WP4 – Roadmapping

Probabilistic Pathways – SIF Discovery Phase

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ESO

Contents

INTRODUCTION

The key objectives of this work package and an overview of the existing landscape.

Overview – System Transition

- One of National Grid ESO's key responsibilities is planning the UK's future electricity grid infrastructure to assure security, sustainability, and affordability of supply[1].
- As the ESO transitions to the NESO, it will also assume responsibility for the UK energy system, including gas and hydrogen energy sources.
- The ESO is responsible for developing credible future energy scenarios, each of which has different energy demands, end users, and sources, which makes comparisons and future planning complicated.
- Increasing complexity is driven by the need to co-optimise planning decisions across multiple energy vectors, while growing uncertainty is driven by the need to make high value decisions based on a range of projected system scenarios.
- As the energy transition accelerates, this complexity and uncertainty makes long-term energy system planning decision-making more important.

Overview - Modelling

- Modelling techniques can be a powerful tool for future planning as they allow organisations to explore and prepare for a variety of potential outcomes before making key decisions.
- As part of the Discovery Phase, a variety of different modelling methods have been researched and assessed. The proposed Alpha stage project centres on the combination of three data science techniques:
  - **Probabilistic modelling** is a statistical methodology used to represent uncertainty in data and make predictions based on probability distributions[1]:
    - These techniques are recommended for scenario modelling of whole systems, as they are adaptable, good at complex problems, and good at handling the uncertainty common to scenario modelling.
    - These techniques have been used in the energy industry previously for scenario planning.
  - **Surrogate modelling** is a technique used to approximate complex systems with simpler, computationally inexpensive models, allowing for much faster modelling and analysis[1] :
    - The low computational burden of the models allows for fast low-fidelity analysis which enables multiple pathways to be considered before decision gates, creating more informed decisions.
    - These methods have been used to optimise system designs and maintenance regimes.
  - **Reinforcement learning** is a branch of machine learning, that aims to find optimised solutions to problems[1]:
    - Reward based learning allows trained agents to find optimised solutions to a given problem through trial and error, much faster than humans.
    - Their main strength and utility lies in optimisation problems, such as system control or scheduling tasks.

WP4 Objectives

- The objectives of this Work Package (WP4) are as follows:
  - Assess the barriers, enablers, risks and opportunities that exist related to the deployment of advanced modelling techniques.
  - Undertake a qualitative benefit assessment, with case studies to demonstrate previous examples of when the solution could have provided benefit.
  - Develop a SIF roadmap, including how the proposed solution aligns with organisational and wider industry transition.

BARRIERS & ENABLERS

A review of key barriers, enablers, risks and opportunities of advanced modelling was undertaken by the project team, with a STEEPLE analysis to explore additional macro-environmental factors influencing the project.

Barriers & Enablers

Barriers[1]

1. **Data Quality and Availability**: Insufficient data or inaccurate assumptions can hinder the effectiveness of algorithms, although one of the strengths of probabilistic modelling techniques is to extract value from low volumes of data.
2. **Regulatory Compliance**: Compliance with existing regulations and standards might be a barrier, especially for the application of AI techniques to decision-making.
3. **Technical Complexity**: Implementing advanced modelling techniques requires specialised technical knowledge and infrastructure, which may not be readily available or easily scalable.
4. **Resistance to Change**: Resistance from stakeholders who are accustomed to traditional planning methods could impede the adoption of advanced modelling techniques, including implementation within existing processes.

Enablers[1]

1. **Advancements in Technology**: Rapid advancements in modelling techniques, computing power, and data storage make it increasingly feasible to apply these techniques to complex energy planning **scenarios.**
2. **Data Accessibility:** Improved data collection methods and the proliferation of web technology could provide a wealth of data that can be leveraged for advanced modelling.
3. **Stakeholder Engagement:** Engaging stakeholders early in the process and demonstrating the benefits of advanced modelling techniques can build support and facilitate adoption.

Risks and opportunities

Risks

1. **Algorithm Bias:** Artificial Intelligence/Machine Learning (AI/ML) models may inadvertently incorporate biases present in the training data, leading to unfair outcomes or inaccurate predictions, particularly in energy planning where equitable distribution and access are essential[1]
2. **Cybersecurity Concerns:** Increased reliance on data and algorithms makes energy infrastructure susceptible to cyberattacks, potentially disrupting operations and compromising sensitive information.
3. **Overreliance on Technology:** Overreliance on modelling techniques without human oversight could lead to flawed decision-making or neglect of critical factors not captured by the models.
4. **Lack of Interpretability:** Complex AI/ML models may lack interpretability, making it difficult to understand how decisions are made or to justify recommendations to stakeholders.
5. **System Planning Evolution:** The process for planning the future system is evolving to a new Centralised Strategic Energy Plan approach, which must be kept under review to ensure that the project outputs remain relevant.

Opportunities

1. **Improved Decision Making**: Advanced modelling techniques can analyse vast amounts of data and generate insights to optimise energy network planning, leading to more informed and efficient decision-making.
2. **Resilience and Flexibility**: Probabilistic modelling can help identify vulnerabilities and anticipate disruptions in the energy network, enabling proactive measures to enhance resilience and flexibility.
3. **Sustainability**: By optimising energy resource allocation and infrastructure planning, advanced modelling techniques can contribute towards the transition towards more sustainable whole energy systems.
4. **Innovation**: Integrating advanced modelling techniques into energy planning processes fosters innovation and encourages the development of new solutions to address emerging challenges in the energy sector.

External Influences

The STEEPLE analysis provides a high-level view of the external macro-environmental factors that influence the project, which should be continually considered, but sit outside of the project's control.

Social (S)

- Decarbonisation of heating
- Decarbonisation of transport
- Reduced energy costs for consumers

Technological (T)

- Distributed renewables integration
- Hydrogen infrastructure
- Smart grid technologies

Economical (E)

- Optimal energy system costs
- Energy market evolution is uncertain
- New job opportunities will exist through transition

Environmental (E)

- Climate change mitigation
- Impact of new infrastructure on local environment

Political (P)

- Improved impact assessment of proposed policy
- Political will for net zero
- Government incentives/ subsidies

Legal (L)

- NESO expanding statutory responsibilities.
- Regulatory changes

Ethical (E)

- Equitable access to clean, affordable energy
- Artificial Intelligence faces ethical concerns

BENEFITS ASSESSMENT

A mostly qualitative benefits assessment was completed, with case studies to demonstrate real-life examples of previous investment decisions that could have been enhanced.

Benefits of the proposed enhancements
For the network planning process

- The ESO is currently obligated by Ofgem to undertake Cost Benefit Analysis, uncertainty and sensitivity analyses for business proposals, to demonstrate the decisions are the best value for customers[1].
- However, costing decisions are incredibly complex, with calculations to predict transmission line costs dependent on a wide variety of factors including distance, capacity, voltage, location, and type [2].
- The potential advantages for the ESO of implementing the proposed enhancements are given in the table below:

Advantage	Description	ESO Benefits
Faster Modelling	The proposed enhancements will be able to generate scenarios and optimised outcomes faster than current systems [3, 4, 5, 6, 7].	▪ More time to consider future scenarios. ▪ Real-time optimised solutions to grid changes. ▪ More efficient use of time in planning meetings. ▪ Cost savings due to faster modelling times.
Ease of implementation	Models could have easier implementation through use of available open-source material or transfer learning from existing systems. Pretrained models can also be used on less complex hardware [4, 5, 6, 7].	▪ Implementation cost savings, for both development and deployment. ▪ Hardware cost savings.
Risk Modelling	The proposed probabilistic methods can generate risk and uncertainty profiles for their outcomes [6].	▪ Better understanding of future risks and uncertainty. ▪ Faster identification of potentially poor decisions.
System Complexity	The proposed reinforcement learning method is capable of optimising complex systems, even with multiple parameters [4, 5, 6, 7].	▪ Allows more comprehensive modelling of existing and future grid. ▪ Enables optimised design and operation decisions. ▪ Enables future digital twin and siblings systems[8].
Forecasting	The proposed surrogate model will be capable of predicting future events based on historical data and probabilities [4, 5, 6, 7].	▪ Enables informed mitigation decisions to be made ahead of time.

Benefits of the proposed enhancements
For the energy system and customers

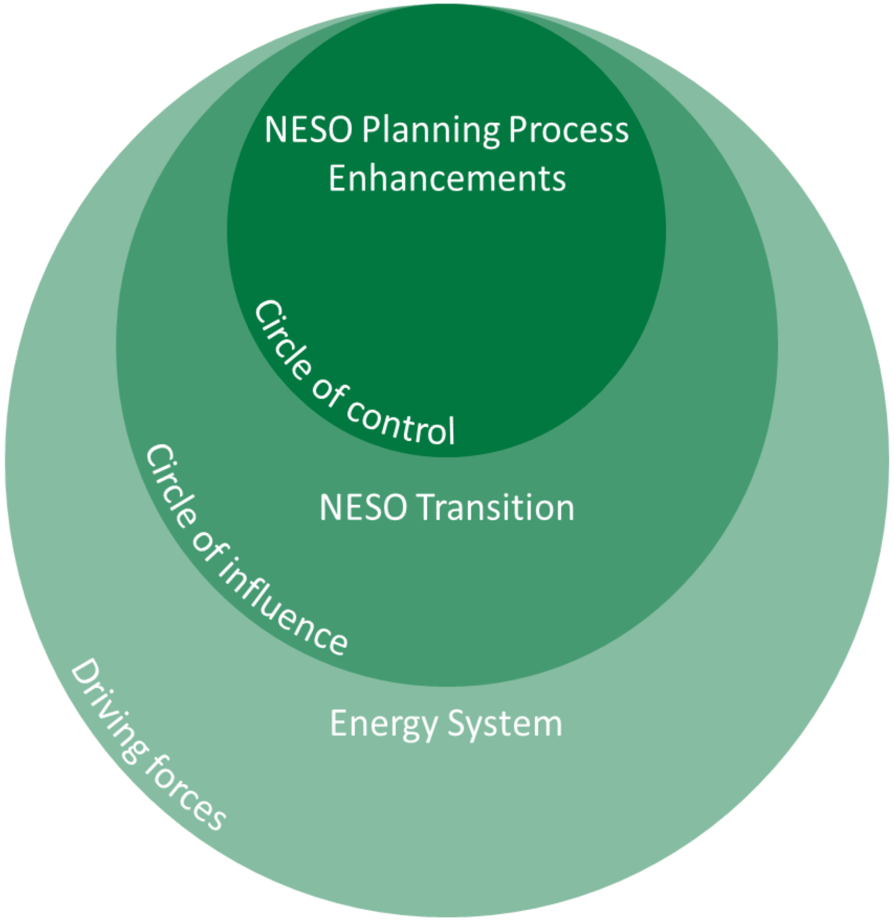
- The proposed enhancements to the network planning process would have direct impacts on the operation of the GB energy system, and downstream to customers. These are given in the table below:

Advantage	Description	Energy System Benefits
Network Reliability	A more reliable energy system, with better understood behaviours and less outages, or power peaks [1, 2].	▪ Enables optimised design and upgrades of current systems. ▪ Easier integration of new energy sources and storage in optimised locations.
Network Resilience	A network able to respond to changing conditions at a faster pace, and with more options to do so [1, 2, 3].	▪ Faster integration of future energy sources, offsetting predicted medium-term supply shortages. ▪ Faster identification and mitigation of potential bottlenecks.
Lower Carbon Emissions	A network that uses more lower carbon sources of energy, and wastes less energy, resulting in lower carbon emissions[2, 3].	▪ Easier integration of renewable systems. ▪ Better-informed decisions on network upgrades could reduce the need for curtailment of renewable energy sources.
Lower Costs to Consumers	Energy delivered to end users at the lowest possible transmission and generation costs[2, 3].	▪ Optimised network, both in design and operation, with upgrades made at the right time, would reduce energy costs to end users.

ROADMAP

An overview of the proposed process, and how this aligns with existing process, including a roadmap to demonstrate how the proposed SIF project timelines correspond with NESO and wider energy system transition milestones.

Roadmap Scope



The proposed enhancements need to be considered in the context of the wider system:

- The planning process itself is within the circle of control for this project
- New responsibilities imposed by the transition to NESO will influence what is required of the planning process
- As the energy transition accelerates, complexity and uncertainty associated with long-term planning and decision-making grows

Each of these three scopes are shown as a separate “swimlane” (row) on the roadmap.

Roadmap

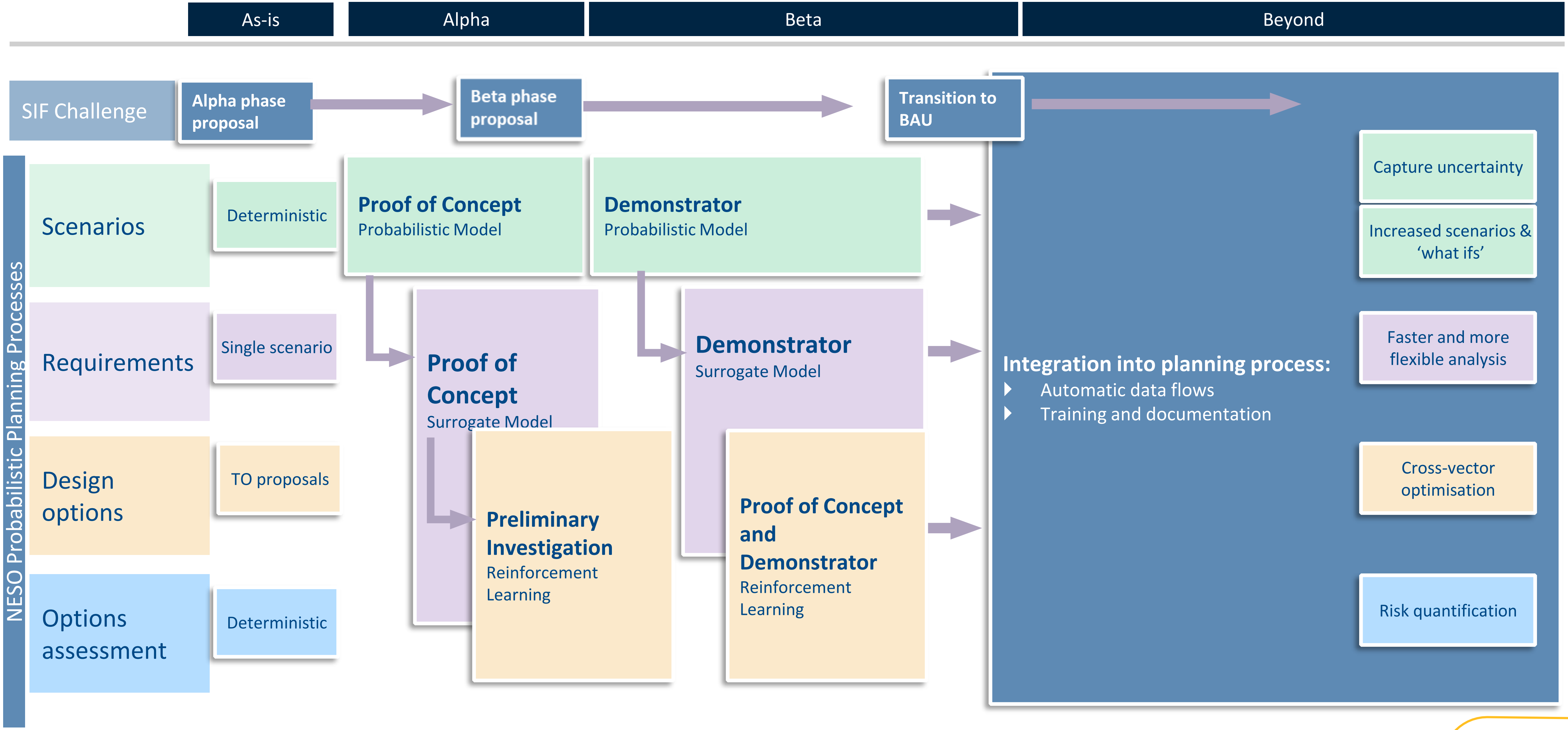
	Alpha	Beta	Beyond
NESO Probabilistic Planning Processes	Alpha phase proposal **Proof of Concept** Probabilistic & Surrogate Model **Preliminary Investigation** Reinforcement Learning	**Demonstrator** Probabilistic & Surrogate Model **POC and Demonstrator** Reinforcement Learning	**Integration**
NESO Transition	NESO Established FES → Gas System Planning	Developing documentation First SSEP →	Internal Training for advanced modelling Internal AI Policy consultation needed CSNP → Holistic Network Design RESP Implementation

NESO Operating Environment

- UK Government elections
- 1m EVs on UK roads
- 2GW Hydrogen production capacity[2]
- First 100% Hydrogen village[3]
- 600k/year heat pump installs[5]
- 10GW Hydrogen production capacity[2]
- Hydrogen backbone completion
- Natural gas boiler phase out
- Hinkley Point C[4]
- 50GW Offshore wind by 2030[1]
- Advanced Nuclear Technologies (ANTs)

Growing complexity and uncertainty

Project Roadmap



CONCLUSIONS

Key findings for consideration in subsequent phases of this SIF project.

Conclusion

- There are significant costs to be saved by making better-informed planning decisions, whether by identifying reinforcement needs more accurately, or by ensuring investments are timed most efficiently.
- Advanced modelling can play a crucial role in improving decision-making, by analysing the risks and uncertainties involved, and by efficiently optimising complex systems.
- This has economic benefits such as lower energy and investment costs but also contributes to environmental sustainability.
- Phases of the SIF project roadmap align with the ongoing transition from National Grid ESO to NESO and offer a timely opportunity to optimise planning decisions in the face of ever-increasing complexity.
- A risk associated with this project, which the alpha and beta phases aim to address, is ensuring the advanced modelling techniques are developed such that they can integrate with the already complex and changing planning process. This also represents an opportunity to use the outputs of the project to make improvements to the process while they being updated, to improve future integration activities.

Glossary

AI –Artificial Intelligence

ANT – Advanced Nuclear Technologies

CSNP – Centralised Strategic Network Plan

FES – Future Energy Scenarios

IoT – Internet of Things

ML – Machine Learning

National Grid ESO – National Grid Electricity System Operator

NESO – National Energy System Operator

PoC – Proof of Concept

RESP – Regional Energy System Planners

SIF – Strategic Innovation Fund

SSEP – Strategic Spatial Energy Plan

TO – Transmission Owner