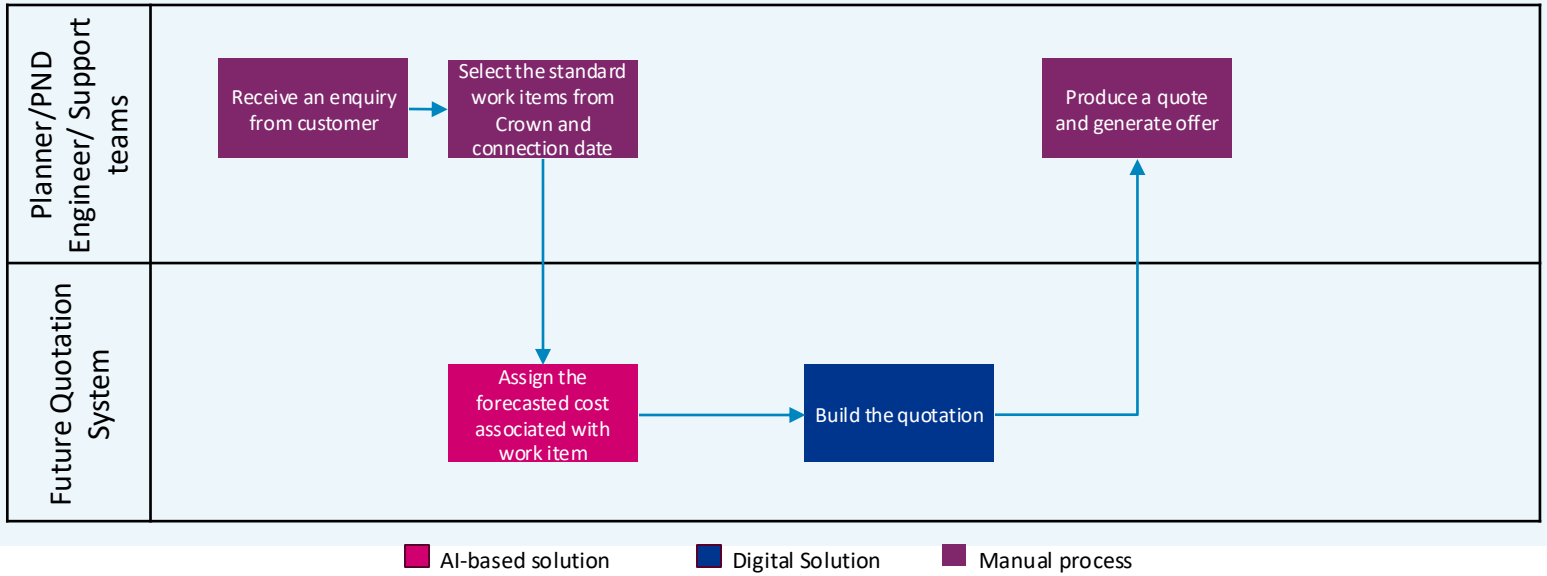
AI Use Case 5: AI based commodity pricing reporting

High level overview of the solution

- A new commodity price estimation tool that utilises machine learning time series forecasting methods to understand pressure price curves for commodities such as copper and steel. This will help NGED understand their exposure across several projects and help plan interventions required to minimise the commodity price risk for NGED. The tool will have applications beyond connections and into projects and delivery of large capital schemes.
- The tool will leverage a variety of data sources, such as historical prices. Pending use case formation, model outputs can be inputted into options or futures calculations.
- The model will produce a probabilistic output, a commodity price range that a given commodity is predicted to achieve within, across a predetermined timeframe. The solution can be used in conjunction with budget estimation tool

High level process flow with the solution



Impact on NGED Commitments within ED2

High	Medium	Low

- **GM1: Customer Satisfaction**
- **GM2: Awareness of Competition**
- **GM3: Guaranteed Standards of Performance**
- **GM4: Stakeholder Engagement**
- **GM5: Published Information**
- **GM6: MCTTQ/MCTTC**

Impact Description

- Quotations developed using commodity prices will provide a more accurate reflection of what customers are likely to pay, thereby improving transparency, which should help improve customer satisfaction (GM1)

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Risks, Dependencies, Barriers and Considerations

Risks

- Customers may delay projects hoping prices will fall, or rush applications when prices are low, leading to an inefficient “stop-start” pattern of connection demand. This can make planning for connections hard as it increases the uncertainty over the number of quotations that will be accepted.
- Volatile pricing could also damage the DNO’s reputation as customers can perceive this as unfair treatment - Two identical projects could pay very different amounts purely based on timing. This could render projects non-viable or delay them during commodity price spikes, conflicting with net-zero and growth objectives.
- The current regulation allows DNOs to recover additional costs incurred by DNO beyond their control. Hedging would make it difficult for DNOs to reasonably exercise this right.
- The actual cost treatment of material used in connections would be challenging as these materials are procured in bulk, leading to problems in cost recovery.

Mitigation

- Develop a transparent indexation mechanism where certain cost components of a connection charge move with a published commodity index.
- Instead of continuous fluctuation, the DNO could update connection charge rates at set intervals (e.g. quarterly or semi-annually) based on commodity trends, and hold them constant in between.
- Build a modest contingency into connection quotes to cover foreseeable commodity fluctuations, or set a “cap and collar” (upper and lower limit) on how much the charge can change by completion time.

Dependencies

- This solution will require integration with trading organisations such as the London Metal Exchange (LME), where futures and forward exchange on base metals takes place, to extract price data through APIs to automatically extract and store relevant commodity data on a periodic basis. The LME offers hedging and worldwide referencing pricing which informs the prices to physically procure metals such as Aluminum, Copper and Steel.

- This solution can complement the quotation generation solution and would be dependent on the delivery of the core quotation engine to produce quotation based on hedged commodity prices.

Regulatory barriers and considerations

Barriers:

- NGED are obliged to charge in accordance with the Common Connections Charging Methodology (CCCM). The CCCM prevents costs from being uplifted to reflect predicted changes in costs over time.
- Ofgem historically sets ex-ante allowances for costs and expects DNOs to manage within them, with only limited provisions for uncertainty or indexation. Directly passing commodity price changes to connecting customers could be seen as a form of cost pass-through that Ofgem has not explicitly sanctioned for connections.

Due to regulatory constraints, this use case cannot be executed for Connections

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AI Use Case 6: AI based module to answer customer enquiries

Overview

- The customer enquiry process places a significant burden on planning teams. Independent Connection Providers (ICPs) frequently raise queries with planners and PND engineers—ranging from project status updates to technical design clarifications. It's estimated that these teams spend up to one full day each week addressing such customer enquiries, many of which are directly linked to connections and engineering policy.
- Customers often lack transparency into the detailed construction timeline or key milestones, as internal schedules are not routinely shared externally. As a result, they are uncertain about what to expect and when. This lack of visibility, combined with response times that can extend up to 20 working days, leads to growing frustration among customers.

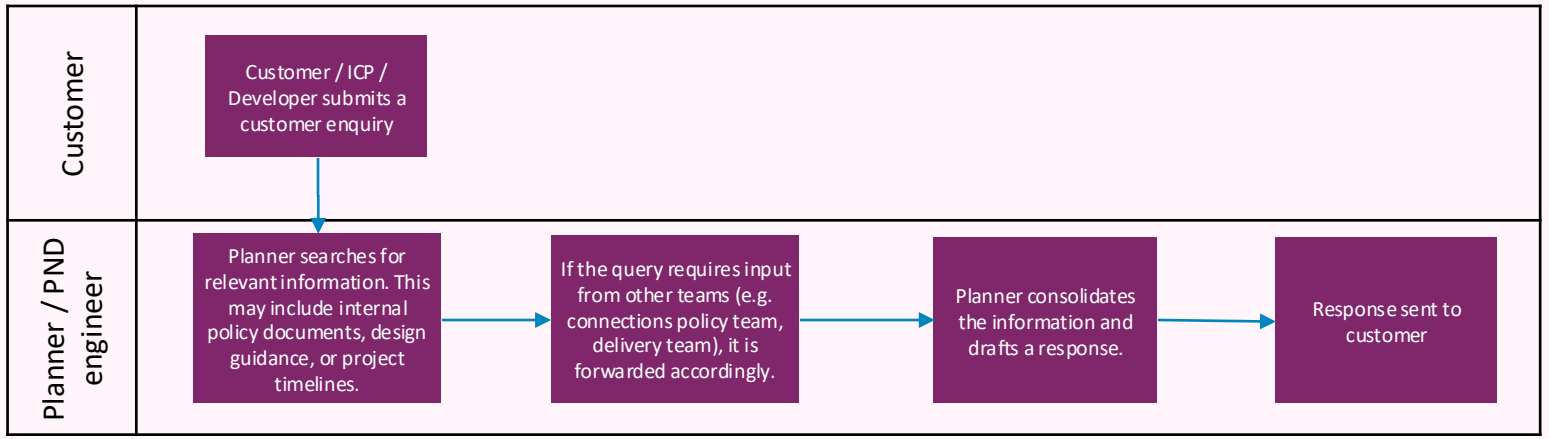
Stakeholders who are impacted

11kV Planners

PND Engineers

Customers/ ICPs/ Developers

Current Process



AI-based solution Digital Solution Manual process

Connections Journey and Process Steps

- Agreement to Energisation: Planning, Pre-construction, construction

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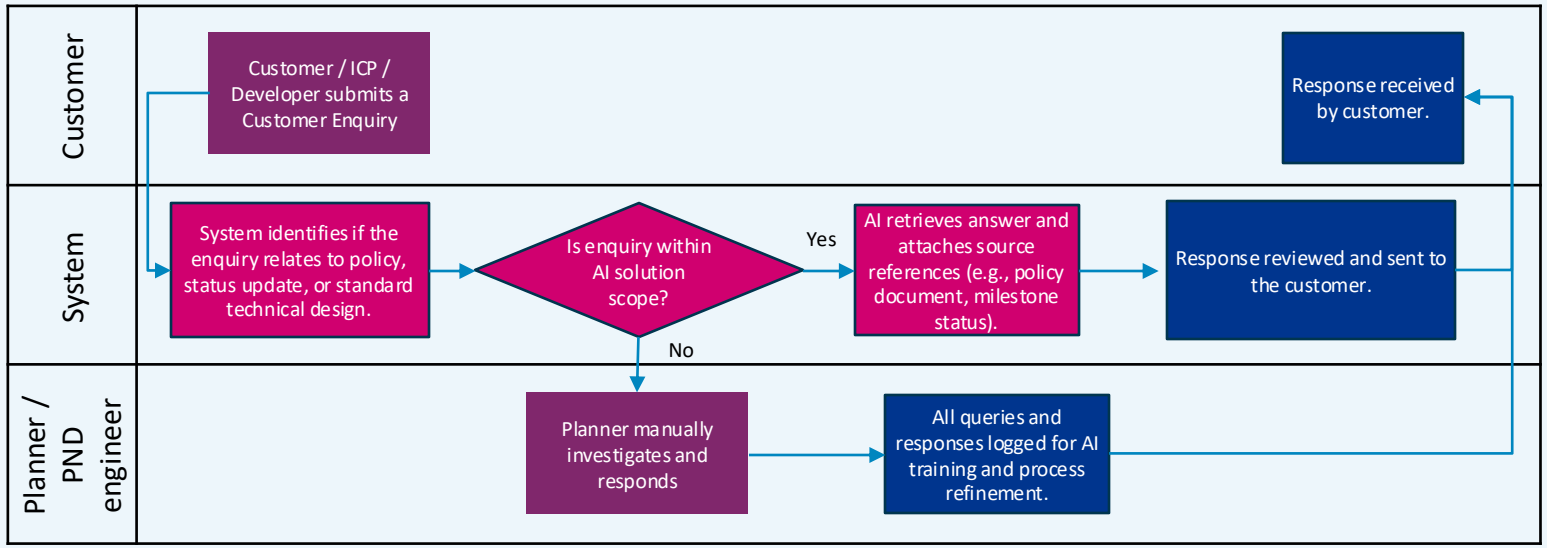
AI Use Case 6: AI based module to answer customer enquiry

High level overview of the solution

- AI RAG system capable of answering customer enquiries submitted by the customers by dynamically analysing the NGED application data against the relevant connections and engineering policies, and project-related documents that are submitted in Crown and other Grey IT systems, to produce a concise response to the user.
- This solution should become part of a digital end-to-end connection solution, where it is able to access all connection-related information from policies to application and project status.
- The output will consist of a curated response in an agreed structure by NGED.

High level process flow with the solution



AI-based solution | Digital Solution | Manual process

Impact on NGED Commitments within ED2

High	Medium	Low

- **GM1: Customer Satisfaction**
- **GM2: Awareness of Competition**
- **GM3: Guaranteed Standards of Performance**
- **GM4: Stakeholder Engagement**
- **GM5: Published Information**
- **GM6: MCTTQ/MCTTC**

Impact Description

- Reduces workload on planning teams by handling common, repetitive queries. This enhances operational efficiency. (GM1)
- Enhances customer satisfaction through faster, accurate, more transparent communication (GM1).
- Improves engagement with existing stakeholder through accelerating response times – however not expected to significantly impact total number of customers engaged.
- Supports ongoing refinement through usage analytics and feedback loops.

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Risks, Dependencies, Barriers and Considerations

Risks

- AI solutions of this nature can be subject to hallucinations, potentially generating incorrect of false responses.
- Training data bias - There may be insufficient high-quality, structured policy and engineering data available to effectively train the AI model, particularly for nuanced scenarios or edge cases.
- Update and maintenance challenges: The customer enquiries patterns, project processes and policies will evolve. If the AI system isn't consistently reviewed and regularly updated (re-trained where necessary), accuracy will degrade over time.

Mitigation

- AI Hallucinations: Implement retrieval-augmented generation (RAG) to ground responses in approved policy documents.
- Apply confidence scoring and human-in-the-loop review for critical and high-risk outputs and introduce fact-checking layers against authoritative sources.
- Fine-tune on domain-specific technical policies, engineering standards, and customer enquiries history. Perform an audit on the training data to check training data accurate, high-quality and up to date. The data audit should check for bias. Perform data quality checks and bias audits regularly.
- Consider use of data augmentation and active learning to capture edge cases. Synthetic data should be considered to address deficiencies in the real-world datasets.
- Establish a regular update cycle aligned to policy/process changes. Use incremental learning to refresh the model without full retraining.
- Maintain version-controlled policy repositories and automated change detection to trigger retraining. Build monitoring and feedback loops with planners and users to spot degradation early.

Dependencies

- Access to up-to-date project information: The tool requires real-time or regularly updated access to construction plans, project timelines and policy documents.
- Centralised policy and design specification knowledge base: Effective response depends on well organised, curated repository of engineering and connections policies.
- Integration with communication platforms: The AI tool may need to interface with email systems, customer portals and internal ticketing tools.
- Training dataset quality: A well-defined training set built on historical customer enquiries and responses is essential for reliable model performance.
- Feedback from users: Mechanisms for planners and customers to flag incorrect or unclear responses to improve the AI solution over time.
- Implementation of use case 2, policy search and interpretation tool to enable customers to get responses for questions that may be related to policy

Regulatory barriers and considerations

Barriers

- The scope of the tool would need to be limited to areas where NGED are allowed to respond to direct customer queries.

Considerations

- Where there is a dedicated forum for discussion, such as CIC forums for ICPs, the tool should not provide direct responses to queries. Instead, it should direct the user to the formal channel (or be designed to prevent the user from accessing the tool in the first place).

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AI Use Case 7: AI based ICP Design Assessment

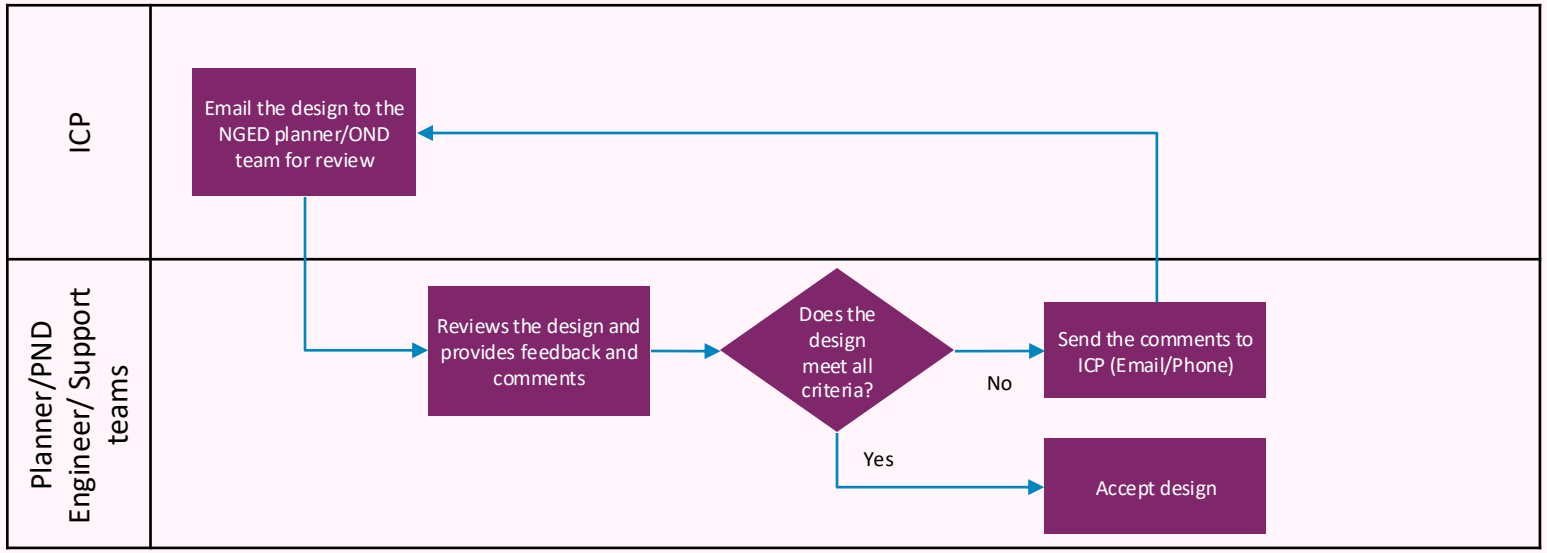
Summary of the issue

- The design submissions from customers often lack consistency, with some providing unnecessary information, while others lacking sufficient quality. This lack of standardisation means reviewers spend time just locating relevant details and often have to request missing information, leading to additional email exchanges and delays.
- Planners dedicate a considerable amount of time to manually examining and validating customer or ICP design submissions against connection offer and engineering standards. It is common to encounter multiple iterations of design submissions and revisions, leading to inefficiencies and wasted time. Design review process is influenced by the skill of the individual planner.
- Checking a complex design against engineering standards can be tedious and prone to missing discrepancies, especially when planners juggle multiple projects and much of the communication takes place over emails and phone calls, making it difficult to keep track of issues and when they have been resolved, especially in the event of multiple comments.

Stakeholders who are impacted

Planners and PND Engineers

Current Process



AI-based solution Digital Solution Manual process

Connections Journey and Process Steps

- Agreement to Energisation: Planning, Pre-construction, and construction

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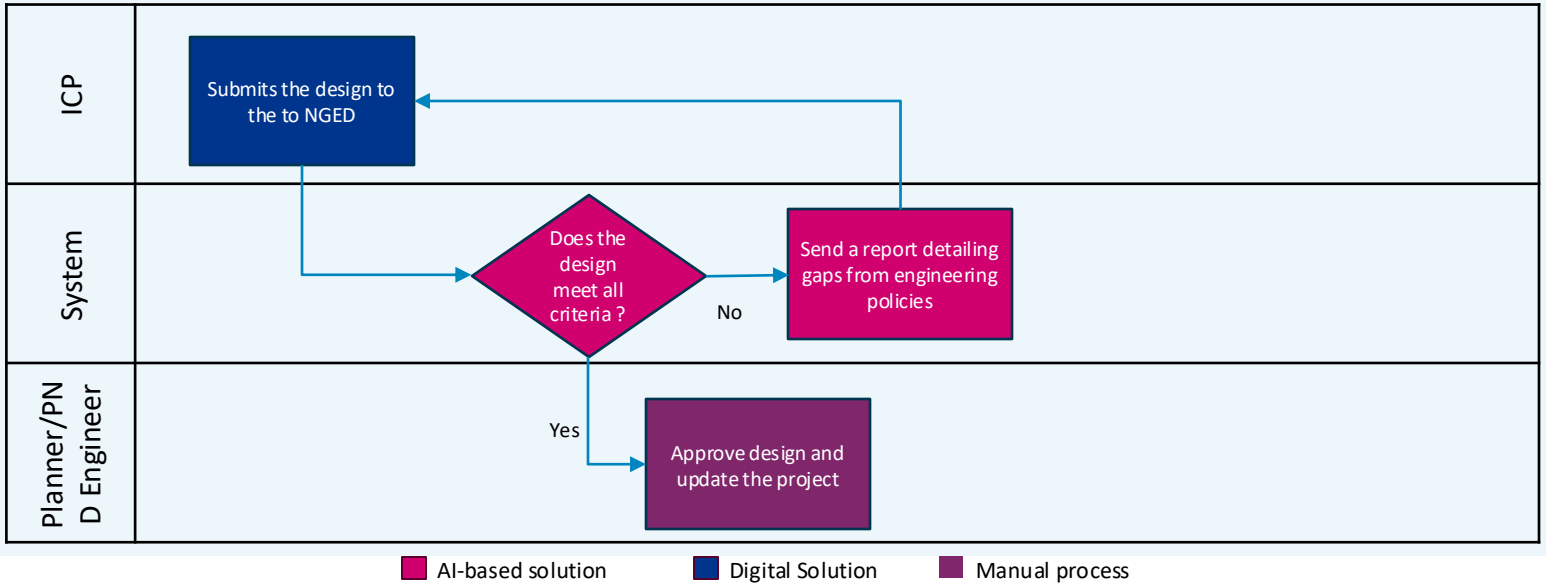
AI Use Case 7: AI based ICP Design Assessment

High level overview of the solution

- An **automated ICP design analysis tool** would act as a smart assistant, quickly evaluating submitted designs against the DNO's requirements. The system would ingest design documents and engineering policies to review ICP designs.
- A multimodal RAG system capable of assessing uploaded design documents against the pertinent design principles outlined in Engineering policies and evaluating them against design standards. This system ensures that the design submission adequately addresses the feedback provided by planners prior to undergoing another review.
- The output will consist of a standardised report detailing design compliance with the relevant policies, including references to those policies, along with a compilation of recommendations and a summary of any non-compliance issues.
- The report would be presented to the planner/PND design for review, and once enough confidence in the solution is built could be fully automated if desired.

High level process flow with the solution



Impact on NGED Commitments within ED2

High	Medium	Low

- **GM1: Customer Satisfaction**
- **GM2: Awareness of Competition**
- **GM3: Guaranteed Standards of Performance**
- **GM4: Stakeholder Engagement**
- **GM5: Published Information**
- **GM6: MCTTQ/MCTTC**

Impact Description

- This solution will review all ICP submissions in a standard manner, eliminating variability caused by planner expertise, thereby enhancing overall customer satisfaction. Consistently vetted designs result in improved network safety and resilience. (GM1)
- Enables faster connection project delivery as projects can get energised sooner, impacting MCTTC stats. (GM6)
- Improved connection project delivery, providing the ability to handle more work without increasing expensive resource headcount.

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Risks, Dependencies, Barriers and Considerations

Risks

- Not all design validation rules or guidelines used by planners are formally documented, meaning the AI solution lacks access to all standards and business rules in a format it can interpret.
- ICPs can submit designs in non-standard formats, complicating the tool's ability to process these submissions effectively.
- The system may struggle to interpret novel and innovative solutions introduced by ICPs, as it is not trained to recognise them.
- There is a potential risk that planners may become overly dependent on the tool, which could diminish their critical thinking.

Mitigation

- NGED is required to initiate a project aimed at documenting all engineering and technical standards and regulations necessary for the review of ICP designs.
- Implementing a digital solution to limit acceptable file formats, combined with proactive communication and efficient change management, can reduce the risks related to non-compliant submissions.
- The solution should be audited and have a human in the loop to validate and handle validation of complex designs and provide final sign-offs.
- The DNO's connections policy team must update the tool whenever standards change and put a process in place.
- To reduce the over-reliance on the tools, the engineers must continue to be trained on new changes to audit the tool's performance and to provide cover to handle submissions escalated by the tool.

Dependencies

- The DNO must codify all relevant standards, business rules, and typical design practices into machine-readable form to ensure all checks can be performed in a consistent manner.
- ICPs may need to provide data in a structured format (such as inputting conductor lengths and transformer specifications through a web form) or to submit CAD drawings that adhere to specific standards, in order to enable machine processing.
- As engineering standards evolve and new equipment and technologies are introduced, these should be codified and the system must be trained/ updated to identify the new changes.

Regulatory barriers & considerations

Barriers:

- No regulatory barriers have been identified that prevent the use of AI in ICP Design assessments.

Considerations

- However, the tool should ensure that users submitting design submissions are appropriately National Electricity Registration Scheme (NERS) accredited and prevent unauthorised access.

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AI Use Case 8: AI based assistant to minute customer conversations

Overview

- The communication between planners and customers is not always efficient and may be reactive rather than proactive. Communication between field technicians and customers can at time be unclear or ineffective. Sometimes customers have to "chase" for information from planners. It is prone to delays, and dependencies are not proactively communicated to the customer.
- Planners and PND teams handle a lot of customer communication. They are often expected to take detailed minutes after discussions with customers and mail them to the customers. The task of minuting talks is essential, but it contributes to the workload of planners. This workload is currently highly manual, and planners often find it burdensome.

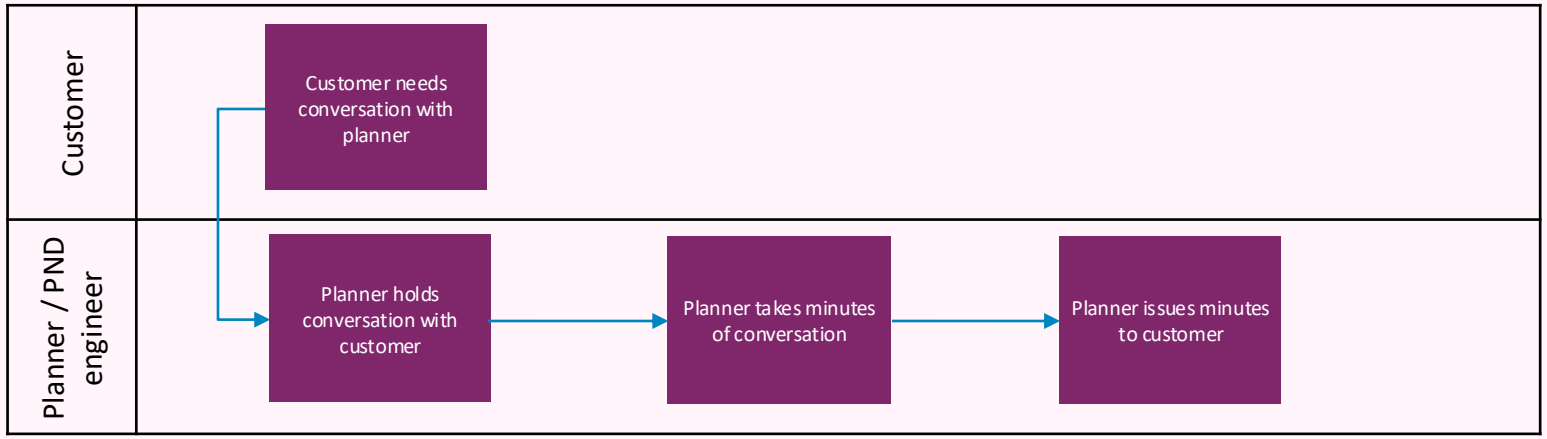
Stakeholders who are impacted

11kV Planners

PND Engineers

Customers/ ICPs/ Developers

Current Process



AI-based solution Digital Solution Manual process

Connections Journey and Process Steps

- Agreement to Energisation: Planning, Pre-construction, construction

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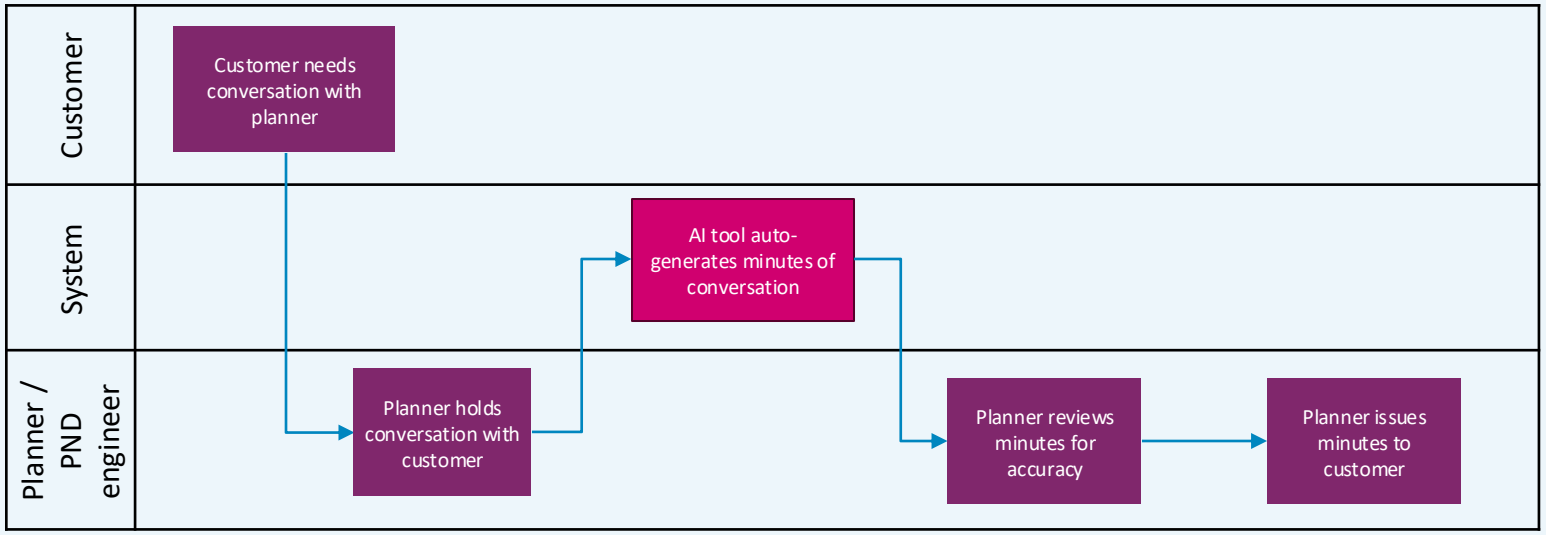
AI Use Case 8: AI based assistant to minute customer conversations

High level overview of the solution

- Well established AI solutions such as Microsoft Co-pilot have the following minuting capabilities:
- Speech-to-Text Transcription: Using Natural Language Processing methods, it can capture audio from meetings and convert it to text either in real-time or after the meeting has concluded.
- Extraction of Key Points and Action Items: AI detects critical decisions, follow-up tasks and responsibilities that arise during the meeting.
- Automatic Summarisation: Summarisation algorithms condense discussions into clear and concise minutes with responsibilities clearly assigned.
- Context and Sentiment Analysis: AI interprets subtleties, tone, and intention to provide deeper insights into the discussions.

High level process flow with the solution



AI-based solution | Digital Solution | Manual process

Impact on NGED Commitments within ED2

High	Medium	Low

- **GM1: Customer Satisfaction**
- **GM2: Awareness of Competition**
- **GM3: Guaranteed Standards of Performance**
- **GM4: Stakeholder Engagement**
- **GM5: Published Information**
- **GM6: MCTTQ/MCTTC**

Impact Description

- Reduced workload for planners and PND teams, allowing greater focus on other tasks such a conducting network studies. This increases planner efficiency.
- Enhances customer satisfaction through faster, clearer, more transparent communication between the network operator and the customer. (GM1)
- Supports ongoing refinement through usage analytics and feedback loops.

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Risks, Dependencies, Barriers and Considerations

Risks

- Speech-to-text transcription may misinterpret technical terms, abbreviations, accents, or poor audio quality, leading to inaccurate meeting records.
- Automatic summarisation may omit critical details or misrepresent key discussion points.
- Context and sentiment analysis could misclassify tone or intent, potentially escalating misunderstandings with customers.
- Data privacy and confidentiality risks if sensitive customer information is stored or processed insecurely.
- Over-reliance on AI-generated notes could reduce planners' vigilance in validating key actions.
- Limited transparency in AI decision-making may reduce user trust in outputs.
- Integration issues with existing communication platforms could hinder adoption.
- Many conversations currently happen through non-digital platforms (e.g. phone calls) and/or consent for recording may not be obtained. Prevalence of use may therefore be restricted.

Mitigation

- Apply domain-specific speech recognition models trained on technical and utility-specific terminology. Encourage adoption of noise cancellation software to improve audio quality.
- Combine automated summarisation with human validation to ensure completeness and accuracy.
- Calibrate sentiment and context models with real customer communication data for better alignment.
- Implement strict data security measures, including encryption and access controls, to protect sensitive information.
- Maintain human-in-the-loop review for critical meetings and decisions.
- Ensure smooth integration with existing virtual meeting tools and workflows through robust APIs.
- Introduce voice recording to platform where possible and consent can be obtained. Where not possible, consider utilising hybrid approaches, such as planners providing verbal recaps for AI to summarise immediately following non-digital or non-consented conversations

Dependencies

- Reliable virtual meeting setup with high-quality audio capture to enable accurate transcription.
- Procurement and implementation of AI tools such as Microsoft Co-pilot or equivalent transcription/summarisation platforms.
- Access to historical customer conversations to fine-tune models for terminology and context.
- Strong data governance framework to manage storage and use of sensitive customer information.
- Continuous feedback loop from planners and engineers to refine AI-generated minutes.
- Alignment with NGED's digitalisation and customer communication strategy.
- Getting customer consent to use Co-pilot and similar tools to listen into customer conversations.

Regulatory Barriers and Considerations

Barriers

- No explicit regulatory barriers

Considerations

- As per all conversations with customers, NGED personnel must remain vigilant to comply with GDPR requirements.

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AI Use Case 9: Use of AI in draft connections agreements

Summary of the issue

- The process of drafting and approving connection agreements is labour-intensive and varies by voltage level and region. Creating a complete contract package takes time; HV planners use templates, while EHV designers rely on a central contracts team. Outdated tools contribute to inconsistencies due to manual changes.
- Contracts often circulate among teams (design, legal, policy) for revisions if they fail to meet corporate standards, with errors sometimes identified late in the process.
- Each region has developed its contract processing methods, leading to inconsistent knowledge. One area might include specific technical schedules or special conditions that others don't. Staff transitioning between regions encounter a steep learning curve due to differing technical schedules or special conditions.

Stakeholders who are impacted

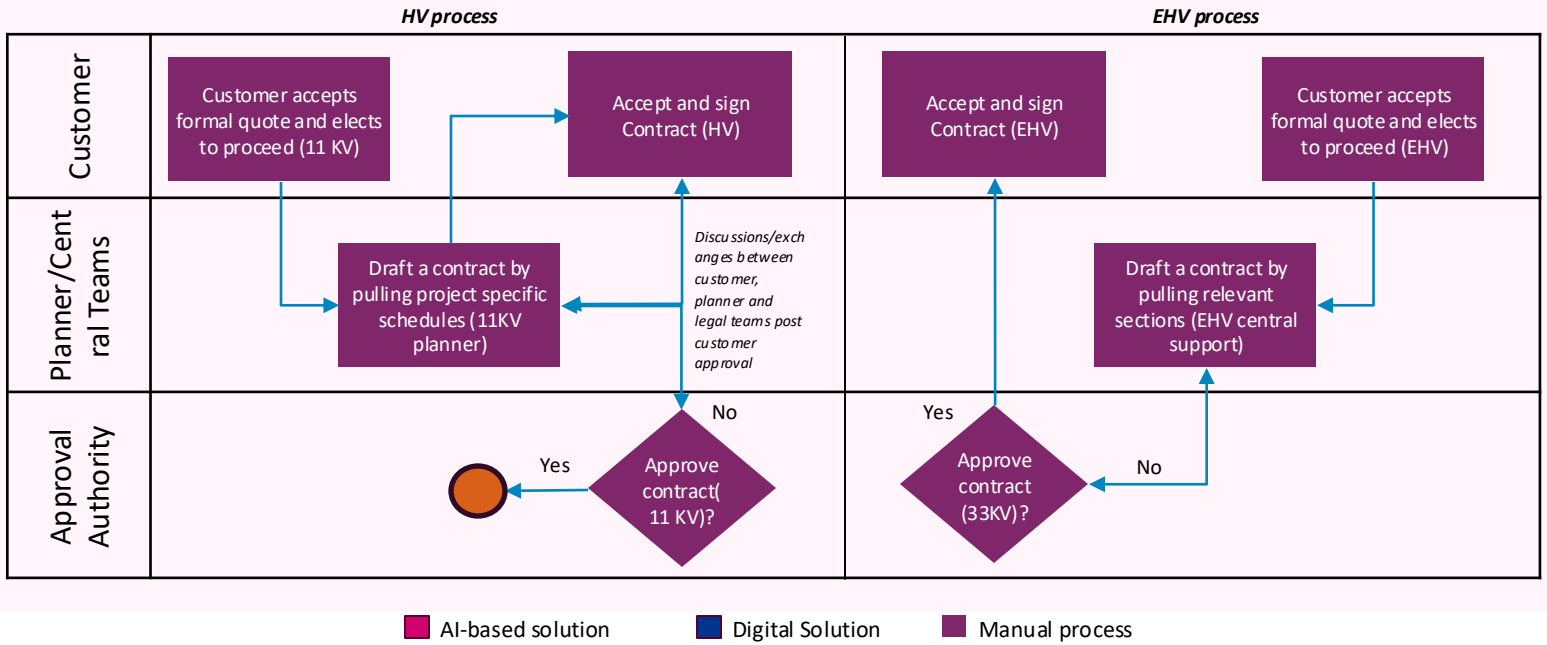
Planners and PND Engineers (design)

Connections Policy Team

Customers

Legal Team

Current Process



Connections Journey and Process Steps

- Agreement to Energisation: Connection Agreement

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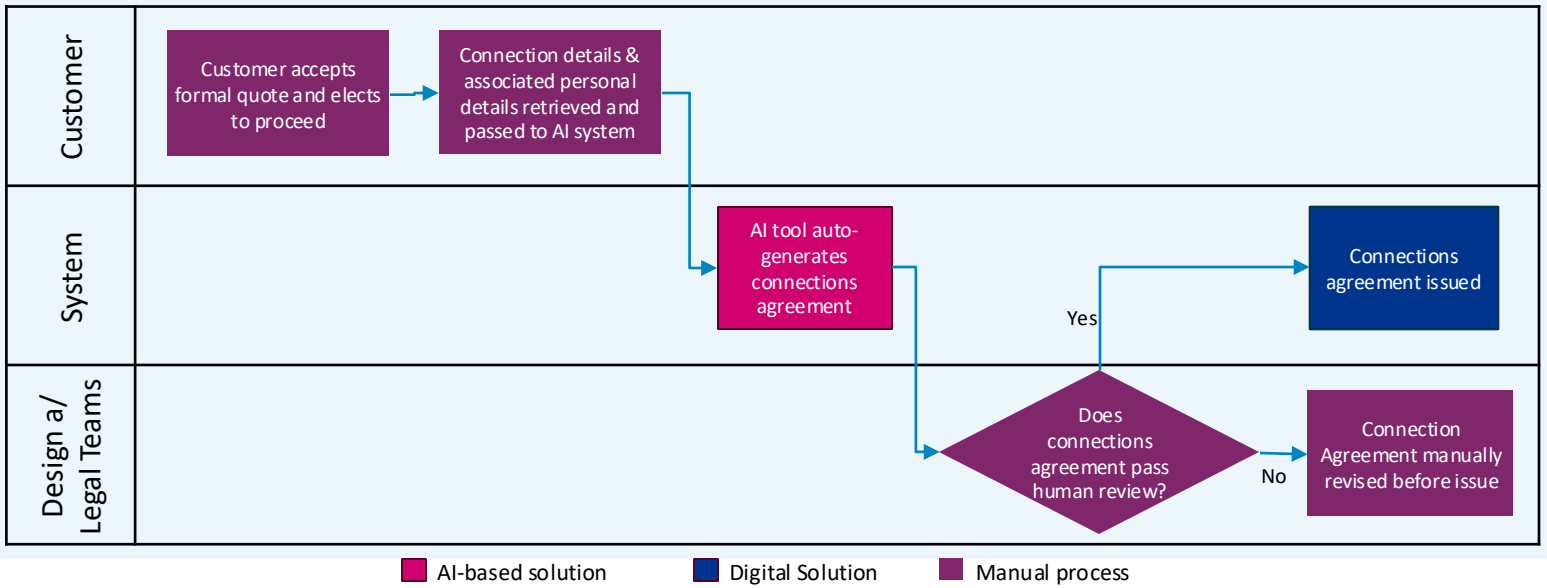
AI Use Case 9: Use of AI in draft connections agreements

High level overview of the solution

- An AI-based contract review and creation solution to draft contracts automatically - potential to leverage Luminence, which is already in place with National Grid Group.
- Additionally, developing a playbook or checklist for contract completion, along with streamlining andstandardising contract production and review processes at all voltage levels, ensuring clear methodologies are in place for every connection type.
- This solution will form part of an end-to-end digital connections solution that will provide customer details, manage the workflow for approval based on the voltage level and provide sign off.

High level process flow with the solution



Impact on NGED Commitments within ED2

High	Medium	Low

- **GM1: Customer Satisfaction**
- **GM2: Awareness of Competition**
- **GM3: Guaranteed Standards of Performance**
- **GM4: Stakeholder Engagement**
- **GM5: Published Information**
- **GM6: MCTTQ/MCTTC**

Impact Description

- Contracts are completed in a standardardised manner for all customers connections. Newly established process leveraging AI enhance process efficiency, reducing delays and freeing resource to handle more applications. (GM1)
- Streamlined and efficient process that reduces the to and fro of connection agreements between customers and NGED teams, ensuring timely completion of connections thereby reducing the impact on MCTTC. (GM6)

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Risks and Dependencies

Risks

- AI-driven solutions may mistakenly phrase or exclude essential legal clauses or introduce incorrect terms, leading to contracts with unenforceable or non-compliant provisions.
- Overreliance on AI-generated contracts might reduce planners' diligence in reviewing key sections, thereby raising the likelihood of compliance issues in the contracts issued.
- It is crucial for models to stay updated with the latest contract templates and policies; failure to do so risks the inclusion of outdated terms.
- Distributing contracts containing unchecked compliance errors can erode customer trust.
- A major risk of automated systems is the widespread propagation of errors, which can result in increased effort and costs for both customers and NGED teams to address the resulting problems and minimising impact.

Mitigation

- Human reviews are essential to verify the accuracy of the connection agreements produced by the AI solution, and, where necessary, make refinements before the connection agreements are issued to customers.
- These checks should be implemented as part of a layered validation and fail-safe measures.
- Implementation of a template gatekeeper that ensures no change to contract policy goes live until the AI model/template is updated and tested on a sample and implementing version controlling for templates

Dependencies

- Establishing standardised policies for contract creation and optimising the contract development process and approval workflow across all voltage levels.
- Harmonising contract templates across all regions and connection types. NGED's connection policy team is developing a unified set of standard agreements for LV, HV, and EHV to be adopted region-wide.
- Implementing a digital workflow system (preferably part of an end-to-end connection management system) for contract approval that directs the draft contract to the appropriate experts for review and authorisation before reaching the customer.
- Providing training for planners and project engineers on the significance of contract clauses and strategies to prevent common errors.

Regulatory barriers and considerations

Barriers

- No regulatory barriers have been identified

Considerations

- The connections process must be designed in a way that agreement must be in place prior to energisation, where it is for HV or above, or contains embedded generation, to ensure compliance with the Distribution Code.

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AI Roadmap for NGED

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NGED's Connection Journeys AI - Roadmap

Our proposed roadmap assumes

ED2- Building the foundations

- Predominantly Innovation led, this phase is all about **laying the groundwork** for AI adoption within NGED
- Some of the underlying capabilities such as cloud migration, ML ops platforms and large language models will be delivered within ED2, which will form the bedrock for some of the AI use cases moving forward
- Use cases proposed for BAU roadmap will be tested through an innovation project/Proof of Concept development to establish the feasibility considering the availability and quality of data.
- Some of the proposed use cases such as 8 and 9 will run through a pilot phase which will help gather valuable lessons for wider BAU implementation.
- The use cases will feature within the wider Connections Digitalisation Strategy and Roadmap for NGED. This strategy will help inform and qualify the IT Capex required as part of the ED3 business plan that comes into force in Apr'28.

ED3 – Unlocking Efficiencies

- The focus shifts from innovation Proofs of Concept to implementation of AI solutions in BAU processes in ED3.
- The order of value, ROI delivered by the AI use cases and the business change effort required to embed these use cases will play a key role in sequencing of the AI initiatives.
- Efforts will be spent in expanding the scope of the pilot projects and innovation activity will shift gears towards proving the use cases earmarked for ED4 implementation.
- The proposed additional innovation funding mechanisms that enable embedding innovation into BAU be an important factor in deciding the scale and scope of the implementation.
- ED3 will witness the realisation of the wider Digital Connections roadmap, and the AI use cases will form part of it.

ED4 – Enhancing Customer Service

- The focus in ED4 will be firmly on realising a customer centric vision and delivering a seamless, intelligent experience for users such as ICPs.
- Planner and PND teams will continue to utilise AI solutions developed in ED3 and further enhancements will be delivered using the foundations laid during earlier price controls to enable self service capability for customers.
- Additional AI solutions will be developed, subject to successful innovation-led Proof of Concepts taking place during ED3 and the required AI technologies maturing such they are ready for BAU implementation.

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AI Roadmap: Phased Deployment

NGED's AI roadmap has been designed based on value, complexity, dependencies, funding requirements and technology maturity, while aligning with RIIO business planning cycles.

ED2 (2023–2028) Building Foundations

- **Use Cases 8 and 9** (customer conversation minuting, contract drafting) can be delivered rapidly using commercially available tools. They provide early efficiency and customer satisfaction benefits and can generate Return on Investment (ROI) within ED2.

ED3 (2028–2033) Unlocking Efficiencies

- **Use Case 3** (ML-based budget quotation) offers high value but the time required to fully integrate with existing systems to get the solution production ready would be best supported by a request for RIIO-ED3 funding. It is therefore scheduled for ED3, once digitalisation is further advanced.
- **Use Case 4** (cable routing optimisation) is dependent on Use Case 3 and builds further efficiency and accuracy into quotation processes, so follows in ED3.
- **Use Case 2** (policy search and interpretation) is also possible within ED2, but requires a digitised engineering and connection policy repository. It is therefore sequenced after Use Cases 3 and 4.

ED4 (2033–2038) Enhancing Customer Service

- **Use Case 1** (application integrity checking) is relatively low complexity but provides lower value than Use Cases 3 and 4. It is sequenced for ED4 after core quotation tools are in place. However, it is possible this could be accelerated should the perceived value increase.
- **Use Cases 6 and 7** (customer enquiry handling, ICP design assessment) deliver high customer and efficiency benefits, but depend on a fully digitalised HV/EHV process and more mature RAG technology. These are therefore scheduled for ED4.

Excluded

- **Use Case 5** (commodity price forecasting) was removed from the roadmap due to regulatory barriers preventing the use of indexed or forecast pricing in customer quotations.

Refer Appendix for further information on Roadmap Use Case Sequencing Logic

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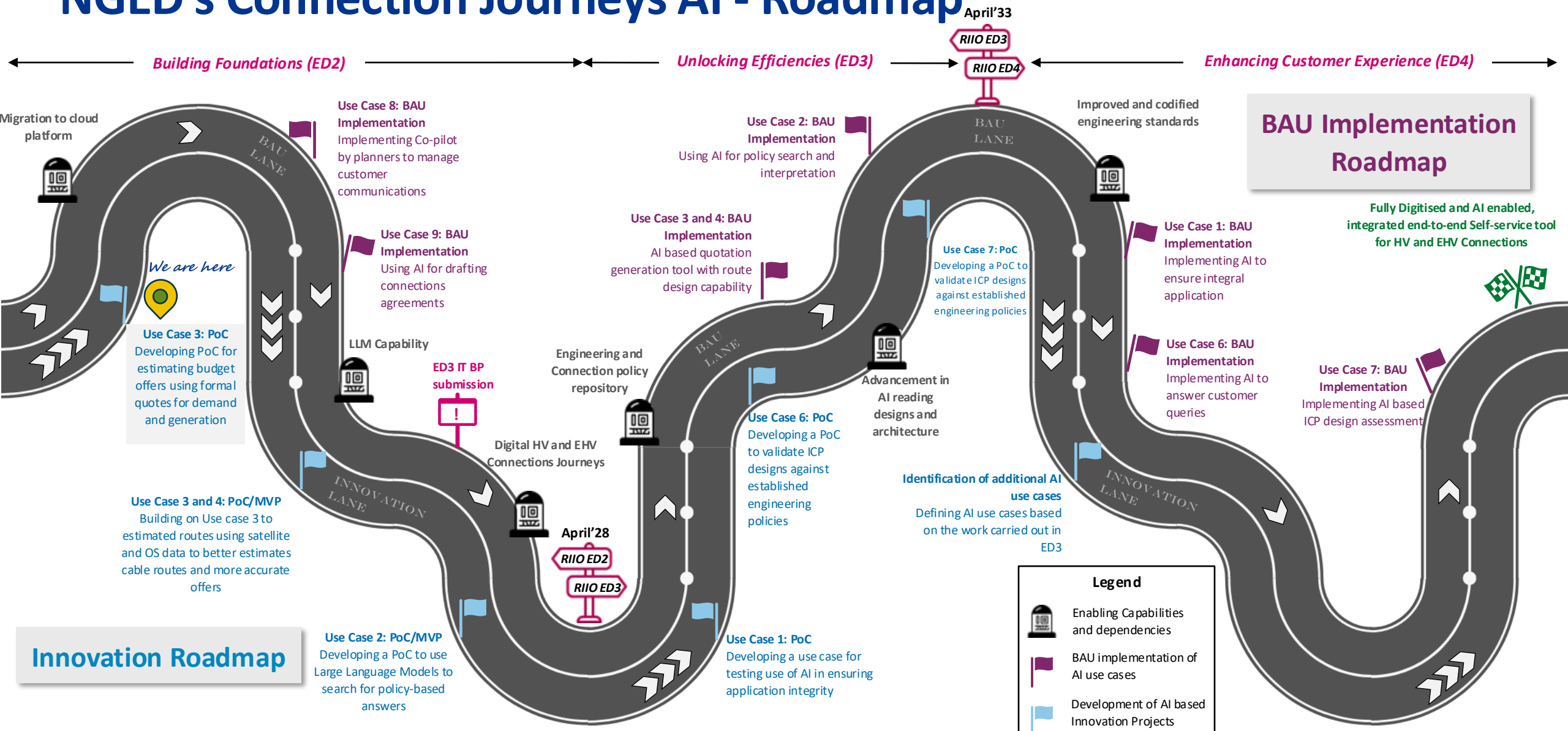
NGED's Connection Journeys AI - Roadmap



BAU Implementation Roadmap

Innovation Roadmap

This roadmap outlines the suggested sequence of AI projects and use cases designated for the BAU and Innovation teams, respectively. The top half of the map describes the BAU implementation plan, and the bottom half represents the Innovation plan.

nationalgrid Baringa ea technology

Proof of Concept Development

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Proof of Concept Approach

Adopting a multi-staged approach to develop a Machine learning model

- The development of the Proof of Concept was carried out over multiple stages.
- Each stage delivered key insights and learnings that influenced the steps taken in the subsequent stages.
- Analysis of data surfaced that EHV connections are highly complex, low in volume and could be connected at multiple voltages. Owing to these complexities, it was agreed to limit the scope of PoC to HV connections only.

Data Collection

- ✓ *Source data from CROWN*
- ✓ *Application at HV level as input*
- *Finalise dependent variables (what we are predicting)*

Exploratory Data Analysis

- *Explore distributions, trends and anomalies within the application data.*
- *Visualise the relationships to better identify patterns.*
- *Understand any potential biases, limitations or imbalances within the data.*

Data Preprocessing

- *Handle any missing values.*
- *Identify and correct errors where appropriate.*
- *Remove duplicates and outliers.*

Feature Engineering

- *Create new features from base data if appropriate.*
- *Transform / encode / scale data to optimise for training.*
- *Create the final set of salient features for training.*

Model Training

- *Split data into training/validation/test sets.*
- *Choose candidate models for the dependent variables.*
- *Train models on the training dataset, feeding back optimisations into Feature Engineering stage.*

Evaluation & Report

- *Competitively test the models against chosen metrics.*
- *Establish any potential under or overfitting.*
- *Perform hyperparameter tuning on best performing candidate models.*
- *Write methodology report.*

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Exploratory Data Analysis

EDA was targeted at assessing the suitability and quality of data provided by NGED for modelling purposes

Exploratory Data Analysis

- Involved statistical summarisation and data visualisation to reveal patterns, anomalies, and correlations within the dataset
- The data received in 3 ‘waves’ was sourced from NGED’s CROWN system, which manages the lifecycle of connection enquiries and quotations

EDA Observation 1: 21.9% of provided records were outside the NGED License Area

EDA Observation 2: 18.1% of Provided Enquiries are for the HV Part of the Network

EDA Observation 3: Enquiry formal offer costs range from ~1000 to >1,000,000

EDA Observation 4: 90.6% of HV Enquiries have Category “Metered Demand HV with LV end Connections”

EDA Observation 5: No cable length observed in the data provided however, it can be proxied using cost factors

Conclusion

- Key structural characteristics, including the predominance of formal offers, the presence of outliers, and notable gaps in data completeness, were identified particularly within supplementary tables such as generator and import information.
- The findings highlight both the strengths and limitations of the available data. While the final dataset provides a comprehensive basis for modelling formal offer costs, persistent challenges remain, including missing values, inconsistent feature definitions, and the risk of data leakage from associated enquiries.
- The exploratory data analysis established a clear understanding of the dataset structures and constraints, providing essential guidance for data preparation and model development. The results underscore the importance of ongoing data quality improvements to support more accurate and reliable predictive modelling in future phases.

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Feature Engineering

Create a robust set of features that capture the principal drivers of the Final Offer Cost.

Feature Name*	Description
derived_cable_length_m	Proxy for distance from site to grid based on cable length ordered
county	County where site location is in
enq_cat_desc	Enquiry description category
contractor	The contractor that was used to perform the delivery work
import_info_import_capacity_sum	Total import capacity requirement of the site in kVA
import_info_import_record_count	Total number of import devices at site location
generator_installed_size_sum	The SUM of “installed size” for all generator devices listed against the enquiry
generator_total_size_sum	The SUM of “installed size” for all generator devices listed against the enquiry
Ps_longitude	Longitude location of primary substation
Ps_latitude	Latitude location of primary substation
Distance_true_km	True distance between site location and primary substation using Amazon Location Services
Distance_walking_km	Walking distance between site location and primary substation using Amazon Location Services
Distance_car_km	Driving distance between site location and primary substation using Amazon Location Services
Altitude_start_m	Altitude of the site location
Altitude_end_m	Altitude of the primary substation
NGED region	NGED region site location falls under
Start_year	Year the enquiry was started

Target Features

- The feature being predicted was the Final Offer Cost of connecting a site location to the grid

*These features were used to train the resulting machine learning models.

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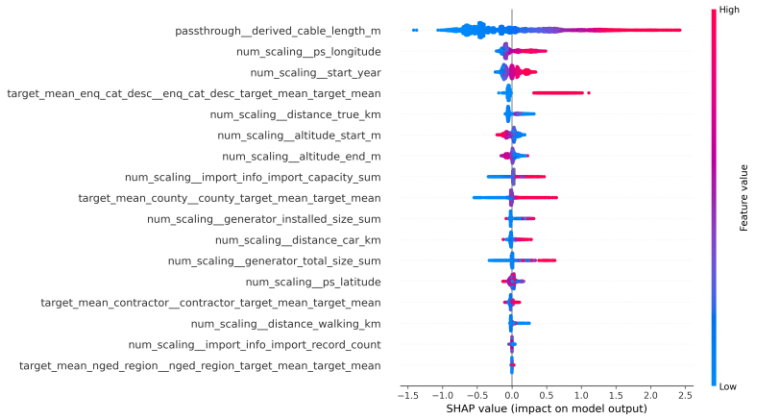
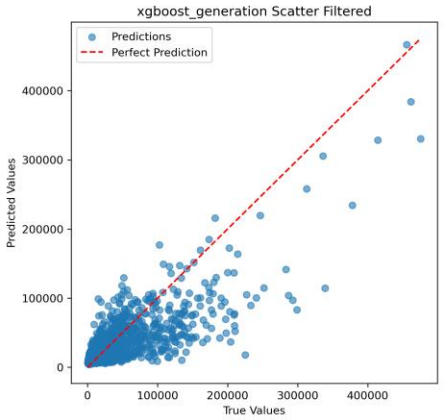
Modelling

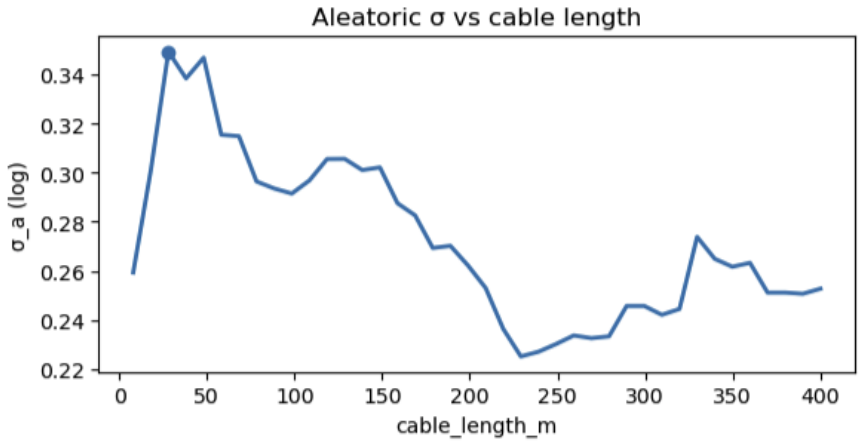
XGBoost model delivered the best results, achieving R^2 of 0.72, indicating strong predictive capability



- Cable length drives the outcome: shorter cables lower the predicted value, while longer cable length raises it.
- Model accurately reflects physical feature-cost relationships and generalises well.



- Model predicts small and medium costs reasonably accurately, closely following the diagonal.
- The model underestimates higher values due to data sparsity.



- There is random noise (aleatoric uncertainty) in the data at lower cable lengths which impacts the model, which aligns with the SHAP plot.
- At higher cable lengths uncertainty stems from lack of values, in agreement with the scatter plot.

Conclusion

- Models were trained on log-transformed cost values, and subsequently exponentiated (absolute crown cost) to provide a comprehensive view of model robustness and interpretability. Among the methods evaluated, XGBoost demonstrated the highest performance, achieving an R^2 of 0.72 for absolute cost prediction, thereby accounting for a substantial proportion of observed variance.
- Feature importance analysis identified derived cable length as the principal predictor, with other variables contributing less, possibly due to data sparsity.
- While the derived cable length field was the main predictor, the aleatoric uncertainty analysis (uncertainty caused by data noise), suggests this is less accurate at the lower end of cable lengths, possibly due to confusion alongside other quantity fields. The need for a robust cable length feature is required.
- With only one feature showing strong prediction power available, there is a need for more quality data including network reinforcement, traffic management and more.

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Conclusion and Future Recommendations

The model demonstrates strong predictive ability; Enhancing data accuracy and features could further boost performance and reduce uncertainty.

The PoC model shows promising performance, with a final R-squared of 72% and sMAPE of 30%, indicating strong predictive ability.

Future enhancements could reduce noise caused by imprecise cable length data and uncertainty caused by missing features/data such as traffic management, network reinforcement, cable type, and terrain.

The model shows that cable length has a strong influence on the model; however, being a derived field from free text data, the accuracy is limited. NGED is recommended to include precise cable length data from sources such as EMU and CROWN in future modelling efforts supported by real-time shortest-route geospatial algorithms to generate accurate routes at model inference time.

Future model versions should consider other factors such as existing and committed demand / generation, technical parameters such as capacity, voltage, and thermal headroom alongside attributes such as traffic management, network reinforcement or if the site is a candidate for cost sharing under ECCR.

Future modelling should further explore inclusion of temporal data such as inflation, commodity prices and other macroeconomic factors that can often significantly impact cost of components and materials that are sensitive to market volatility and supply-chain shocks.

For next steps, it is recommended that NGED tests the future iterations of the model as part of a wider Digital Connection Solution. An MVP solution will allow planners to leverage AI-generated quotes and will provide valuable lessons regarding efficacy of the outputs, governance and behavioral aspects of an AI solution.

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AI Governance and Regulatory Frameworks

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Considerations for Ethical AI use in the Energy Sector

AI implementation within NGED should be aligned to Ofgem's Guidance for Ethical use of AI

Background

The energy sector is at a pivotal moment. The transition to renewable energy is central to many strategies, with the increasing need to diversity our energy systems and the cost of renewable technologies taking a prominent role in discussions. AI presents a significant opportunity to support the energy sector during this transition. Fully realising the potential of AI could have significant implications for the future of the energy sector, particularly in ensuring a robust and future-proof system that benefits all consumers and operators. However, the integration of AI also brings important considerations and implications. We expand on some of these below.

Ethical Considerations

Ofgem outline 4 areas of focus for AI solutions

Safe AI: Any use cases for AI should consider the impacts of failure or misuse. Some applications may have negligible impacts on safety should they fail, while others could have far-reaching implications for national energy infrastructure.

Secure AI: As a rapidly advancing field, cyber security must be integral to the AI design process. Security measures should be considered at the outset of new AI implementations and wrapped into the full AI life-cycle.

Fair AI: AI can inadvertently introduce bias, resulting in direct or indirect discrimination. AI systems must be implemented such that they serve consumers fairly and transparently.

Environmentally Sustainable AI: AI has the potential to consume significant levels of electricity due to the demands of data centres and computing power. To help counter this, users should employ cohesive governance policies across the entire AI lifecycle from inception and deployment to monitoring and decommission.

Implementation Considerations

Governance

- Organisations should have clear lines of accountability with transparent strategies for implementation and management.
- Any arrangements do not need to be AI-specific but should always account for AI characteristics.

Competencies

- Stakeholders must have the correct knowledge, skills and capability to support and realise AI opportunities.
- Potential AI users should familiarise themselves with frameworks from the UK government and AI providers such as Microsoft, to ensure compliance and adherence to best practices.
- Implement robust training and knowledge management policies and procedures to ensure knowledge is maintained to required levels and users keep up to date with emerging technology.

Risk

- Take an outcome focussed approach to risk rather than setting prescriptive rules around the use of AI.
- Identify potential points of failure or behaviour drift and implement mitigations wherever possible.
- Consider the technical and human systems surrounding the element, there may be uncertainties associated with these in addition to the AI system itself.
- Only employ AI when it is relevant to do so, not all challenges require AI.
- Set clear requirements on AI inputs and outputs.
- Understand the impact of AI on the broader system and its impact on overall reliability.
- Finally, consider the impact of human confidence or lack of trust on AI systems and their usage.

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What steps can NGED take to meet regulatory requirements while adopting AI?

Effective AI governance requires collaboration across the entire organisation, impacting all areas by introducing new workflows and adding responsibilities.

Documentation

- Increased levels of documentation required for all AI systems
- Automatically created documentation will embed sustainable practices

Policies

- Most policies will require refreshing to accommodate AI use
- New AI, ethics and model development policies will also be required
- Data classification clarity is critical to GenAI use

Procurement

- Considerations around governing the purchase, implementation and use of 3rd party tools
- Areas such as contracts, IP, data extraction and storage, cybersecurity, data ownership, model transparency and data protection should be reviewed

Responsible AI

- Ensuring alignment with principles for fairness, transparency, explainability, people and planet impacts and non-discrimination
- Will need to be monitored and evidenced

Automated monitoring

- New requirements to automatically log all AI systems to ensure traceablility of outputs
- Monitoring of model performance also required to evidence accuracy

Awareness and training

- Organisation-wide training required to optimise usage and minimise risks from genAI usage
- Training on new ways of working will include refreshed policies, development standards and enhanced accountabilities

Human in the loop

- Innovative approaches to address this are required to ensure scalability
- Processes need to be designed with an opt-out and supervision by design

Model governance

- Enhanced scrutiny and documentation required around the full model lifecycle
- Data collection and quality, algorithm selection, data processing, bias mitigation, validation testing and deployment

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Incentive performance and regulatory frameworks

How incentives for Major Connections are likely to evolve from ED2 and beyond

- Under the current RIIO-ED2 framework, DNOs are incentivised to provide timely, efficient connections for all major (HV and EHV) and minor (LV) connection customers. This translates into a distinct incentive mechanism for major connections: **Major Connections Incentive (MCI) – A performance scheme for major connections (large demand/generation, HV/EHV projects), primarily penalising poor service**. Its goals are to ensure DNOs deliver timely, customer-focused service for big connections and continuously improve their processes, incentivising DNOs to meet targets (7.41 out of 10) for *major connection customer satisfaction* and timely service or face revenue penalties up to 0.35% of base revenue. The Major Connections Incentive requires NGED to:
  - ❑ Publish an annual Major Connections Report (the MCAR) detailing its performance and initiatives for large connection customers
  - ❑ Track and report specific metrics:
    - Major Connections Customer Satisfaction Survey (MCCSS) – an independent survey of large connection customers, scored 1–10.
    - Time to Quote (MCTTQ) for major connection offers – average working days for HV/EHV quotations.
    - Time to Connect (MCTTC) for major jobs – average time from acceptance to energisation of major connections.
  - ❑ Deliver a Major Connections Strategy (MCS) – a plan of improvement initiatives (e.g. new tools, process changes, stakeholder engagement) to better serve major customers. The MCAR updates progress on these commitments annually.
- Looking ahead, the RIIO-ED3 price control (2028 onwards) will likely raise the bar on connections with tighter targets: faster timelines, higher customer satisfaction expectations, and new ways to reward DNOs for unlocking capacity quickly. It is also expected to evolve connection incentives further. Some likely developments for ED3 include:
  - ➢ More Symmetrical Incentives for Major Connections: DNOs may push for upside rewards for exceptional performance on Major Connections. By ED3, Ofgem might introduce a financial reward (expected between 0.5-1% of RORE) for exceeding ambitious targets.
  - ➢ Quality of Connection Offers: There could be incentives (or strengthened standards) around the quality and options in connection offers – e.g. offering flexible connection arrangements or better information
  - ➢ Incentivising Overall Connection Speed: ED3 might implement a mechanism to encourage DNOs to invest and manage queues to facilitate earlier connections proactively. For instance, a DNO could earn rewards for reducing average connection project timelines by X%, adjusted for factors outside its control.
  - ➢ Connections and Capacity "Growth" Incentives: As networks face huge volumes of new requests (renewables, EV charging, heat pumps), ED3 might combine connection incentives with output measures for capacity provided. For example, connecting capacity faster and ahead of need.

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Glossary

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Glossary of Terms

Term	Definition
AI	Artificial Intelligence
API	Application Programming Interface
BESS	Battery Energy Storage System
CAD	Computer Aided Design
CAT	Customer Application Team
CCCM	Common Connections Charging Methodology
CP30	Clean Power 2030
DCUSA	Distribution Connection and Use of System Agreement
DNO	Distribution Network Operator
DPIA	Data Protection Impact Assessment
ED2	Short for RIIO-ED2, the current regulatory period running until 31st March 2028
ED3	Short for RIIO-ED3, the next regulatory period anticipated to run from 1st April 2028 to 31st March 2033
ED4	Short for RIIO-ED4, the next regulatory period anticipated to run from 1st April 2033 to 31st March 2038

Term	Definition
EHV	Extra High Voltage
ENA	Energy Networks Association
ENWL	Electricity North West Limited
ETR	Estimated Time of Restoration
EV	Electric Vehicle
GDPR	General Data Protection Regulation
GNN	Graph Neural Network
GRT	Guaranteed Response Time
GSOP	Guaranteed Standard of Performance
HV	High Voltage
ICP	Independent Connection Provider
LCT	Low Carbon Technology
LLM	Large Language Model
LV	Low Voltage
MCAR	Major Connections report
MCCSS	Major Connection Customer Satisfaction Score
LME	London Metal Exchange

Term	Definition
MCI	Major Connections Incentive
MCS	Major Connections Strategy
MCTTQ	Major Connections Time to Quote
ML	Machine Learning
MVP	Minimum Viable Product
NERS	National Electricity Registration Scheme
NGED	National Grid Electricity Distribution
OS	Ordanance Survey
PND	Primary Network Design
PoC	Proof of Concept
PV	Photovoltatics
RAG	Retrieval-Augemented Generation
SPEN	Scottish Power Energy Networks
SSEN	Scottish and Southern Electricity Networks
TTQ	Time to Quote
UKPN	UK Power Networks

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Appendix 1: Further Justification for Roadmap Sequence

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Considerations for the Roadmap

The development of the AI roadmap for NGED took into account the following factors:

- Necessary infrastructure dependencies to support the identified AI use cases.
- NGED's preparedness to implement these use cases.
- The potential value these use cases are expected to unlock.
- Availability of possible funding to integrate the use cases into BAU.
- The current maturity of AI solutions and their anticipated evolution moving forward.

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Dependencies

The roadmap considers dependencies required in order to develop each AI solution.

- The project team identified the dependencies required to enable each AI solution.
- The roadmap timelines the dependencies based on the project teams understanding of NGED's development timelines.

#	Use case Description	Dependencies
1	Use of AI to ensure the integrity of the incoming application	Infrastructure Cloud Platform | LLM Ops Platform | Fully Digitalised Connection Process for HV and EHV
2	Use of AI in searching relevant policies and uniform interpretation of policies for planners and PND engineers	Infrastructure Cloud Platform | LLM Ops Platform | Engineering / Technical Policy Repository
3	Generating Budgetary quotes and Application Factors using AI	Infrastructure Cloud Platform | LLM Ops Platform | Fully Digitalised Connection Process for HV and EHV
4	AI based optimal route selection to the point of connection	Infrastructure Cloud Platform | LLM Ops Platform | AI Use Case 3: Generating Budgetary Quotes
5	AI based commodity pricing reporting	AI Use Case 5 is **excluded** from the roadmap due to regulatory barriers mandating provision of lowest costs quotes to customers in today's prices.
6	Use of AI in responding to Customer Enquiries from customer	Infrastructure Cloud Platform | LLM Ops Platform | Fully Digitalised Connection Process for HV and EHV
7	AI based ICP design assessment	Infrastructure Cloud Platform | LLM Ops Platform | Fully Digitalised Connection Process for HV and EHV connection ICP providers
8	Use of AI in assisting planner and PND teams to minute customer conversations	None
9	Use of AI in draft connections agreements	None

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NGED Preparedness

- NGED are currently modernising their IT and digital systems. NGED's internal roadmap for this process is emerging.
- AI Use Cases 8 and 9 can be integrated with NGED's current systems.
- AI Use Cases 3, 4, 1, 6 and 7 all rely upon a fully digitalised connection process for HV and EHV connections, which NGED have committed to delivering by the end of RIIO-ED2. These use cases therefore cannot be implemented until after this is delivered.

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Value

The prioritisation exercise assessed each AI use case for the value it is anticipated to deliver, based on direct input from NGED stakeholders from engineering, policy, CAT teams and refined by discussion with senior NGED stakeholders.

- The impact on customer satisfaction assessed the benefits to customers through decreased time to quote and connections, improved accuracy, better access to information and enhanced communication.
- The impact on efficiency assessed the impact on NGED operation efficiency, through time savings, improved processes , reduced training requirements.

#	Use case Description	Impact on Customer Satisfaction	Impact on Efficiency
1	Use of AI to ensure the integrity of the incoming application	Low	Medium
2	Use of AI in searching relevant policies and uniform interpretation of policies for planners and PND engineers	High/Medium	Medium/Low
3	Generating Budgetary quotes and Application Factors using AI	High	High/Medium
4	AI based optimal route selection to the point of connection	Medium	Medium
5	AI based commodity pricing reporting	Medium	Low
6	Use of AI in responding to Customer Enquiries from customer	High/Medium	High
7	Ai based ICP design assessment	High	High/Medium
8	Use of AI in assisting planner and PND teams to minute customer conversations	Medium	Medium
9	Use of AI in draft connections agreements	Low	High

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Funding

All AI solutions identified during the projects will require funding to be adopted. The project timeline has accounted for procurement of funding for the solutions.

- **AI Solutions 8, 9 and 2** are anticipated to be quick to implement and have anticipated Return on Investment within RIIO-ED2. A business case could be developed to secure the funding within RIIO-ED2.
- **AI Solutions 3 and 4** unlock efficiency benefits in NGED's operational practices within RIIO-ED3. Accounting for development, a positive Return on Investment will not be possible within RIIO-ED2. Therefore, it is recommended NGED apply for funding to implement these solutions within the RIIO-ED3 business planning process.
- **AI Solutions 1, 6 and 7** are anticipated to be delivered within RIIO-ED4, with a positive Return on Investment within the ED4 business period. Therefore, it is recommended NGED apply for funding to implement these solutions within the RIIO-ED4 business planning process.

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Maturity of AI Solutions

AI technology is rapidly maturing, with distinct AI methodologies anticipated to mature at different rates. The roadmap sequencing accounts for the existing and anticipated changes in AI technology maturity to guide the development and launch of solutions.

- **AI Use Cases 8 and 9** rely on AI solutions that are commercially available off-the-shelf. NGED would not be required to take on costly and risky development activities to deploy these AI solutions.
- **AI Use Case 2** requires configuring an LLM to NGED's policy repository for a solved problem, naming querying an existing knowledge base. Configuring an AI solution is significantly less risky and costly than training AI models.
- **AI Use Case 3** uses the relative mature technology of Machine Learning. Development is required here, but relative to less mature technologies such as Retrieval Augmented Generation (RAG), this is lower risk.
- **AI Use Cases 4, 1, 6 and 7** rely on the AI technology of RAG. This technology is currently at an early stage of maturity and is continuing to rapidly evolve. Therefore, there is benefit in waiting for this technology to mature and stabilise before committing the risky and costly development required to build these models.

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Sequencing of AI Solutions

The recommended sequencing of deployment of AI solutions has been compiled accounting for all factors discussed in the slides above.

- **AI Use Cases 8 and 9** are sequenced to occur within RIIO-ED2, since they rely on commercial solutions available off-the-shelf and are anticipated to deliver return on investment within the RIIO-ED2 business period.
- **AI Use Case 3** delivers high value, but carries a degree of complexity that will not enable a return on investment within ED2. It is therefore sequenced in ED3. **AI Use Case 4** delivers further value once AI Use Case 3 is implemented, and as such is scheduled following deployment of **Use Case 3**
- **AI Use Case 2** also has potential to return on investment within ED2, but relies on the development of a centralised, digitalised policy repository. It is therefore sequenced to occur after AI Use Case 3 and 4.
- **AI Use Cases 1, 6 and 7** rely on the AI technology of RAG. This technology is currently is continuing to rapidly evolve. **Use Case 1** is relatively low complexity, but delivers less value than **use cases 3 and 4** so is sequenced after these in ED4. Use Cases 6 and 7 deliver high value but rely on a fully digitalised HV/EHV connections journey and maturing technologies. These are therefore scheduled for delivery in ED4.
- **AI Use Case 5** is not included within the roadmap, due to regulatory barriers preventing network operators from providing quotes accounting for future price changes (in e.g. materials and labour).

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