Enhancing the Real Options CBA tool

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  - Re-platformed CEM tool additional functionalities
  - Example using the enhanced ROCBA tool

Background and timeline

2015

Problem statement in ED1: Support the development of flexibility by creating a tool to evaluate flexibility and asset solutions equitably and help choose the minimum intervention(s)' whole life cost.

2016

ENWL developed **ROCBA** as part of an innovation project. It has been used since autumn 2016 to inform our decision-making, comparing the cost of different network investment solutions, e.g. the cost of reinforcement against the cost of flexibility, and assessing the risks and benefits under the five DFES scenarios.

2019

Ofgem flagged the **inconsistent approach** as DNOs were experimenting with flexibility with different evaluation methods.

2020

ROCBA's holistic approach to network investment analysis has been recognised by the **Open Networks Project** and Workstream 1A, Product 1 developed a **Common Evaluation Methodology** (CEM) for flexibility services.
ENWL/SPEN led the development of the CEM tool, based on Ofgem's CBA and ROCBA tools.
All DNOs agreed to use the CEM tool for evaluating flexibility from April 2021.

2021

Problem statement in ED2: Positively engaging with as many solution providers as possible to ensure that we have the widest range of options possible for evaluation and adopt the most suitable economic approaches and deliver efficiencies for customers. This requires the ability to quickly and easily run hundreds of flexibility option assessments.

ED2 Business Plan proposals: Continue to further develop the capabilities of the ROCBA tool to maintain its position as a state-of-the-art decision support tool across all network investment strategies.

Executive summary (1/6)

Why did we create ROCBA in RIIO-ED1

- With the **greater uncertainty around widespread distributed energy resources** (**DER) and low carbon technologies (LCTs) and demand growth** in distribution networks, it is crucial to ensure that the most **cost-efficient** and **risk-aware solutions** to release network capacity are deployed.
- A **Cost Benefit Analysis (CBA) tool** is required by DNOs to evaluate flexibility and asset solutions equitably and help choosing the minimum intervention(s)' whole life cost/least regret option.
- A **Real Options approach** highlights in a quantitative way the **value** of the **flexibility of decision-making** under **multiple uncertain future scenarios*,** compared to a deterministic CBA approach which assumes **one single view of the future**.
- This entails the option/ability to **adjust the intervention strategy**, responding to **new information** as it arrives **over time**.
- In 2016, ENWL developed, in collaboration with the University of Manchester, a **Real Options CBA (ROCBA) Excel tool** to quantify the costs and benefits of several long-term investment strategies to provide network capacity under uncertainty, testing them against all possible future scenarios.

* Defined by our Distribution Future Electricity Scenarios (DFES). Online: https://www.enwl.co.uk/dfes

ROCBA’s strengths and weaknesses

- For each strategy, the tool calculates ***different* cost and risk metrics** considering **long-term uncertainty** in future **peak demand growth** ('macro scenarios') as well as sources of **'micro' uncertainty** and **small-scale variations** around each macro scenario, following a **probabilistic representation** of relevant **random variables,** (e.g. energy prices and weather conditions).
- In our ED2 business plan, we highlighted that positively engaging with as many solution providers as possible is key to ensure that we have the widest range of options possible for evaluation, to adopt the most suitable economic approaches and deliver efficiencies for customers. This requires the ability to quickly and easily run hundreds of flexibility option assessments.
- However, the Excel implementation of the tool comes with **limited scalability and flexibility,** e.g. in the number of macro scenarios, strategies and intervention types, and there is **complexity** regarding its **outputs’ inspection and visualisation**.
- For example, the calculation of **flexibility ceiling price** requires multiple simulations while **manually** changing flexibility services capacity payments.
- Moreover, it is **not straightforward** to **update** and **improve** the functionalities of the tool, as some of the wider network and societal impacts of the different interventions, such as changes in Customer Interruptions (CIs) and Customer Minutes Lost (CMLs), carbon emissions, oil leakage, health and safety are not included.

Executive summary (3/6)

Why did we help create the CEM tool and CEM tool’s limitations

- In 2019 Ofgem flagged the ***inconsistent approach*** as DNOs were experimenting with different evaluation methods for flexibility.
- ROCBA’s holistic approach to network investment analysis was recognised by the ***ENA Open Networks Project.*** In 2020, under Workstream 1A, Product 1, ENWL/SPEN used the experience and know-how of the industry to lead the development of a ***Common Evaluation Methodology*** (CEM) for flexibility services and a CEM Excel tool, based on Ofgem’s CBA and ROCBA tools.
- The CEM tool can perform a scenario-weighted average as well as a Least-Worst Regret Net Present Value (LWR NPV) analysis, and determines the **'ceiling' price of flexibility**, thus capturing the option value of flexibility under multiple uncertain future scenarios.
- The tool has been used by *all* DNOs since April 2021, promoting **consistency** and **transparency** on the decision-making process.
- However, **scalability and flexibility of the tool is limited** as only up to **10 scenarios for each strategy** can be simulated, along with time issues of manual operations.
- Unlike the ROCBA tool, the CEM tool models only macro scenarios and it is **not possible** to perform a **probabilistic assessment of costs (through micro scenarios)** and **evaluate the financial and physical network risks** of a strategy.

Executive summary (4/6)

Why are we enhancing ROCBA

- In order to **facilitate and speed up** the **assessment process** of multiple **investment strategies** across a wider range of future network forecasts, in our ED2 business plan we committed to further develop the capabilities of the ROCBA tool* to maintain its position as a state-of-the-art decision support tool across all network investment strategies.
- In autumn 2024, we successfully re-platformed the ROCBA tool to Python and automated and expanded its original functionalities. The decision to use Python lies in the flexibility of the platform along with its widespread use across the industry in conjunction with other system planning tools.

What has been done

- The **new enhanced script-based ROCBA tool** implementation follows an **object-oriented structure.** This architecture enhances the tool's **scalability and flexibility** across **both macro and micro scenarios**, as a theoretically unlimited number of interventions, strategies and sites can be simulated under multiple future scenarios.
- Functionalities such as **flexibility ceiling price/yearly budget** calculation and the **creation/storage of outputs** (as separate Excel files) are now **automated**. This facilitates output results visualisation, inspection and analysis.
- Finally, cost components previously overlooked in the Excel ROCBA tool, e.g. flexibility services utilisation payments, depreciation, RAV, CIs, CMLs, oil leakage, health and safety costs and carbon emissions, are now explicitly considered.

***** CEM is a 'cut-down' version/'industry equivalent' of the ROCBA tool for flexibility services procurements evaluations.

What has been done (continued)

- As the CEM is a 'cut-down' version of the ROCBA tool for flexibility services procurement evaluations, the re-platforming of ROCBA resulted in an enhanced re-platformed automated version of the CEM tool* as a 'by-product', which also has the ability to run multiple micro-scenarios.
- Compared to the original Excel **CEM tool**, not only could the interventions be triggered at a specific user-defined point in time, but also by the demand growth under each different scenarios (and associated volatility in micro-scenarios). This new functionality unlocks the option to run a **probabilistic assessment** of **costs as well as the financial and physical network risks** of a strategy.
- To demonstrate the successful re-platforming and automation of the ROCBA tool, a first step we took was to validate against the CEM tool as a 'subset' of its capabilities, i.e. without micro-scenarios**.
- After demonstrating that the results of the Python-based and Excel-based CEM tool match with an illustrative example, we also show the full range of capabilities of the new enhanced Python-based ROCBA tool.

* With interventions taking place at specific user-defined 'tipping points' (i.e. years) rather than being led by peak demand scenarios.
** The validation of the new enhanced tool with respect to the full ROCBA functionalities, including micro-scenarios, is more complex. In fact, it is not straightforward to replicate the same set of Monte Carlo simulations (i.e. micro-scenarios) as these rely on the generation of a set of random numbers by two different platforms (i.e. Excel vs Python).

Executive summary (6/6)

- ROCBA/CEM tool Python scripts will be made available to download from our website and shared with other DSOs.
- This is to encourage other DSOs to use, review and provide feedback on it.
  - ENWL is available to hold briefings and training sessions to disseminate knowledge.

- No change in transparency commitment.
  - ENWL will continue to publish results of evaluations.

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Context: Obligations and responsibilities

DNO obligations

- Subject to a combination of licence obligations and incentives from Ofgem, DNOs must comply with very high standards regarding **security of electricity supply**, **customer service** and **customer safety**, while guaranteeing the **most efficient** solutions **for the consumer**.

Risks and uncertainty

- With the **greater uncertainty from widespread DER and LCTs** in distribution networks, there is a **risk** of investing too much or too little in network capacity, potentially leading to an inefficient use of network assets*.

Managing the risks/uncertainty using appropriate tools

- A **CBA tool** is used to **evaluate** a wide range of potential **interventions.** This is very important for DNOs as they must ensure that the most **cost-efficient** and **risk-aware interventions** to release network capacity are deployed.
- In particular, DNOs require a tool to evaluate flexibility and asset solutions equitably and help choosing the minimum intervention(s)' whole life cost/least regret option, and ensure that load-related investment is well-justified from a regulatory and business perspective

* Traditional network investments are relatively inflexible: underinvestment could lead to greater connections delays, becoming a blocker to net zero, and incentive penalties on the DNO; overinvestment could cause the underutilisation and stranding of certain assets.

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A Real Options (RO) approach (1/2)

- A **deterministic CBA approach** assumes **one single view of the future**, as in Ofgem's CBA tool, and that the investment decision is a now-or-never decision, not capturing the **option value of flexibility** under **multiple uncertain future scenarios**.
- A **Real Options approach,** based on the rationale of financial option pricing methods, refers to the option/ability to adjust the intervention strategy, responding to new information as it arrives over time**.**
- The 'best' strategy is selected among the list of possible flexible strategies, considering the range of possible futures, with their relative likelihoods, and subsequent adaptations to them.
- Real Options do not 'create' flexibility but **highlight in a quantitative way** the **value** of the **flexibility of decision-making**, both in the timing of a decision and in the design of the project, **under uncertainty**, which is particularly important in a network investment context.

A Real Options (RO) approach (2/2)

- **'Real options' in engineering** are useful for investments when:
  - **Strategic flexibility exists**, that is the possibility to take 'intermediate' actions (e.g. by procuring distribution flexibility service capacity, the options to invest, abandon, defer or expand are created based on how the future unfolds).
  - Decision to invest based on **uncertain information** (e.g. demand growth).
  - Financially material uncertainty, e.g. in future movements of key variables influencing future cash flows.
  - Investment is fully/partly irreversible. In the context of network investment, this condition applies, as there is typically an irreversible loss of capital due, for example, to high sunk costs or depreciation.
- In 2016, in collaboration with the University of Manchester, we developed a **Real Options CBA (ROCBA) Excel tool** to quantify the costs and benefits of several long-term investment strategies to provide network capacity under uncertainty, testing them against all possible future scenarios.
- Since 2016, we have adopted this tool to compare investment solutions, based on different decision criteria, including reinforcement vs flexibility services, reinforcement vs like-for-like asset replacements.

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ROCBA tool (2016-2024) (1/3)

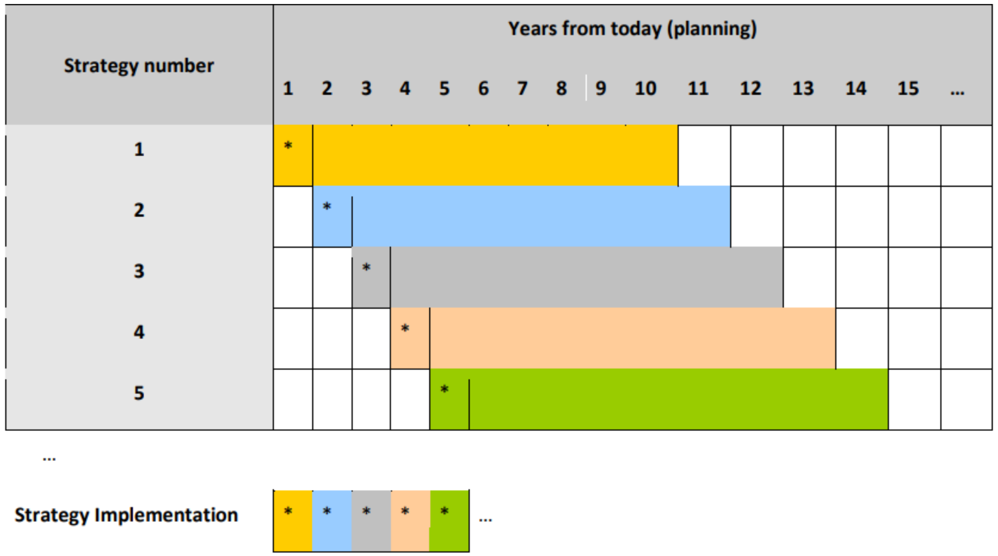
Functionalities and capabilities

- The tool allows us to assess and analyse ***different* cost and risk metrics, both financial and technical**, associated with different strategies, accounting for **long-term uncertainty** in future **peak demand growth** (i.e. 'macro' scenarios).
- Each strategy, associated to a specific worksheet, is a predefined set of interventions that may take place at 'tipping points', either user-defined or in accordance with demand growth scenarios (and associated volatility in micro-scenarios). All scenarios are modelled within each strategy, so that each worksheet 'Strategy X' contains each and all scenarios.
- In addition, the model may also consider sources of **'micro' uncertainty and small-scale variations** around each macro scenario through Monte Carlo simulations, based on a **probabilistic representation** of relevant **random variables,** (e.g. energy prices and weather conditions).
- For each worksheet 'Strategy X' and each and all scenarios, Monte Carlo simulations are run to create the corresponding probability distribution for each specific combination of 'Strategy X'.
- The analysis can be performed from different 'financial views/perspectives', i.e. DNO commercial vs regulatory, with consequent impacts on CBA time scales as well as discount rates and inclusion of social costs.

ROCBA tool (2016 – 2024) (2/3)

Outputs of the tool include:

- 'Optimal' investment strategy for the current year, identified in accordance with a pre-determined decision-making criterion, to be reassessed every year as new information on the scenarios and estimated uncertainty arrives over time (i.e. receding horizon approach).
- Ranking of the considered strategies by different metrics (expected cost, LWR, expected cost weighted with risk metrics, and so on).
- Probabilistic distribution of future costs and network risk of each strategy, through the corresponding Value at Risk (VaR) and Conditional Value at Risk (CVaR), along with the overall probability-weighted distribution of future costs and risks for each strategy.
- Trajectory of network capacity and cash flow outputs per macro-scenario.



ROCBA tool (2016 – 2024) (3/3)

MS Excel implementation limitations

- In our ED2 business plan, we highlighted that positively engaging with as many solution providers as possible is key to ensure that we have the widest range of options possible for evaluation, to adopt the most suitable economic approaches and deliver efficiencies for customers. This requires the ability to quickly and easily run hundreds of flexibility option assessments. However:
- **Scalability and flexibility is limited** as:
  - The long-term peak demand uncertainty model is restricted to 5 scenarios.
  - Only up to 2 strategies, consisting of a sequence of up to 3 interventions* taking place at 'tipping points' over the CBA period can be analysed.
  - The number of Monte Carlo simulations to model small-scale variations occurring within each long-term peak demand scenario is currently set to 100.
- Despite the Excel tool user-friendliness, it is **not straightforward** to **update** and **improve** its functionality. For example, the calculation of **flexibility ceiling price** requires multiple simulations while **manually** changing flexibility service capacity payments.
- Additionally, there is **complexity** regarding its **outputs' inspection and visualisation**. For example, outputs (i.e. diagrams and tables) appear in different spreadsheet tabs (many of them duplicated).

* i.e. 'Invest in asset/reinforce' or 'flexibility' intervention types or 'do nothing'.

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CEM tool (1/2)

Background

- In 2019 Ofgem flagged the ***inconsistent approach*** due to the different evaluation methods being used by DNOs experimenting with flexibility services as alternative solutions.
- In 2020, the ***ENA Open Networks Project*** recognised ROCBA's holistic approach to network investment analysis and used the tool as the foundation* to develop a ***common evaluation methodology*** (CEM) for flexibility services and an associated Excel-based CEM tool. This work, under Workstream 1A, Product 1, was led by ENWL in collaboration with the other DNOs.
- The tool has been used by *all* DNOs since April 2021, promoting **consistency** and **transparency** on the decision-making process to meet network needs, choose the most economical solution between traditional network asset solutions and procure flexibility services. The tool can be used for evaluating a range of intervention options.
- This also promotes greater **visibility** and **confidence among flexibility providers**, boosting volumes and market competition, potentially reducing costs for customers.

Functionality

- The CEM tool **captures the option value* of flexibility** under multiple uncertain future scenarios, whether through a scenario-weighted average or LWR NPV analysis.
- The CEM tool also determines the **'ceiling' price of flexibility** that could be justified beyond which it is no longer cost-effective to defer reinforcement (i.e. NPV=0).

*Along with Ofgem CBA tool.
** The intrinsic value of flexibility is the value corresponding to a single 'best view' scenario, the total option value relates to the value when looking across all scenarios, e.g. through LWR or weighted average approach.

CEM tool (2/2)

Strengths and limitations

- Its methodology considers some of the wider network and societal impacts of different interventions, such as the impact of changes in CIs and CMLs, carbon emissions, oil leakage, health and safety, which are not included in ROCBA, as well as network losses (included in ROCBA).
- With regard to facilitating and speeding up the assessment process across a wider range of future network forecasts, **scalability and flexibility is limited** as the CEM tool allows only up to **10 scenarios for each strategy*** to be simulated.
- Within the CEM tool, **only macro scenarios** are simulated, whereas the impact of micro scenarios** and the probabilistic assessment, enabled within the ROCBA tool, is not included. Therefore, it is **not possible to calculate** the **distribution of costs and evaluate the financial and physical network risks** of a strategy.
- Additionally, the CEM tool only takes the regulatory perspective, following the Ofgem CBA tool.

*While ROCBA has 2 breakpoints (i.e. 3 intervention stages), the CEM has 1 'breakpoint', i.e. one point in time over the CBA period where the network investment can occur (i.e. 2 intervention stages, being flexibility services procurement followed by traditional network investment). Therefore, a 'strategy' corresponds to a different number of deferral years.
**e.g. shorter-term uncertainty from flexibility contract prices, availability, peak load adjustments, weather.

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New enhanced script-based ROCBA tool (autumn 2024)

- In autumn 2024, we successfully re-platformed the ROCBA tool to Python as well as automated and expanded its original functionalities. The decision to use Python lies in the flexibility of the platform along with its widespread use across the industry.
- The **new enhanced script-based ROCBA tool** implementation follows an **object-oriented structure.** This architecture enhances the tool's **scalability and flexibility** across **both macro and micro scenarios**, as a theoretically unlimited number of interventions, strategies and sites can be simulated under multiple (unconstrained number of) future scenarios.
- When the interventions take place at specific user-defined 'tipping points' (i.e. years), the CEM tool can be considered a 'cut-down' version' of the ROCBA tool.
- Hence, the re-platforming of ROCBA resulted in an enhanced re-platformed automated version of the CEM tool as a 'by-product'.
- In fact, compared to the original Excel **CEM tool**, not only could the interventions be triggered at a specific user-defined point in time, but also by the demand growth under each different scenarios (and associated volatility in micro-scenarios). This new functionality unlocks the option to run a **probabilistic assessment** of **costs as well as the financial and physical network risks** of a strategy.
- A summary of the enhancements to the ROCBA tool is provided in the next slide.

New enhanced script-based ROCBA tool (autumn 2024)

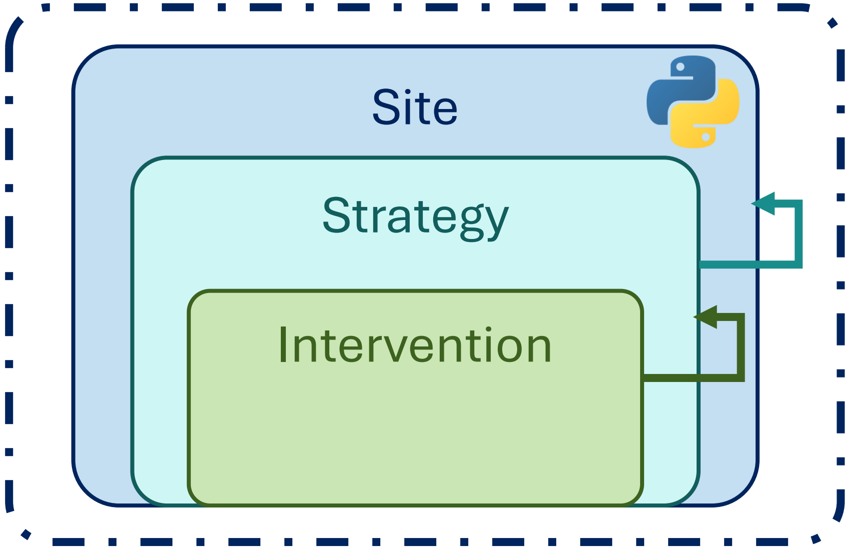
Summary of enhancements to the ROCBA tool

Old ROCBA Excel-based tool	New ROCBA Python-based tool
Applicability **limited to 2 strategies**, **3 interventions** (i.e. 2 'tipping points'), **5 macro scenarios** and **100 Monte Carlo simulations**.	**Scalable and flexible. Unlimited number** of interventions, strategies and Monte Carlo simulations (i.e. 'micro' scenarios) run under multiple macro scenarios.
Determination of the **flexibility ceiling price** requires multiple simulations performed by **manually** changing flexibility service capacity payments.	**Flexibility ceiling price/yearly budget** automatically calculated based on price sensitivity analysis.
Cost components e.g. flexibility service utilisation payments, depreciation, RAV, CI, CML, oil leakage, health and safety costs and carbon emissions, are not explicitly considered.	Incorporates flexibility services utilisation payments, depreciation, RAV, CI, CML, oil leakage, health and safety costs and carbon emissions costs.
The model can only calculate the loss effects of the 1^{st} and 2^{nd} traditional intervention.	Losses calculation extended to all successive intervention within each strategy.
Difficult to visualise, inspect and analyse the outputs.	**Automated creation/storage of outputs** (as separate Excel files).

New enhanced script-based ROCBA tool: High-level architecture

Inputs

(e.g. techno-economic parameters of each intervention, demand growth by scenario for site under analysis, etc.)



Each site is assessed for multiple strategies

Each strategy 'object’ is modelled as a set of one or more intervention 'objects'

Object-oriented implementation in Python

Unrestricted/unlimited number of intervention types, strategy types and sites can be simulated under multiple scenarios.

Scalable and flexible across macro scenarios

Outputs

(e.g. risk and costs assessment and results for each strategy)

Each site (e.g. substation) is characterised by its specific demand growth profiles under multiple macro scenarios.

New enhanced script-based ROCBA tool: Summary of input data

Intervention
Type (i.e. flexibility services or network reinforcement)
Additional capacity for network solution
First/last year of operation
Asset loading threshold
Asset lifetime and lead time
Embedded emissions
Losses parameters
Maximum flexibility total availability
Average size of contract per customer
Minimum flexibility contract length
Flexibility contract type
Cost parameters

Strategy
Sequence of intervention
Oil leakage (litres)*
#fatal/non-fatal injuries*
CML*
#CI*
For flexibility strategies, total flexibility availability and utilisation per year per scenario*

*if activation of each intervention is user-defined.

Site
Initial firm capacity
Demand growth trends
Scenario probability weights and volatility
'Best view' scenario
Sequence of strategies
Initial losses parameters
Weather-related volatility
Financial view
Financial parameters: e.g. discount rate, planning horizon, totex treatment, capitalisation rate, WACC, cost per fatal/non-fatal injury, cost per litre oil, cost per CI/CML
Baseline strategy

New enhanced script-based ROCBA tool: Summary of outputs (1/2)

To facilitate results visualisation, inspection and analysis, the tool's outputs include a **separate Excel file to store**:

- **Trajectory of network capacity** for each strategy under each macro scenario.
- **NPV analysis** of each strategy, assessed in absolute terms as well as with respect to a pre-determined baseline strategy (with breakdown of costs associated with losses), along with LWR analysis of both financial/cash flows and network risk.
- **Probabilistic distribution** of **future costs and network risk** of each strategy along with the overall scenario probability-weighted distribution of future costs for each strategy.

Example of network capacity trajectory output in excel

A	B	C	D	E	F
	Falling short	Consumer Transformation	Best View	Leading the Way	System Transformation
2024	17.5	17.5	17.5	17.5	17.5
2025	17.5	17.5	17.5	17.5	17.5
2026	17.5	17.5	17.5	17.5	17.5
2027	17.5	17.5	17.5	17.5	17.5
2028	17.5	17.5	17.5	17.5	17.5
2029	17.5	17.5	17.5	17.5	17.5
2030	17.5	17.5	17.5	17.5	17.5
2031	17.5	17.5	17.5	17.5	17.5
2032	17.5	17.5	17.5	17.5	17.5
2033	17.5	17.5	17.5	17.5	17.5
2034	17.5	17.5	17.5	17.5	17.5
2035	17.5	17.5	17.5	17.5	17.5
2036	17.5	17.5	17.5	17.5	17.5
2037	17.5	18	17.5	17.5	17.5
2038	17.5	19	17.5	17.5	17.5
2039	18.5	19.5	17.5	17.5	17.5
2040	18.5	20	17.5	17.5	17.5
2041	19	20.5	17.5	17.5	17.5
2042	19.5	21	17.5	17.5	17.5
2043	20	21.5	18	17.5	17.5
2044	20	22	18.5	17.5	17.5
2045	20.5	22.5	19	17.5	17.5
2046	21	23	19	18	17.5

Strategy_0 | **Strategy_1** | Strategy_2 | Strategy_3

New enhanced script-based ROCBA tool: Summary of outputs (2/2)

- For each strategy, **discounted (and non-discounted) cash flows** for each year and a Monte Carlo simulation under each macro scenario, to facilitate data inspection.
- For each strategy, **residual excess load** for each year and a Monte Carlo simulation under each macro scenario, to facilitate data inspection.
- **Flexibility service ceiling price** and **yearly budget**, both deterministic of each strategy under each scenario, and stochastic (i.e. scenario-weighted).

Example of discounted cash flow outputs in Excel for a specific strategy

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
1		N=1	N=2	N=3	N=4	N=5	N=6	N=7	N=8	N=9	N=10	N=11	N=12	N=13	N=14	N=15	N=16	N=17	N=18	N=19	N=20
2	2024	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	2025	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	2026	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	2027	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	2028	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	2029	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	2030	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	2031	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	2032	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	2033	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	2034	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	2035	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	2036	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	2037	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	2038	0	0	0	0	0	0	0.01655	0	0.01655	0	0	0.01655	0	0.01655	0	0	0.01655	0	0.01655	0
17	2039	0.03198	0.03198	0.03198	0.03198	0.01599	0.03198	0.03513	0.03198	0.03513	0.03198	0.03198	0.03513	0.03198	0.03513	0.03198	0.03198	0.03513	0.03198	0.03513	0.01599
18	2040	0.03699	0.03699	0.03699	0.03699	0.03394	0.03699	0.04	0.03699	0.04	0.03699	0.03699	0.05544	0.03699	0.05544	0.03699	0.03699	0.05544	0.03699	0.05544	0.03394
19	2041	0.05647	0.05647	0.05647	0.05647	0.05357	0.05647	0.05933	0.05647	0.05933	0.05647	0.05647	0.06227	0.05647	0.06227	0.05647	0.05647	0.06227	0.05647	0.06227	0.05357
20	2042	0.07735	0.07735	0.07735	0.06293	0.06017	0.07735	0.08006	0.07735	0.08006	0.07735	0.06293	0.08286	0.07735	0.08286	0.07735	0.07735	0.08286	0.07735	0.08286	0.06017
21	2043	0.08544	0.09937	0.09937	0.08269	0.08006	0.09937	0.10195	0.08544	0.08802	0.09937	0.08269	0.10462	0.09937	0.10462	0.09937	0.08544	0.10462	0.09937	0.10462	0.08006
22	2044	0.10619	0.10885	0.10885	0.10357	0.10108	0.10885	0.1113	0.10619	0.10864	0.10885	0.10357	0.11383	0.10885	0.11383	0.10885	0.10619	0.12729	0.10885	0.11383	0.10108
23	2045	0.12785	0.13038	0.13038	0.12536	0.12299	0.13038	0.13271	0.12785	0.13018	0.13038	0.12536	0.13512	0.13038	0.13512	0.13038	0.12785	0.13768	0.13038	0.13512	0.10998
24	2046	0.15021	0.15262	0.15262	0.13528	0.13303	0.15262	0.14226	0.13765	0.13986	0.15262	0.13528	0.15712	0.15262	0.15712	0.15262	0.13765	0.15956	0.15262	0.15712	0.13055

Falling short | Consumer Transformation | Best View | Leading the Way | System Transformation | ...

Document overview

- Enhancing the Real Options CBA (ROCBA) tool – Executive summary
- Flexibility evaluation tools
  - A real options approach
  - ROCBA tool
  - CEM tool
- Enhancing the ROCBA tool
  - Results validation against CEM tool
  - Re-platformed CEM tool additional functionalities
  - Example using the enhanced ROCBA tool

Results validation against CEM tool

- From an implementation perspective, the ability to run 'micro scenarios' (i.e. through Monte Carlo simulations) around each macro scenario relies on the ability to generate a set of random numbers following a pre-defined probability distribution (e.g. gaussian).
- However, to validate the new enhanced script-based tool with respect to the full ROCBA functionalities, including micro-scenarios, it is necessary for the same set of Monte Carlo simulations (i.e. micro-scenarios) to be run.
- Nonetheless, as these rely on the generation of a set of random numbers by two different platforms with different implementation methods (i.e. Excel vs Python), this limits the replicability of the simulations and makes the validation process more complex.
- For this reason, to demonstrate the successful re-platforming and automation of the ROCBA tool, a first step we took was to validate against the CEM tool as a 'subsection' of its capabilities, i.e. without micro-scenarios.

Results validation against CEM tool: Example

- For the validation, we used the illustrative example reported in the ENA 'CEM User guide' document, and then compared the results.
- In this case, the interventions take place at specific user-defined 'tipping points' (i.e. years).
- We compare a traditional network reinforcement intervention (NR), i.e. 'Baseline' strategy, with other strategies involving the procurement and use of flexibility services for an increasing number of (deferral) years.
- In this regard, the deferred reinforcement costs are used as the counterfactual.
- For the purpose of results comparison (and validation), only one single simulation is run rather than hundreds of Monte Carlo simulations.

Results validation against CEM tool: Example input data

Input data in Python-based tool

- The summary of the different strategies is reported in the table here, where the range of years when the intervention is 'active' is reported in brackets. For traditional network reinforcement (NR) interventions, the first year of operation is reported only.
- In this example, the way the strategies are numbere corresponds directly to the number of deferral years.
- Baseline:
  - Reinforcement costs: 1 £m
  - Intervention start year: 2024
  - Base year (decision year): 2024
- Flex services:
  - Contract shape*: Ramping
  - Availability price: 5 £/MW (fixed)
  - Utilisation price: 10 £/MWh
- All scenarios are assumed to be equally probable.

Strategy	Intervention 1	Intervention 2	Deferral years
Baseline	NR (2024)	-	0
1	Flex (2024)	NR (2025)	1
2	Flex (2024-2025)	NR (2026)	2
3	Flex (2024-2026)	NR (2027)	3
4	Flex (2024-2027)	NR (2028)	4
5	Flex (2024-2028)	NR (2029)	5
6	Flex (2024-2029)	NR (2030)	6
7	Flex (2024-2030)	NR (2031)	7
8	Flex (2024-2031)	NR (2032)	8
9	Flex (2024-2032)	NR (2033)	9
10	Flex (2024-2033)	NR (2034)	10

* See ENA's 'Common Evaluation Methodology and Tool' for more details.

Results validation against CEM tool: Example input data

Input data in CEM Excel-based tool

BASELINE REINFORCEMENT AND UPFRONT CAPEX (TO BE DEFERRED)	2024	2025
Cost 1	£ 1,000,000	
Cost 2		
Cost 3		
Total	**£ 1,000,000**	

Initial flexibility price assumptions

Availability Price (£/MW/h)	£5.00
Utilisation Price (£/MWh)	£10.00

Total capacity of availability procured each year (MW.h/y)	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Flexibility under Best view	1,500.0	1,700.0	1,800.0	2,000.0	2,200.0	2,400.0	2,600.0	2,800.0	3,000.0	3,200.0	3,400.0	3,600.0
Flexibility under Consumer Transformation	1,400.0	1,570.0	1,950.0	2,400.0	2,960.0	3,350.0	4,030.0	5,460.0	7,140.0	8,720.0	10,760.0	12,980.0
Flexibility under Falling Short	500.0	510.0	630.0	750.0	890.0	1,050.0	1,250.0	1,620.0	1,970.0	2,390.0	2,640.0	2,920.0
Flexibility under Leading the Way	1,800.0	2,310.0	2,680.0	3,110.0	3,590.0	4,280.0	5,440.0	6,950.0	8,810.0	10,750.0	12,950.0	15,180.0
Flexibility under System Transformation	1,200.0	1,340.0	1,500.0	1,680.0	1,870.0	2,160.0	2,380.0	2,680.0	3,000.0	3,300.0	4,650.0	5,400.0

Expected annual volume of utilisation dispatched (MWh/y)	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Flexibility under Best view	1,200.0	1,360.0	1,440.0	1,600.0	1,760.0	1,920.0	2,080.0	2,240.0	2,400.0	2,560.0	2,720.0	2,880.0
Flexibility under Consumer Transformation	1,120.0	1,256.0	1,560.0	1,920.0	2,368.0	2,368.0	3,224.0	4,368.0	5,712.0	6,976.0	8,608.0	10,384.0
Flexibility under Falling Short	400.0	408.0	504.0	600.0	712.0	840.0	1,000.0	1,296.0	1,576.0	1,912.0	2,112.0	2,336.0
Flexibility under Leading the Way	1,440.0	1,848.0	2,144.0	2,488.0	2,872.0	3,424.0	4,352.0	5,560.0	7,048.0	8,600.0	10,360.0	12,144.0
Flexibility under System Transformation	960.0	1,072.0	1,200.0	1,344.0	1,496.0	1,728.0	1,904.0	2,144.0	2,400.0	2,640.0	3,720.0	4,320.0

According to the input data, no flexibility is required after 2035.

Results validation against CEM tool: Cumulative benefit by strategy

- The top table is a screenshot of the Excel-based CEM tool, reporting the **total cumulative benefits** (i.e. NPV) of each 'deferral' strategy.
- These results are compared to the NPV calculated by the re-platformed automated tool in Python. An additional row shows the weighted average NPV of each strategy.
- From the comparison, it is clear that the results in the two tables match.

CEM tool

		Cumulative benefit of deferral (excluding benefit from further deferral)	Baseline	1 Defer by 1 year(s) to 2025	2 Defer by 2 year(s) to 2026	3 Defer by 3 year(s) to 2027	4 Defer by 4 year(s) to 2028	5 Defer by 5 year(s) to 2029	6 Defer by 6 year(s) to 2030	7 Defer by 7 year(s) to 2031	8 Defer by 8 year(s) to 2032	9 Defer by 9 year(s) to 2033	10 Defer by 10 year(s) to 2034
Config	*1*	Flexibility under Best view	*£0*	£16,096	£28,687	£39,395	£46,967	£51,596	£53,467	£52,753	£49,621	£44,226	£36,718
Config	*2*	Flexibility under Consumer Transformation	*£0*	£17,604	£32,090	£40,685	£42,807	£37,427	£30,257	£11,937	-£22,864	-£75,920	-£144,886
Config	*3*	Flexibility under Falling Short	*£0*	£31,178	£61,116	£88,312	£112,913	£134,796	£153,856	£169,764	£180,680	£187,143	£188,654
Config	*4*	Flexibility under Leading the Way	*£0*	£11,572	£15,270	£13,577	£6,027	-£7,650	-£29,719	-£65,399	-£117,938	-£190,221	-£281,788
Config	*5*	Flexibility under System Transformation	*£0*	£20,621	£38,460	£53,396	£65,327	£74,302	£79,229	£81,224	£79,520	£74,125	£65,504

Re-platformed CEM tool

	A	B	C	D	E	F	G	H	I	J	K	L
1		Strategy_0	Strategy_1	Strategy_2	Strategy_3	Strategy_4	Strategy_5	Strategy_6	Strategy_7	Strategy_8	Strategy_9	Strategy_10
2	Best View	0.000	16.096	28.687	39.395	46.967	51.596	53.467	52.753	49.621	44.226	36.718
3	Consumer Transformation	0.000	17.604	32.090	40.685	42.807	37.427	30.257	11.937	-22.864	-75.920	-144.886
4	Falling short	0.000	31.178	61.116	88.312	112.913	134.796	153.856	169.764	180.680	187.143	188.654
5	Leading the Way	0.000	11.572	15.270	13.577	6.027	-7.650	-29.719	-65.399	-117.938	-190.221	-281.788
6	System Transformation	0.000	20.621	38.460	53.395	65.327	74.302	79.229	81.224	79.520	74.125	65.504
7	Weighted NPV	0.000	19.414	35.125	47.073	54.808	58.094	57.418	50.056	33.804	7.871	-27.160
8												
9												
10												

Total NPV | Marginal_NPV | Residual_NPV | Overall_NPV | Option value | NPV | NPV_LWR | Net_risk_NP ...

Scenario	Highest NPV
Best View	Strategy 6
Consumer transformation	Strategy 4
Falling short	Strategy 10
Leading the way	Strategy 2
System transformation	Strategy 7

Results validation against CEM tool: Marginal benefit by strategy

- A similar comparison of results is performed over the **marginal benefits** of each 'deferral' strategy, calculated as the additional benefits from deferring reinforcement by an additional year.

CEM tool

	Marginal benefit of deferral (excluding benefit from further deferral)	Baseline	1 Defer from 2024 to 2025	2 Defer from 2025 to 2026	3 Defer from 2026 to 2027	4 Defer from 2027 to 2028	5 Defer from 2028 to 2029	6 Defer from 2029 to 2030	7 Defer from 2030 to 2031	8 Defer from 2031 to 2032	9 Defer from 2032 to 2033	10 Defer from 2033 to 2034
Config *1*	Flexibility under Best view	*£0*	£16,096	£12,591	£10,708	£7,572	£4,629	£1,871	-£714	-£3,132	-£5,394	-£7,508
Config *2*	Flexibility under Consumer Transformation	*£0*	£17,604	£14,486	£8,594	£2,122	-£5,380	-£7,170	-£18,320	-£34,800	-£53,056	-£68,966
Config *3*	Flexibility under Falling Short	*£0*	£31,178	£29,939	£27,196	£24,601	£21,883	£19,061	£15,908	£10,916	£6,464	£1,510
Config *4*	Flexibility under Leading the Way	*£0*	£11,572	£3,698	-£1,693	-£7,550	-£13,678	-£22,069	-£35,680	-£52,539	-£72,282	-£91,567
Config *5*	Flexibility under System Transformation	*£0*	£20,621	£17,839	£14,936	£11,931	£8,975	£4,927	£1,995	-£1,704	-£5,394	-£8,621

Re-platformed CEM tool

	A	B	C	D	E	F	G	H	I	J	K	L
1		**Strategy_0**	**Strategy_1**	**Strategy_2**	**Strategy_3**	**Strategy_4**	**Strategy_5**	**Strategy_6**	**Strategy_7**	**Strategy_8**	**Strategy_9**	**Strategy_10**
2	**Best View**		16.096	12.591	10.708	7.572	4.629	1.871	-0.714	-3.132	-5.394	-7.508
3	**Consumer Transformation**		17.604	14.486	8.594	2.122	-5.380	-7.170	-18.320	-34.800	-53.056	-68.966
4	**Falling short**		31.178	29.939	27.196	24.601	21.883	19.061	15.908	10.916	6.464	1.510
5	**Leading the Way**		11.572	3.698	-1.693	-7.550	-13.678	-22.069	-35.680	-52.539	-72.282	-91.567
6	**System Transformation**		20.621	17.839	14.936	11.931	8.975	4.927	1.995	-1.704	-5.394	-8.621
8												
9												
10												
11												
12												
13												

Total NPV | Marginal_NPV | Residual_NPV | Overall_NPV | Option value | NPV | NPV_LWR | Net_risk_NPV_LWR | Losses NPV | L

Results validation against CEM tool: Residual benefit by strategy

- A similar comparison of results is performed over the **residual benefits** of each 'deferral' strategy.

CEM tool

		Residual benefit after initial deferral	Baseline	1 Defer by 1 year(s) to 2025	2 Defer by 2 year(s) to 2026	3 Defer by 3 year(s) to 2027	4 Defer by 4 year(s) to 2028	5 Defer by 5 year(s) to 2029	6 Defer by 6 year(s) to 2030	7 Defer by 7 year(s) to 2031	8 Defer by 8 year(s) to 2032	9 Defer by 9 year(s) to 2033	10 Defer by 10 year(s) to 2034
Config	*1*	Flexibility under Best view	*£0*	£37,371	£24,780	£14,071	£6,500	£1,871	£0	£0	£0	£0	£0
Config	*2*	Flexibility under Consumer Transformation	*£0*	£25,203	£10,717	£2,122	£0	£0	£0	£0	£0	£0	£0
Config	*3*	Flexibility under Falling Short	*£0*	£157,476	£127,537	£100,341	£75,741	£53,858	£34,797	£18,890	£7,974	£1,510	£0
Config	*4*	Flexibility under Leading the Way	*£0*	£3,698	£0	£0	£0	£0	£0	£0	£0	£0	£0
Config	*5*	Flexibility under System Transformation	*£0*	£60,603	£42,764	£27,828	£15,897	£6,922	£1,995	£0	£0	£0	£0

Re-platformed CEM tool

	A	B	C	D	E	F	G	H	I	J	K	L
1		**Strategy_0**	**Strategy_1**	**Strategy_2**	**Strategy_3**	**Strategy_4**	**Strategy_5**	**Strategy_6**	**Strategy_7**	**Strategy_8**	**Strategy_9**	**Strategy_10**
2	**Best View**		37.371	24.780	14.071	6.500	1.871	0.000	0.000	0.000	0.000	0.000
3	**Consumer Transformation**		25.203	10.717	2.122	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	**Falling short**		157.476	127.537	100.341	75.741	53.858	34.797	18.890	7.974	1.510	0.000
5	**Leading the Way**		3.698	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	**System Transformation**		60.603	42.764	27.828	15.897	6.922	1.995	0.000	0.000	0.000	0.000
8												
9												
10												
11												
12												
13												

Total NPV | Marginal_NPV | **Residual_NPV** | Overall_NPV | NPV | NPV_LWR | Net_risk_NPV_LWR | Losses NPV | Losses_ ...

Results validation against CEM tool: Overall benefit by strategy

- A similar comparison of results is performed over the **overall benefits** of each 'deferral' strategy.

CEM tool

			Baseline	1	2	3	4	5	6	7	8	9	10
		Overall benefit of strategy vs baseline (including benefit of further deferral and the multi-year discount)		Defer by 1 year(s) to 2025	Defer by 2 year(s) to 2026	Defer by 3 year(s) to 2027	Defer by 4 year(s) to 2028	Defer by 5 year(s) to 2029	Defer by 6 year(s) to 2030	Defer by 7 year(s) to 2031	Defer by 8 year(s) to 2032	Defer by 9 year(s) to 2033	Defer by 10 year(s) to 2034
Config	*1*	Flexibility under Best view	*£0*	£53,467	£53,467	£53,467	£53,467	£53,467	£53,467	£52,753	£49,621	£44,226	£36,718
Config	*2*	Flexibility under Consumer Transformation	*£0*	£42,807	£42,807	£42,807	£42,807	£37,427	£30,257	£11,937	-£22,864	-£75,920	-£144,886
Config	*3*	Flexibility under Falling Short	*£0*	£188,654	£188,654	£188,654	£188,654	£188,654	£188,654	£188,654	£188,654	£188,654	£188,654
Config	*4*	Flexibility under Leading the Way	*£0*	£15,270	£15,270	£13,577	£6,027	-£7,650	-£29,719	-£65,399	-£117,938	-£190,221	-£281,788
Config	*5*	Flexibility under System Transformation	*£0*	£81,224	£81,224	£81,224	£81,224	£81,224	£81,224	£81,224	£79,520	£74,125	£65,504

Re-platformed CEM tool

	A	B	C	D	E	F	G	H	I	J	K	L
1		Strategy_0	Strategy_1	Strategy_2	Strategy_3	Strategy_4	Strategy_5	Strategy_6	Strategy_7	Strategy_8	Strategy_9	Strategy_10
2	Best View		53.467	53.467	53.467	53.467	53.467	53.467	52.753	49.621	44.226	36.718
3	Consumer Transformation		42.807	42.807	42.807	42.807	37.427	30.257	11.937	-22.864	-75.920	-144.886
4	Falling short		188.654	188.654	188.654	188.654	188.654	188.654	188.654	188.654	188.654	188.654
5	Leading the Way		15.270	15.270	13.577	6.027	-7.650	-29.719	-65.399	-117.938	-190.221	-281.788
6	System Transformation		81.224	81.224	81.224	81.224	81.224	81.224	81.224	79.520	74.125	65.504
8												
9												
10												
11												

Total NPV | Marginal_NPV | Residual_NPV | Overall_NPV | Option value | NPV | NPV_LWR | Net_risk_NP

Results validation against CEM tool: Option value

- A function to calculate the option value (i.e. 'uncertainty value') is embedded in the Python-based tool. This is stored in the corresponding Excel tab for all strategy/scenario combinations, rather than manually selecting the scenario to visualise in cell D4 in the 'Additional inputs and control' tab in the original Excel CEM tool.

CEM tool

'Falling short' scenario

Option value: NPV at predetermined flexibility price

Option value of Flexibility @ £5/MVA

	Intrinsic benefit	Uncertainty benefit	Total option benefit
Flexibility	£188,654	-£112,369	£76,284

Re-platformed CEM tool

	A	B	C	D	E	F	G	H	I	J	K	L
1		Strategy_0	Strategy_1	Strategy_2	Strategy_3	Strategy_4	Strategy_5	Strategy_6	Strategy_7	Strategy_8	Strategy_9	Strategy_10
2	Best View		22.818	22.818	22.818	22.818	22.818	22.818	23.531	26.664	32.058	39.566
3	Consumer Transformation		33.477	33.477	33.477	33.477	38.857	46.028	64.348	99.148	152.204	221.170
4	Falling short		-112.369	-112.369	-112.369	-112.369	-112.369	-112.369	-112.369	-112.369	-112.369	-112.369
5	Leading the Way		61.014	61.014	62.707	70.257	83.935	106.004	141.684	194.223	266.505	358.072
6	System Transformation		-4.939	-4.939	-4.939	-4.939	-4.939	-4.939	-4.939	-3.235	2.159	10.780
8												
9												
10												
11												
12												

Total NPV | Marginal_NPV | Residual_NPV | Overall_NPV | Option value | NPV | NPV_LWR | Net_risk_NPV_LWR | Losses NPV | Loss

Results validation against CEM tool: Ceiling price
Input data

- Finally, for the purpose of results validation, the re-platformed ROCBA tool is used to calculate, ***for all strategy/scenario combinations***, the flexibility services ceiling price for a *three-year flexibility initial contract* (based on a 'Ramping' contract shape*).
- The screenshot below displays the input data required to run the macro for the ceiling price calculation in the Excel CEM tool. In this example, the availability/capacity price is incrementally changed as well as the utilisation price such that the ratio between the availability and utilisation prices remains constant (i.e. 'lock ratio' feature).

Input data in CEM Excel-based tool

Calculate Ceiling Price

Last run @	29/01/2025 15:42
Last run duration (seconds):	104
Increments from last run:	85
New estimated run time (seconds):	104

Price varied for ceiling price goal seek	Availability (lock ratio)
Goal seek increment (£/MW/h or £/MWh)	1
Maximum price from Simple Ceiling Price (£/MW/h or £/MWh)	£ 26
Maximum price for goal seek (£/MW/h or £/MWh)	£ 85
Initial availability price (£/MWh)	£ 5
Initial utilisation price (£/MWh)	£ 10

Select strategy: Flexibility

* See ENA's 'Common Evaluation Methodology and Tool' for more details.

Results validation against CEM tool: Ceiling price Output

CEM tool

Maximum justified availability price and annual cost of a 3 year flexibility contract

	Configuration	Ceiling availability price (£/MW/h)	Ceiling utilisation price (£/MWh)	Average annual contract cost ceiling (£)
1	Flexibility under Best view	7	14	£30,333
2	Flexibility under Consumer Transformation	7	14	£29,848
3	Flexibility under Falling Short	23	46	£32,691
4	Flexibility under Leading the Way	5	10	£29,423
5	Flexibility under System Transformation	9	18	£31,512

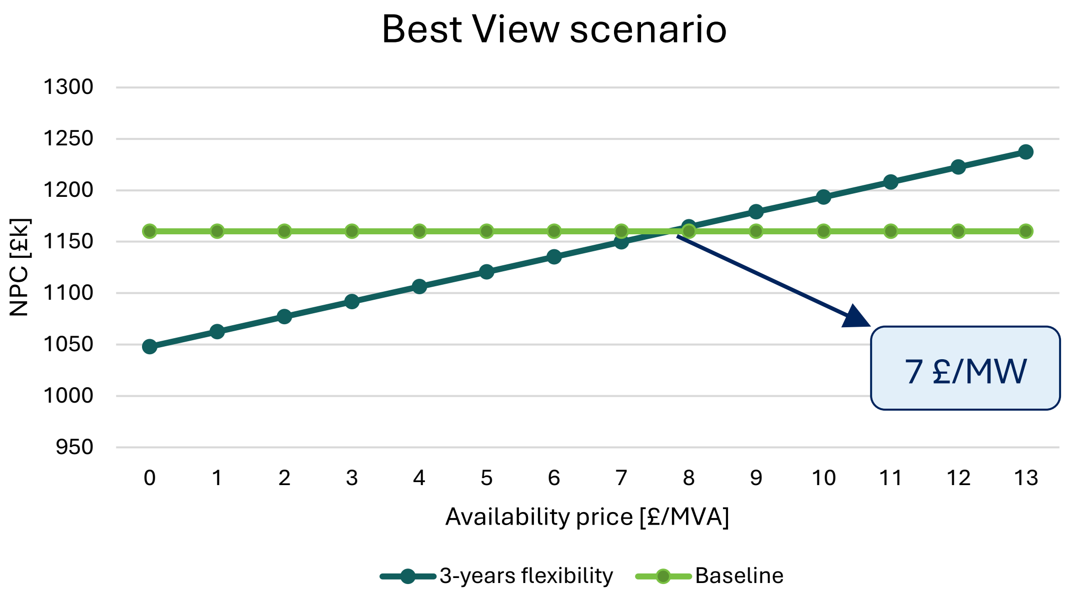
Re-platformed CEM tool

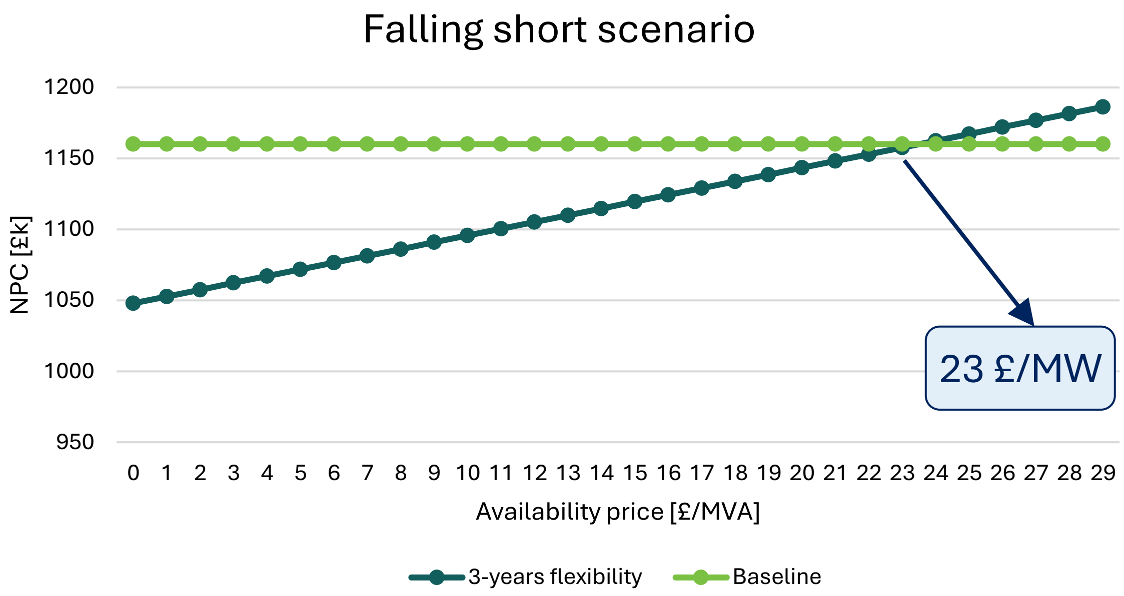
	A	B	C	D
1		Ceiling price k£/MVA/year	Ceiling price k£/MWh/year	Average annual contract cost ceiling (k£
2	Strategy_1 under Best View scenario	0.008	0.016	31.200
3	Strategy_1 under Consumer Transformation scenario	0.009	0.018	32.760
4	Strategy_1 under Falling short scenario	0.025	0.05	32.500
5	Strategy_1 under Leading the Way scenario	0.007	0.014	32.760
6	Strategy_1 under System Transformation scenario	0.01	0.02	31.200
7	Strategy_2 under Best View scenario	0.008	0.016	33.280
8	Strategy_2 under Consumer Transformation scenario	0.008	0.016	30.888
9	Strategy_2 under Falling short scenario	0.025	0.05	32.825
10	Strategy_2 under Leading the Way scenario	0.006	0.012	32.058
11	Strategy_2 under System Transformation scenario	0.01	0.02	33.020
12	Strategy_3 under Best View scenario	0.007	0.014	30.333
13	Strategy_3 under Consumer Transformation scenario	0.007	0.014	29.848
14	Strategy_3 under Falling short scenario	0.023	0.046	32.691
15	Strategy_3 under Leading the Way scenario	0.005	0.01	29.423
16	Strategy_3 under System Transformation scenario	0.009	0.018	31.512
17	Strategy_4 under Best View scenario	0.007	0.014	31.850
18	Strategy_4 under Consumer Transformation scenario	0.007	0.014	33.306
19	Strategy_4 under Falling short scenario	0.021	0.042	32.624
20	Strategy_4 under Leading the Way scenario	0.005	0.01	32.175
21	Strategy_4 under System Transformation scenario	0.009	0.018	33.462

- The top table is a screenshot of the 'ceiling price' tab in the Excel-based CEM tool, whereas the bottom table shows the ceiling price results from the Python-based tool.
- While the screenshot only shows the results for the first 4 strategies, the **results are generated for all 10 strategies** assessed in this example **for each scenario**.
- From the comparison, it is evident that the calculated ceiling prices and the average annual contract cost ceiling are the same.

Results validation against CEM tool: Ceiling price Output (three-year contract)

- Among the many outputs of the re-platformed tool, the results of the sensitivity analysis upon which the ceiling price calculation is based are also stored. This allows us to have better visibility of the calculations performed.
- Taking the 'Best View' and 'Falling short' scenarios as examples, the graphs display the results of the sensitivity analysis of NPC with respect to flexibility service availability/utilisation price. This allows us to identify the 'point' at which the NPC of the flexibility strategy equals and then exceeds the net present costs (NPC) of the baseline strategy.





Document overview

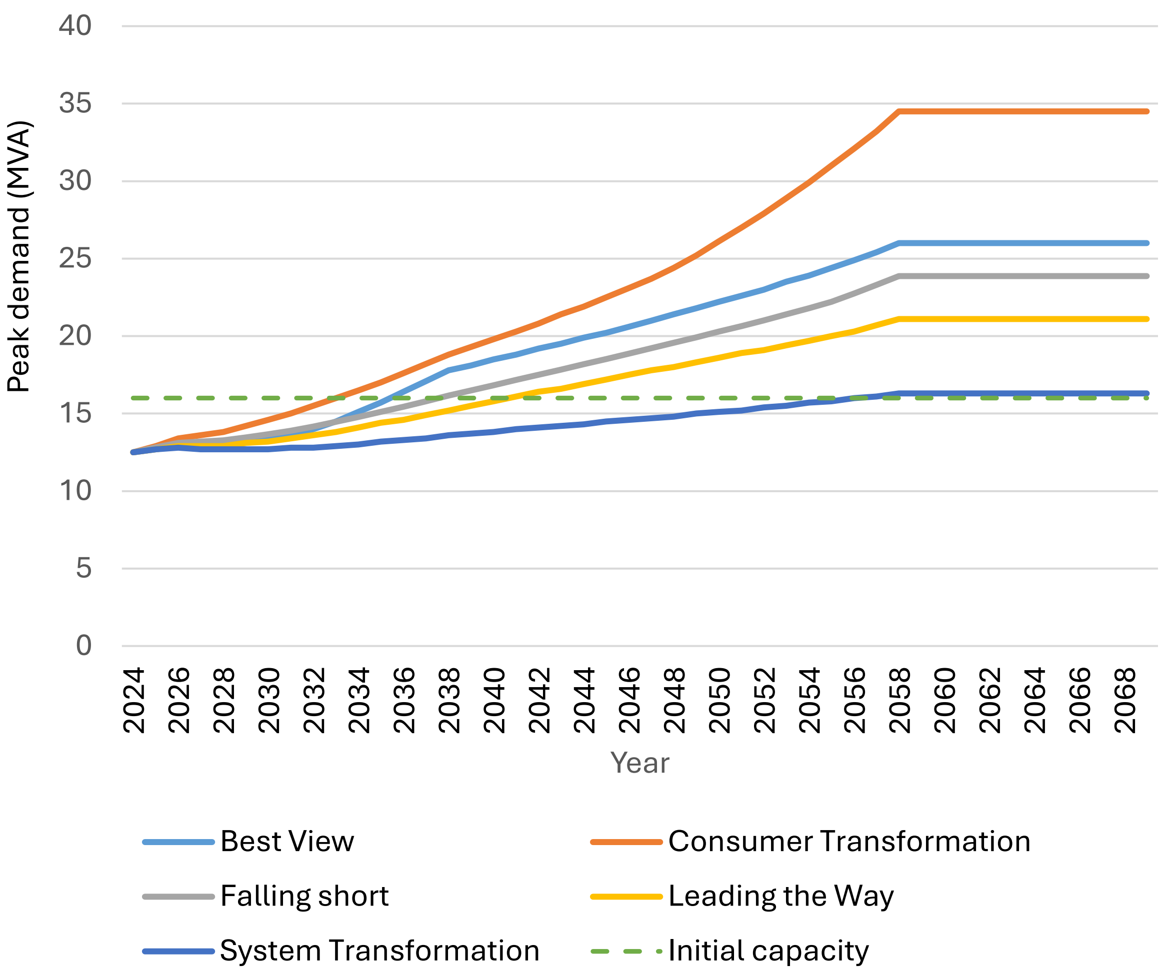
- Enhancing the Real Options CBA (ROCBA) tool – Executive summary
- Flexibility evaluation tools
  - A real options approach
  - ROCBA tool
  - CEM tool
- Enhancing the ROCBA tool
  - Results validation against CEM tool
  - Re-platformed CEM tool additional functionalities
  - Example using the enhanced ROCBA tool

Example: Re-platformed CEM tool additional functionalities

- After demonstrating that the results of the Python-based and Excel-based CEM tool match, we also show the full range of capabilities of the new enhanced Python-based tool.

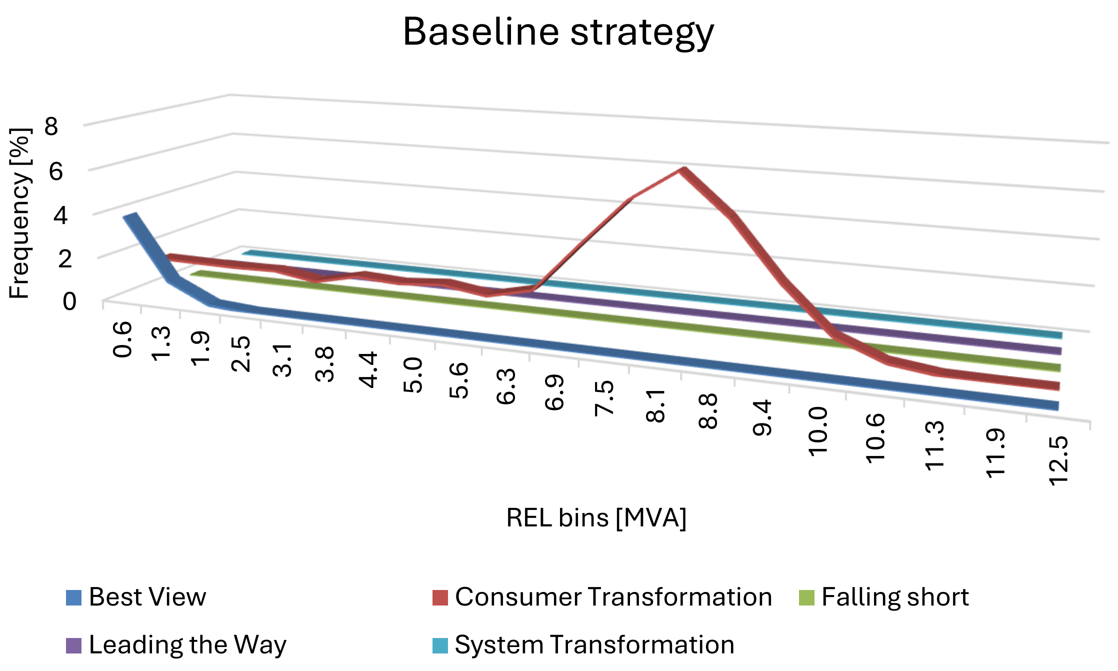
- Considering the same inputs as in the previous example, we now model the variations around peak demand growth of each macro-scenario using 100 micro-scenarios, instead of running a single simulation.

- To illustrate how the tool works and what kind of output information can be visualised, assessed and analysed, for the purpose of this example, we assume that:
    - The peak demand growth of the selected primary substation follows the trend in the graph on the right.
    - The initial capacity of the substation is 16 MVA and the reinforcement required is 10 MVA (to be able to meet the projected maximum demand under the 'Best View' scenario).



Example: Probability distribution of network risk

- With the tool, it is possible to assess the **probabilistic distribution** of **residual excess load (REL)** and **quantify** the **network physical risks of each strategy** across a set of scenarios. The REL, deployed as a measure of network risk, is evaluated as excess MVA (i.e. demand above available network capacity) across all years in the planning horizon.



- From the graph, we can see that the investment strategy of reinforcing the network based on the demand growth projection of the 'Best view' scenario can cope well with the variations associated with most scenarios.
- The volatility associated with the 'Best view' can potentially cause some instances in which capacity may not be sufficient. However, the residual excess load is contained and limited below 4%. On the other hand, the demand growth that could be experienced under the 'Consumer transformation' scenario, can lead to greater network risk with higher frequency.

Each bin represents the intervals/range of values into which the entire range of the data is split into. All the data points that fall within a particular bin are then counted and aggregated to determine the frequency. Frequency is defined as the number of instances in which the REL is above the value of each bin and lower than value of successive one.

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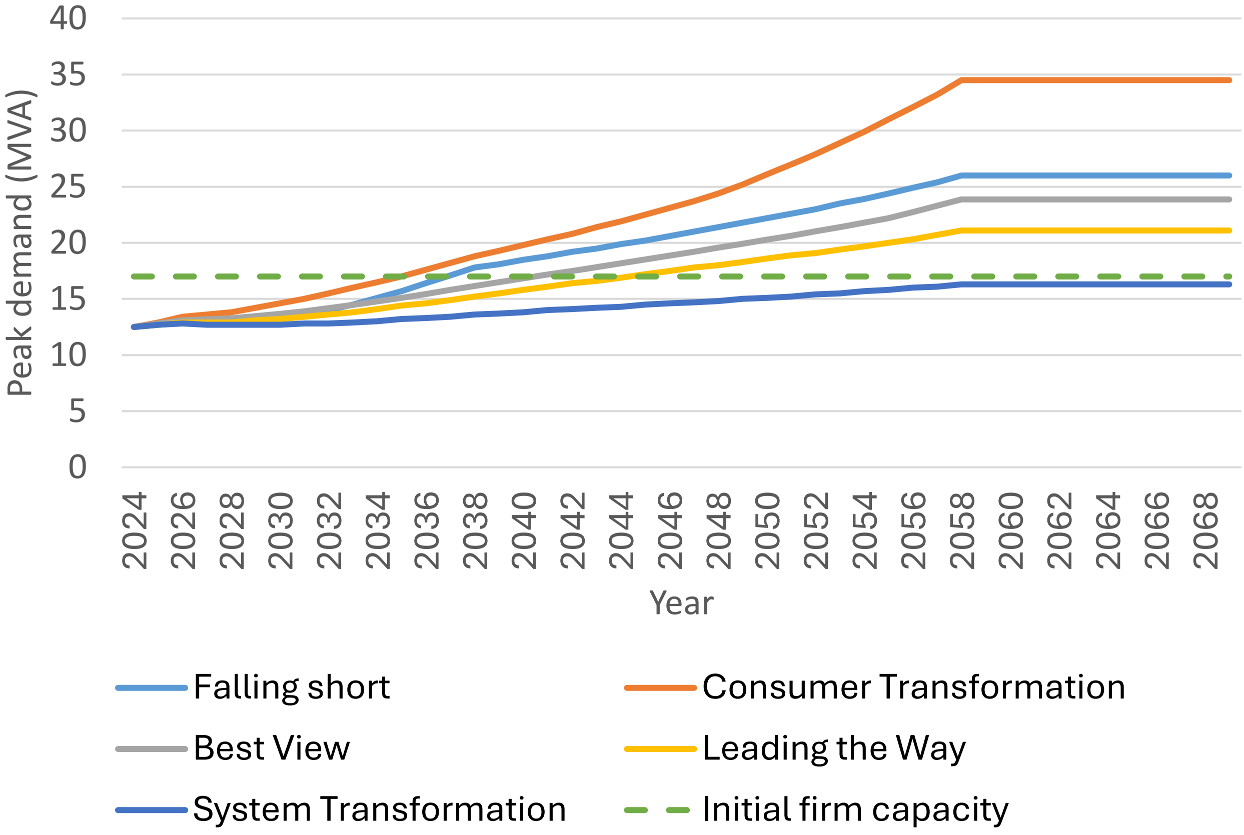
Load growth-triggered intervention activation

- After demonstrating that the results of the Python-based and Excel-based CEM tool match, we now show the full range of capabilities of the new enhanced Python-based ROCBA tool.
- To illustrate how the tool works and what kind of output information can be visualised, assessed and analysed, we evaluate an investment decision using five scenarios for peak demand growth and comparing three different investment strategies with a 'baseline' strategy. Each strategy is a combination of flexibility services ('Flex') and network asset reinforcement/replacement ('Reinf') intervention types.
- For the purpose of this example, the selected site corresponds to a primary substation.
- A summary of the strategies under analysis is reported in the table in the following slide. In the case of traditional network reinforcement intervention, the additional capacity is reported in brackets.
- With respect to flexibility service procurement, only availability payments are made, and the amount of flexible capacity required is automatically calculated by the tool in accordance with peak demand growth and asset loading threshold.
- In this example, availability payments are set to £200/MW.

Example: Tool inputs

- The peak demand growth of the selected primary substation follows the trend in the graph below, and its volatility is set to 0.3%. Further 'shorter-term' uncertainty is accounted for through a weather-related volatility of 2.46%.



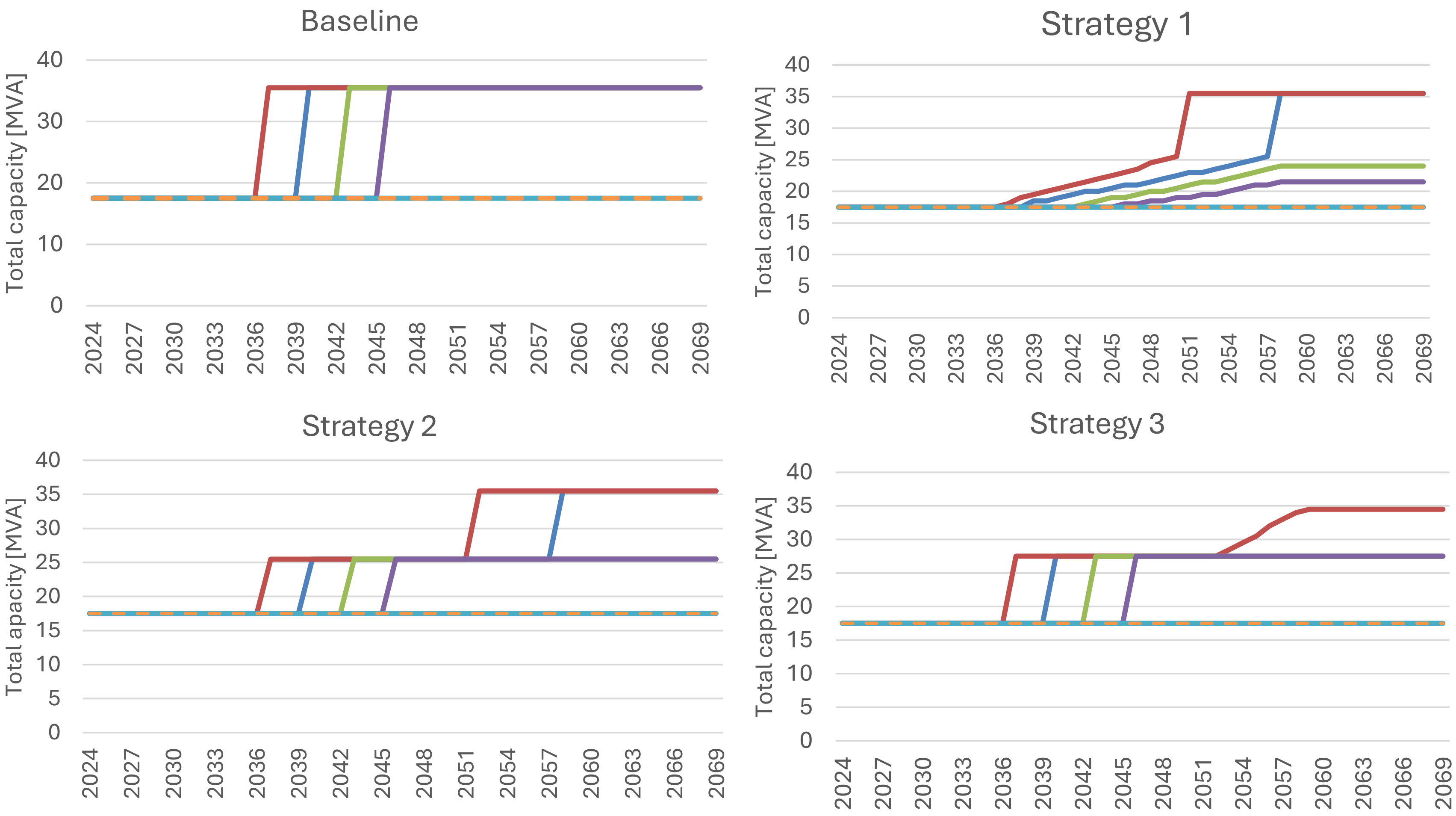
- In this illustrative example, costs associated with losses are disregarded.
- All scenarios are assumed equally probable (20%).

Strategy	Intervention 1	Intervention 2	Intervention 3
Baseline	Reinf (+18 MVA)	-	-
1	Flex	Reinf (+18 MVA)	-
2	Reinf (+8 MVA)	Reinf (+10 MVA)	-
3	Reinf (+10 MVA)	Flex	Reinf (+8 MVA)

Example: New available capacity by scenario

- The tool allows us to analyse network capacity across the years, depending on **which intervention** and **when this is activated** in each scenario for each strategy. **Because of different expected evolution of demand growth, network investments are triggered at different stages**.
- Under certain scenarios, some interventions are not needed, e.g. for Strategies 2 and 3.
- These graphs are for the zero-volatility Monte Carlo simulation.

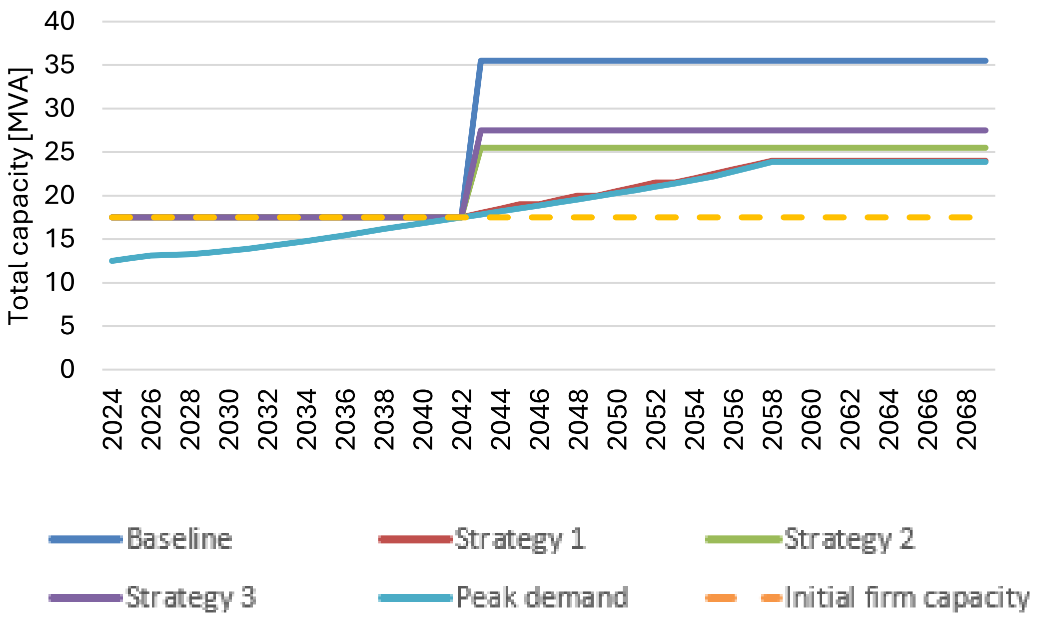
Strategy	Intervention 1	Intervention 2	Intervention 3
Baseline	Reinf (+18 MVA)	-	-
1	Flex	Reinf (+18 MVA)	-
2	Reinf (+8 MVA)	Reinf (+10 MVA)	-
3	Reinf (+10 MVA)	Flex	Reinf (+8 MVA)



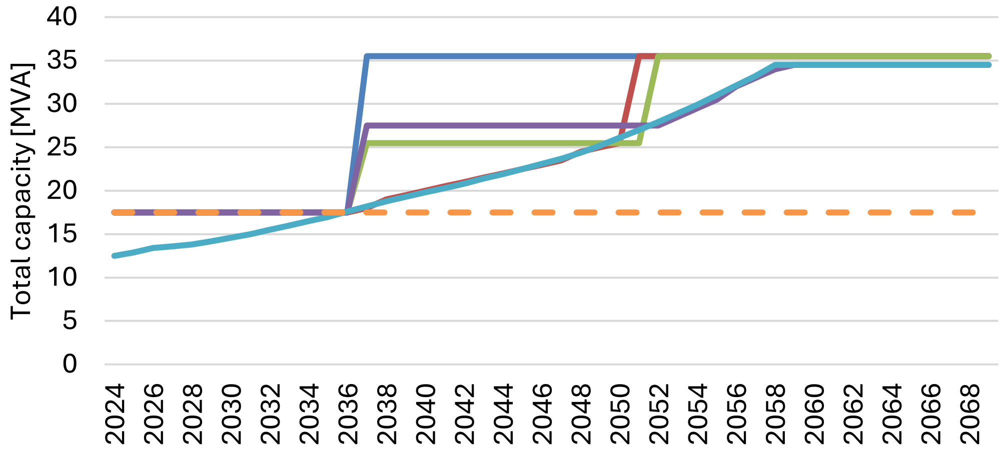
Example: New available capacity under each strategy

- The tool also allows us to understand how a specific strategy unfolds under different scenarios.
- Depending on the demand growth evolution, with a specific strategy, certain interventions may or may not be triggered.

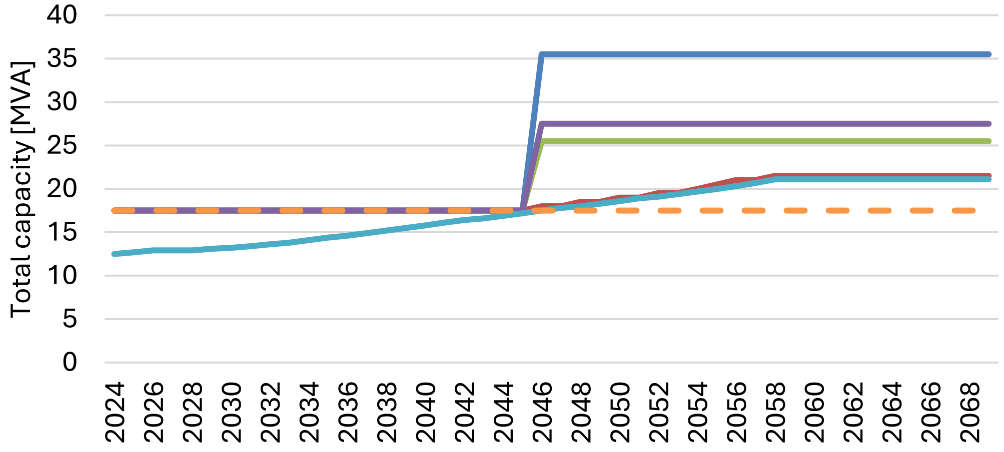
Best View scenario



Consumer Transformation scenario

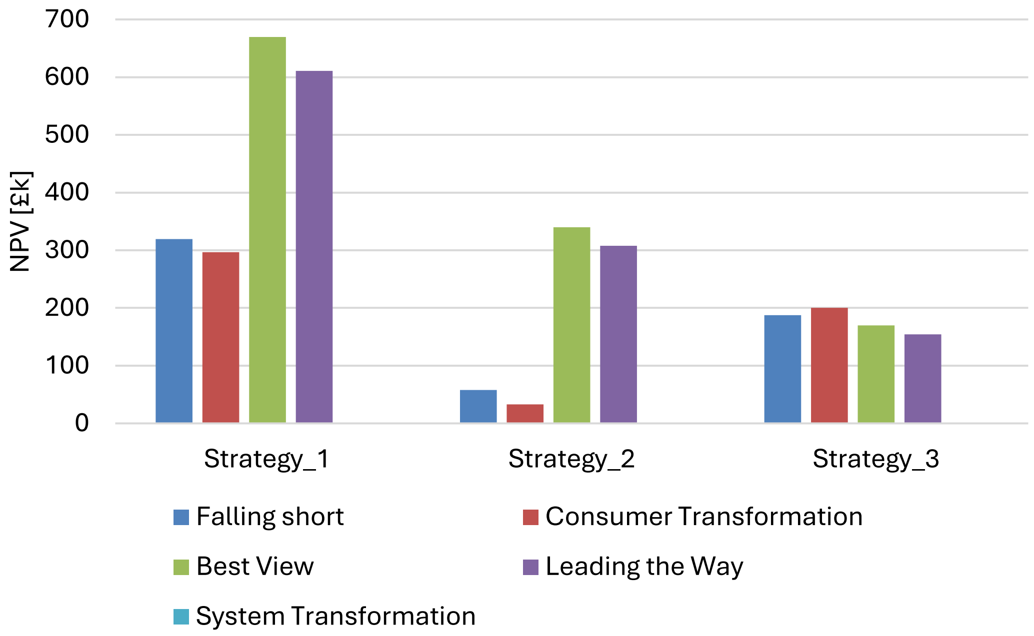


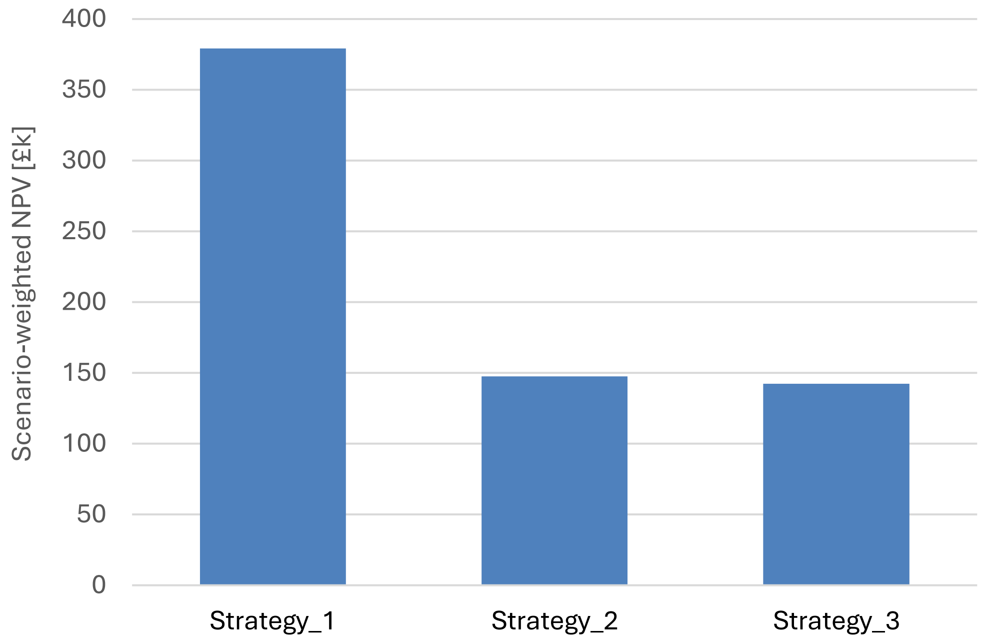
Leading the Way scenario



Example: Scenario-weighted NPV analysis

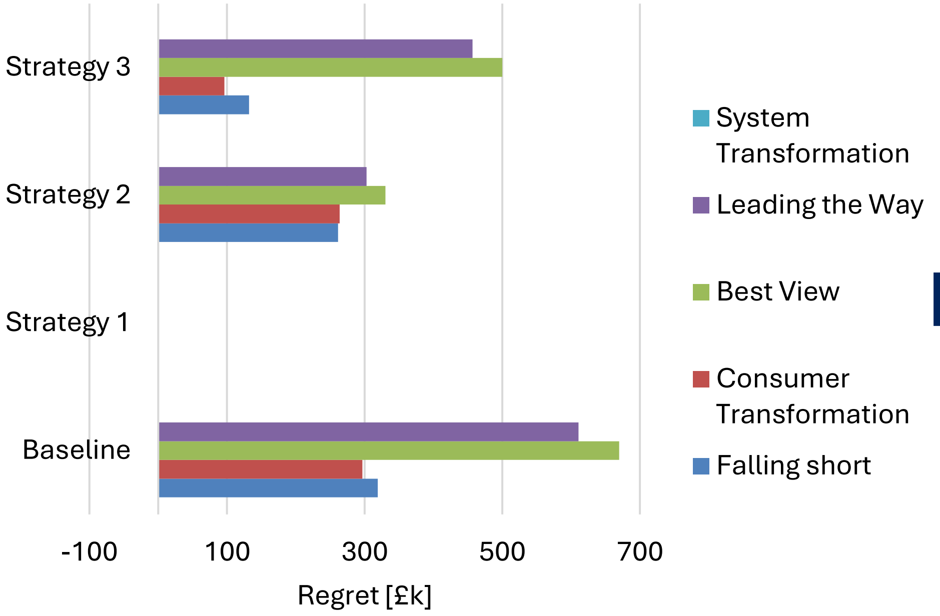
- The tool enables us to perform an NPV analysis, by comparing the net present costs (NPC) of the baseline with the NPC of all other strategies in each scenario.
- Relative to the Baseline strategy, all the other three strategies have lower costs in all scenarios, i.e. positive NPV. When **combining the outcomes across all scenarios** through a weighted-average NPV, Strategy 1 is the best option **from a financial point of view**.

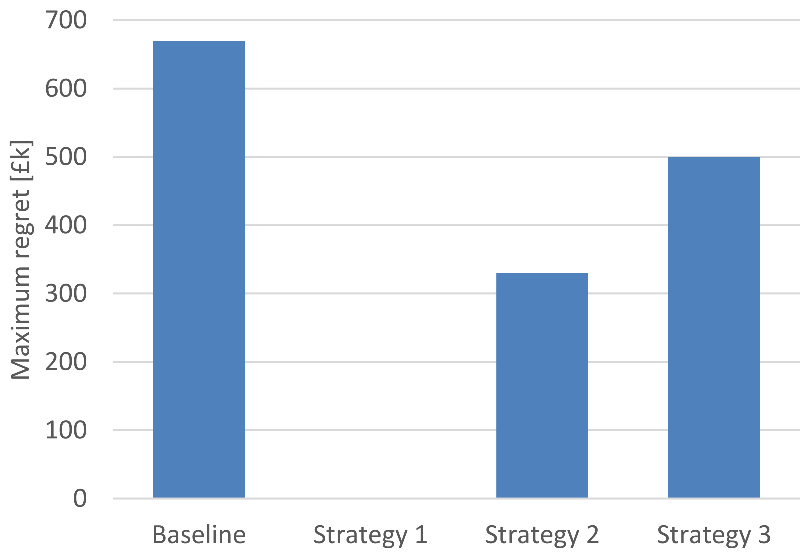




Example: Least-worst regret (LWR) analysis

- The selection of Strategy 1 as the preferred option, is further demonstrated through a **least-worst regret analysis** based on the NPC of each strategy in absolute terms.
- As Strategy 1 shows the lowest NPC (i.e. highest NPV) in *all* scenarios, the financial regret is calculated with respect to Strategy 1's NPC. Then all the strategies can be ranked from a **financial risk point of view**.
- As a result, the Baseline strategy shows the highest maximum regret as it involves the biggest reinforcement investment without any flexibility deferral/gradual network interventions as proposed in the other strategies.
- The tool allows the **financial risks of each strategy to be quantified** across a set of scenarios.

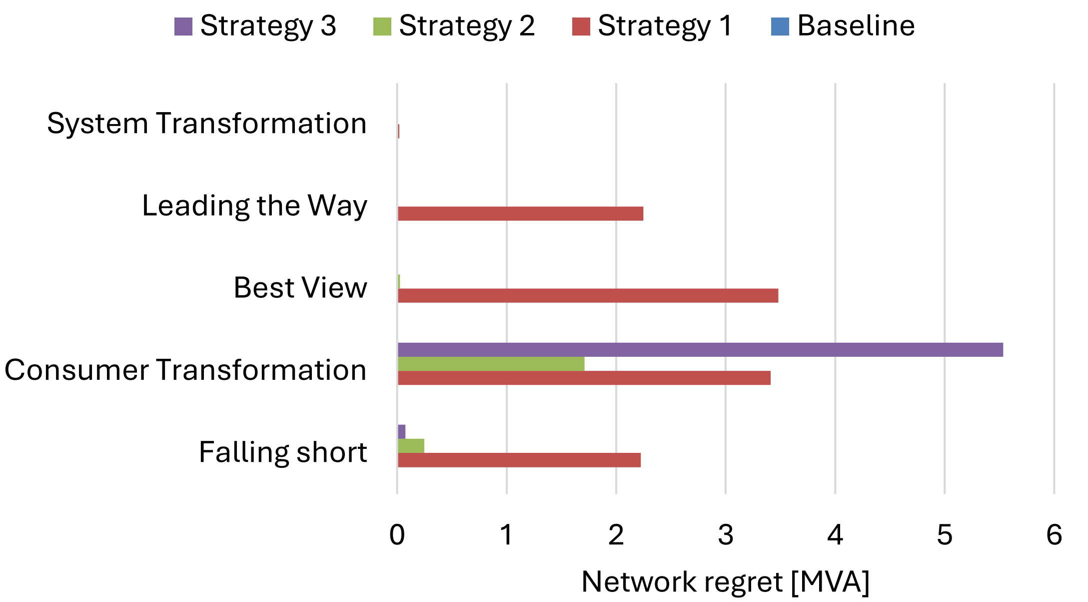


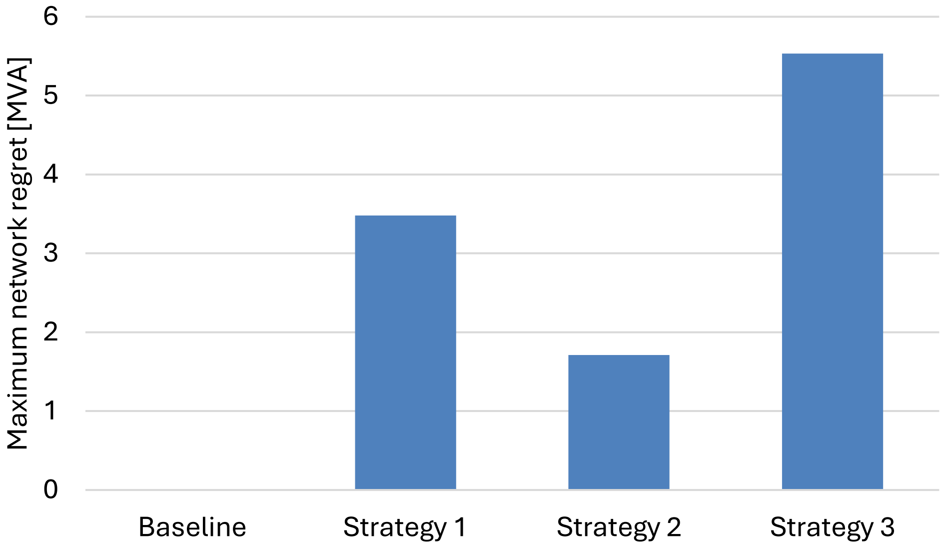


#	Strategy
1	Strategy 1
2	Strategy 2
3	Strategy 3
4	Baseline

Example: LWR analysis of physical network risk

- When adopting a **physical network risk perspective,** the Baseline strategy, which appeared as the 'worst' option from a financial perspective, is in fact the least risky one.
- With a single large network reinforcement investment, this strategy better deals with peak demand volatility, and it is therefore less sensitive compared to other strategies, particularly strategy 1 given the uncertainty of flexibility procurement.
- The tool also allows us to **quantify** the **network physical risks of each strategy** across a set of scenarios.

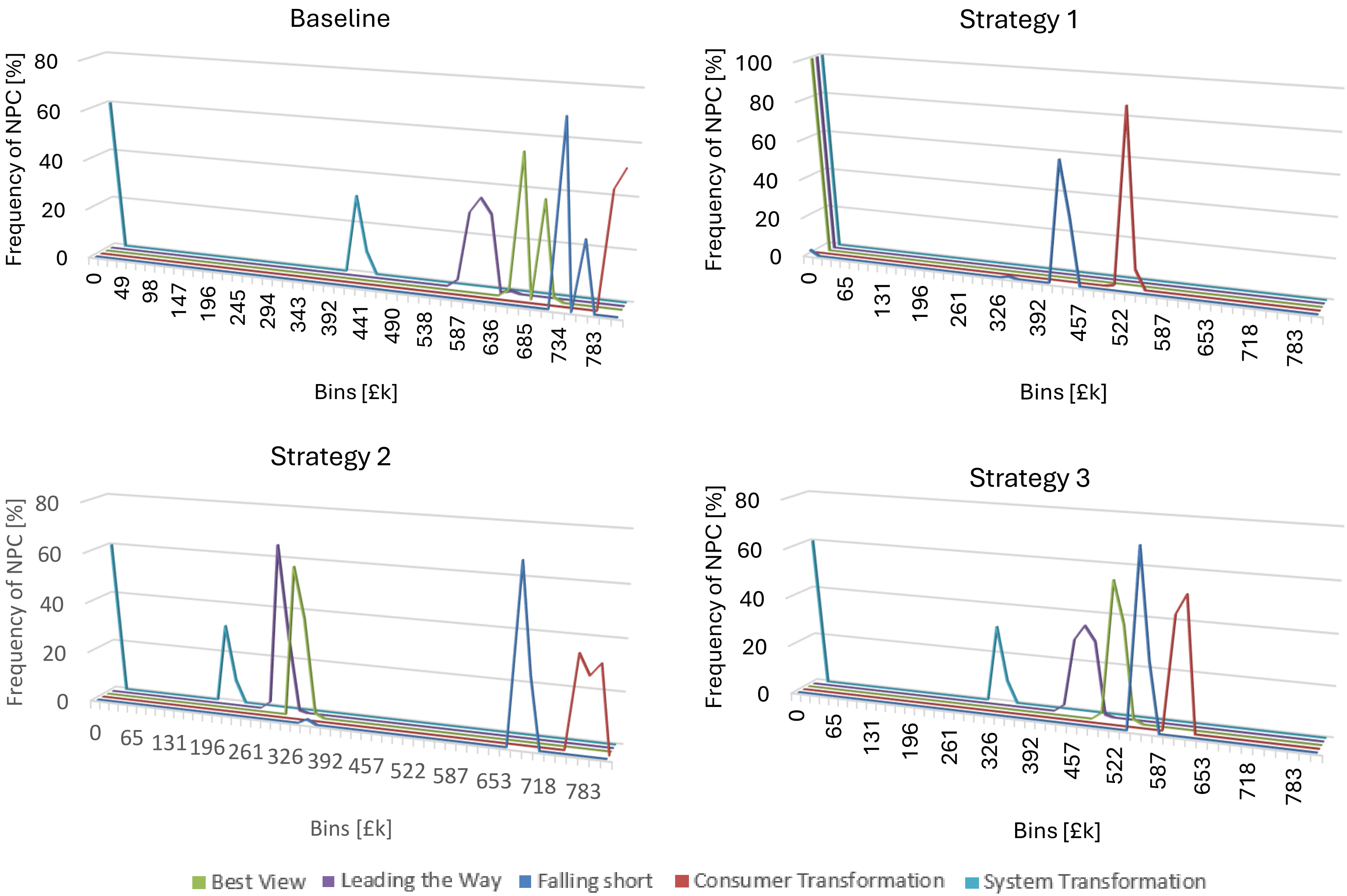




*Network risk evaluated as MVA excess (demand above available network capacity) across all years in the planning horizon (averaged across Monte Carlo simulations), i.e. residual excess load.

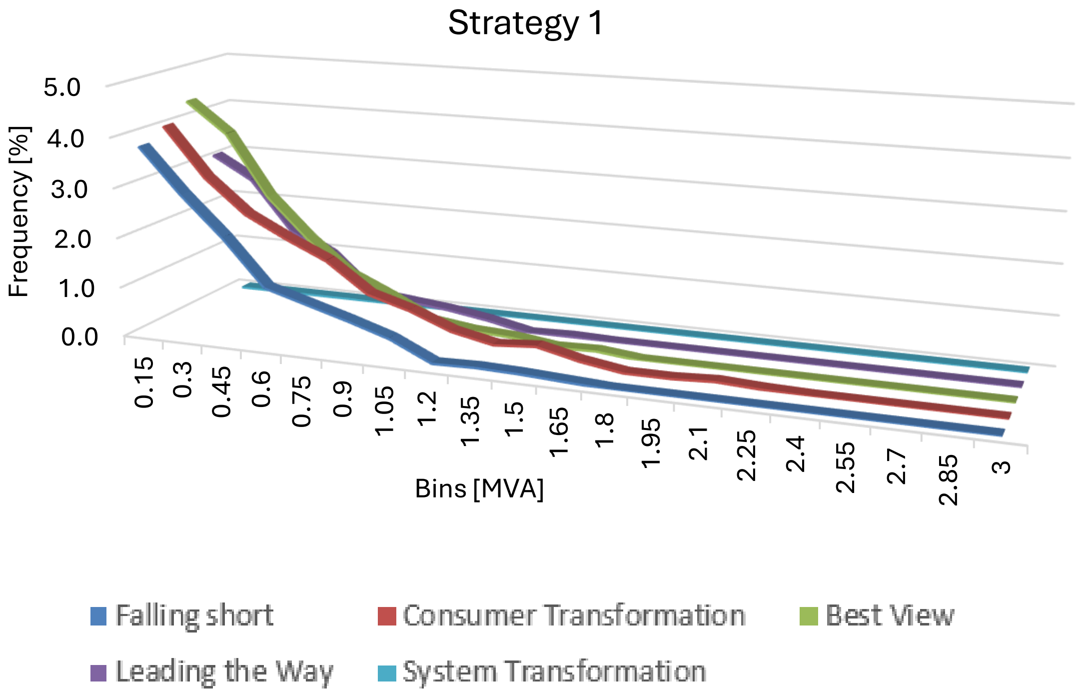
Example: Distribution of costs and network risk (1/3)

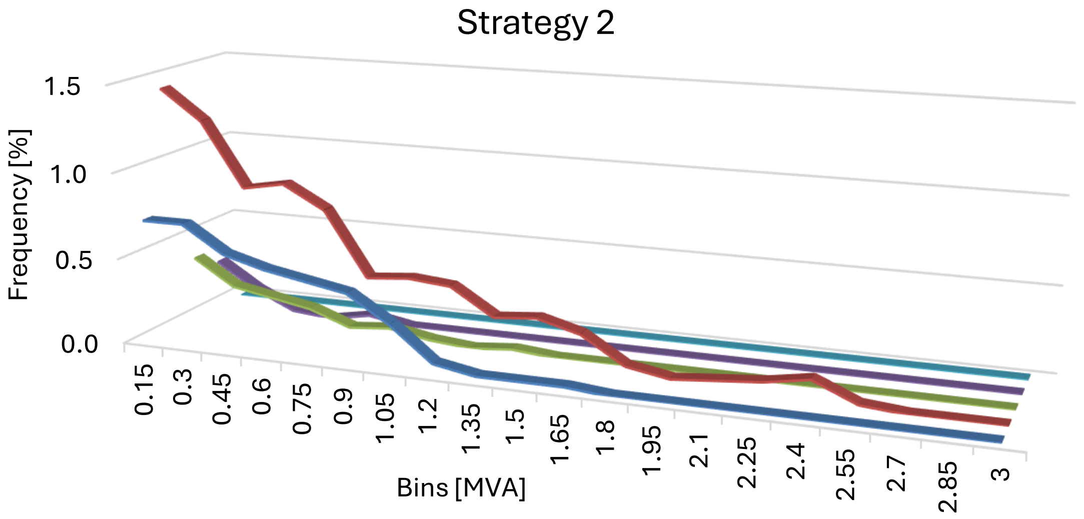
- The tool enables us to assess the **probabilistic distribution** of **future costs** of each strategy along with the overall scenario probability-weighted distribution of future costs for each strategy.
- Each bin represents the intervals/range of values into which the entire range of the data is split.
- All the data points that fall within a particular bin are then counted and aggregated to determine the frequency.
- Frequency is defined as the number of instances in which the NPC is above the value of each bin and lower than the value of the successive one.

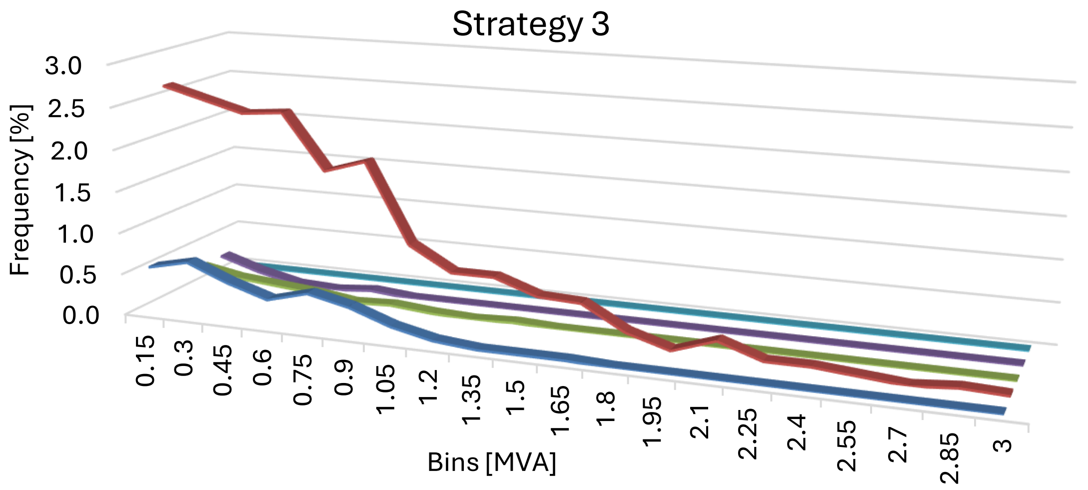


Example: Distribution of costs and network risk (2/3)

- The tool allows us to assess the **probabilistic distribution** of **residual excess load** of each strategy.



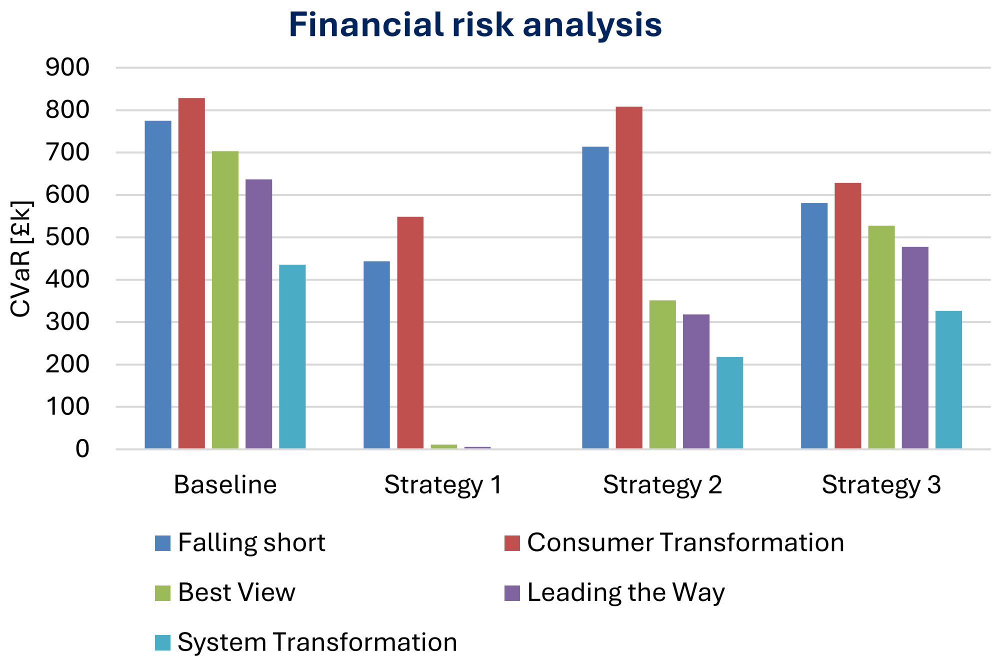


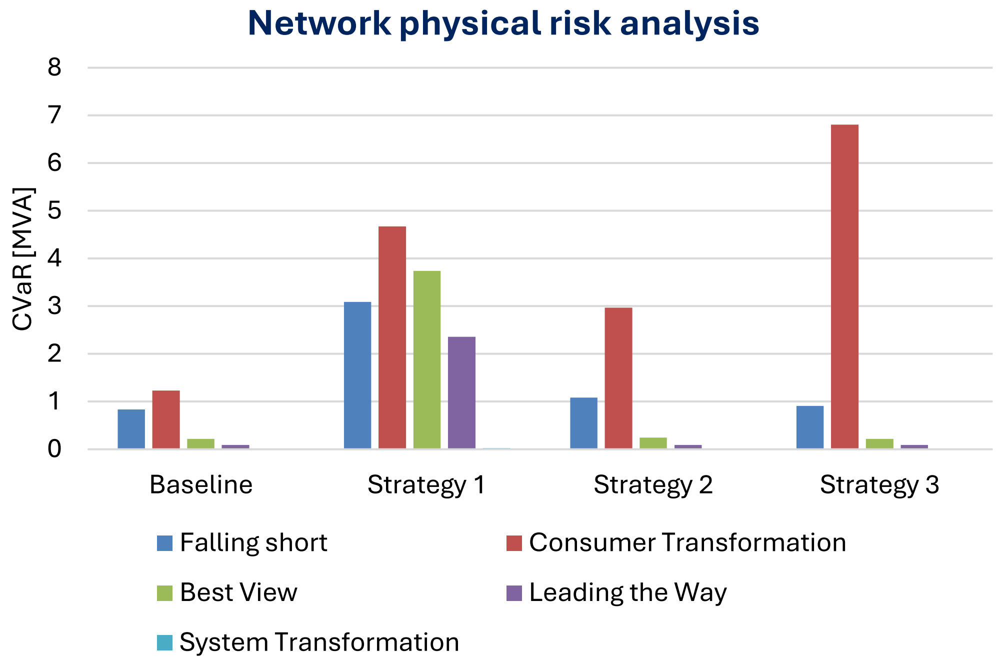


Frequency is defined as the number of instances in which the residual excess load (REL) is above the value of each bin and lower than value of successive one.

Example: Distribution of costs and network risk (3/3)

- By analysing the probabilistic distribution of future costs and residual excess load, it is possible to have a better understanding of both financial and network physical risk of all strategies under each scenario, quantified through the VaR and corresponding CVaR (after choosing a confidence level). These could be combined with each scenario probability.
- In this illustrative example, Strategy 1 and the Baseline strategy are the best options respectively from a financial and network risk perspective.





Confidence level: 95%

Conclusion

- ROCBA/CEM tool Python scripts will be made available to download from our website and shared with other DSOs.
  - This is to encourage other DSOs to use, review and provide feedback on it.
  - ENWL is available to hold briefings and training sessions to disseminate knowledge.

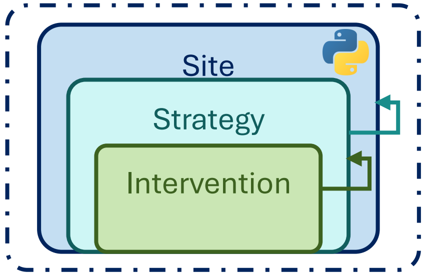
- No change in transparency commitment.
  - ENWL will continue to publish results of evaluations.

References

- J. A. Schachter, P. Mancarella, J. Moriarty, R. Shaw, ‘Flexible investment under uncertainty in smart distribution networks with demand side response: Assessment framework and practical implementation', *Energy Policy*, 2016.
- P. Mancarella, J. Moriarty, ‘Flexible investment strategies in distribution networks with DSR: Real Options modelling and tool architecture’, 2013.
- C. Kaloudas, R. Shaw, ‘Prototype Real Options Model: Tool Description Part of the Network Innovation Allowance’ Project ‘Demand Scenarios with Electric Heat and Commercial Capacity Options’ December 2016.
- ENA, ‘Common Evaluation Methodology and Tool’, 2023.

Annex I: Re-platformed ROCBA tool input data

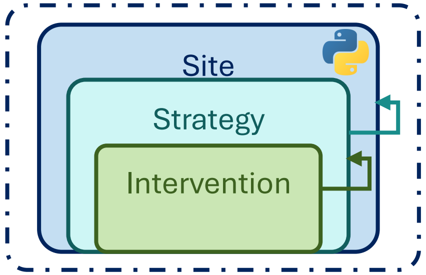
Re-platformed ROCBA tool: Input data (1/6)



Intervention 'object': Technical parameters

- Name
- **Type**, i.e. flexibility or network asset (reinforcement/replacement).
- Capacity (MVA), i.e. **additional** capacity for traditional network asset reinforcement/replacement.
- **Year completed**, i.e. first year in which the intervention is active, for example year 2026. If not known or if interventions are triggered by demand growth, this is set to zero.
- **Year stop**, i.e. year in which the intervention is no longer active, for example year 2036. If not known or if interventions are triggered by demand growth, this is set to zero.
- **Trigger level** (%): asset loading threshold above which the intervention is activated*.
- **Lead time** (years).
- **Embedded emissions**, associated with the component itself and its transportation (tCO2e).
- **Losses parameters**, e.g. fixed losses and peak resistive losses after intervention (MW), loss load factor, etc. to calculate losses based on what/when each intervention is active, unless provided as inputs in separate file.

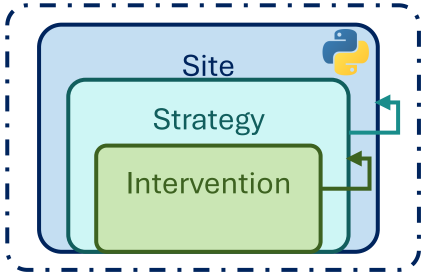
* **Tipping points** may be deterministic (i.e. occurring at user-defined years) or triggered **if and when peak demand** reaches a **certain level**.



Intervention 'object': Flexibility service parameters

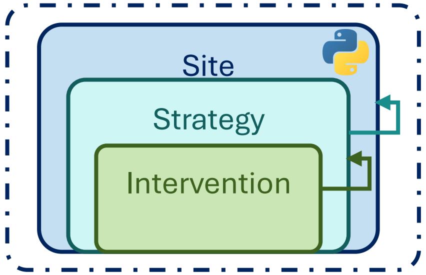
- Maximum customer flexibility total availability (MVA), accounting for additional purchase for customer diversity.
- Average size of contract per customer (MVA)
- Uncertainty around flexibility availability at the time of delivery (%)
- Proportion of HV/LV customers providing capacity (%)
- Minimum flexibility contract length (years)
- Flexibility contract type, i.e. 'Flat' or 'Ramping' to define capacity to be procured (in accordance with CEM tool).

Re-platformed ROCBA tool: Input data (3/6)



Intervention 'object': Financial parameters

- Network investment cost (£): Costs associated with traditional reinforcement.
- Spread of network investment costs (%): It is possible to 'spread' the total investment cost between 'commitment' and 'delivery' years.
- Asset life, used to calculate depreciation (years).
- Cost parameters for flexibility services, including:
  - Network automation costs (to allow flexibility provision) (£)
  - Flexibility service contract set-up cost (£/customer)
  - Flexibility availability and utilisation payment (£/MVA/customer and £/MWh/customer)
  - Multi-year flexibility service contract price discounts (%)
  - Ongoing costs (i.e. remittances, automation maintenance, contract management) (£/year)



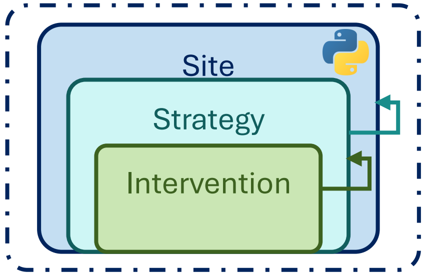
Strategy 'object'

It is defined by the following parameters:

- Name
- Sequence of intervention names, selected from a 'database' of interventions available*. The order in which each intervention is listed also reflects the temporal order in which each intervention may be triggered. For instance, if 'Strategy A' consists of three interventions, i.e. FLEX_1, NET_1 and FLEX_2, this means that intervention NET_1 can be activated only if and after FLEX_1 is triggered.
- Number of fatal/non-fatal injuries
- CMLs
- Number of CIs

* Each intervention name in the database is unique.

Re-platformed ROCBA tool: Input data (5/6)

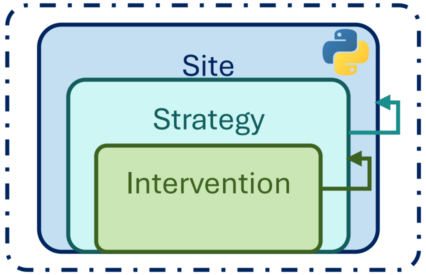


Site 'object'

It is defined, for each scenario, by the following parameters:

- **Name:** It is possible to define as many sites as needed. For example a site can be a substation.
- **Initial firm capacity** (MVA)
- **Demand growth trends** (MVA), from base year up to final year depending on the planning horizon. These may be used to trigger a specific intervention.
- **Scenario probability weight** (%)
- **Volatility (%)** used to simulate short-term uncertainty around the long-term trend of each scenario through Monte Carlo simulations.
- **Sequence of strategies** to be assessed.

Re-platformed ROCBA tool: Input data (6/6)



- **Weather-related volatility** (%): Used to incorporate short-term uncertainty around long-term trends of each scenario for each Monte Carlo simulation.
- Specific **parameters for losses calculation** before any intervention (e.g. fixed losses (MW), loss load factor, latent demand at peak (MW), etc.)
- **Financial views**: to capture different perspectives on costs, for example, DNO commercial (i.e. analysis performed across a five-year horizon) vs regulatory perspective (i.e. analysis performed across a 45-year horizon as in Ofgem's CBA model).
- **Financial parameters**: discount rates (%), planning horizon (years), totex treatment (%), flag to include social costs (e.g. losses, CIs, CMLs, emissions, etc.). These change based on selected 'view'.
- Additional **financial/cost parameters**: e.g. capitalisation rate (%), pre-tax WACC (%), cost per fatality, cost per non-fatal injury, cost per litre oil, cost per CI, CML.
- **'Best view' scenario**
- **'Baseline' strategy**: Benefits of a selected strategy are calculated with respect to baseline's net present costs.