AI-Enabled Flex Orchestration – *robotron*eFlex*

Executive Summary

robotron*eFlex integrates AI-driven forecasting, portfolio modelling, and adaptive optimisation to unlock the full value of flexible energy assets. By continuously responding to market volatility, forecast uncertainty, and asset constraints, it improves hedging performance, enhances arbitrage outcomes, and enables carbon-aware dispatch. This paper demonstrates how embedded AI capabilities deliver measurable commercial value for retailers, aggregators, businesses, and BESS operators.

Electricity flexibility markets are entering a new phase of complexity. Increasing wholesale price volatility[1], renewable intermittency, Distributed energy resource (DER) growth, and hedge exposure pressures require more adaptive optimisation strategies. New Zealand's wholesale electricity market exhibits significant price volatility. While long-term average prices typically sit between $90 and $120/MWh, periods of supply constraint or hydro scarcity can drive spot prices above $500/MWh, with extreme events exceeding $1,000/MWh. Such volatility creates substantial arbitrage and hedging opportunities for flexible assets. Forecast error and volatility regimes can reduce storage profitability by up to 50 %[2] when predictive optimisation is absent, highlighting the importance of adaptive optimisation strategies.

As volatility, uncertainty, and portfolio complexity increase, static optimisation approaches become economically insufficient, making AI-enabled orchestration essential for sustained performance and risk control.

Market Challenges Facing Flex Operators

Increasing Wholesale Volatility

Renewable intermittency, transmission constraints, and shifting generation mixes are increasing daily price dispersion. Flex assets must now operate within highly dynamic price environments where static thresholds, based on **historical information**, rapidly degrade in effectiveness. As volatility regimes shift and price spreads change shape, fixed charge and discharge triggers become misaligned with current market conditions, reducing spread capture, increasing imbalance exposure, and requiring continual manual re-tuning.

New Zealand's electricity system is particularly exposed to volatility due to its high renewable share. Approximately 55–60 % of generation is hydro-based, meaning rainfall patterns and hydro storage levels can materially influence wholesale supply conditions and wholesale price volatility.

During dry-year conditions or transmission constraints, spot prices have exceeded $500/MWh, with extreme events reaching above $1,500/MWh.

Hedge Exposure and Load Uncertainty

Retailers face load forecast deviation driven by EV uptake, solar self-generation, behavioural shifts, and weather variability. Mismatch between hedge positions and realised load exposes portfolios to imbalance risk and margin volatility.

Retail load forecasting is becoming more complex as distributed energy resources expand. New Zealand now has over 69,000[3] rooftop solar installations representing more than 864 MW of distributed capacity[4], while electric adoption continues to transition from gas and fossil fuels to electricity. These changes introduce additional uncertainty into demand forecasts and hedge alignment.

Scaling DER Portfolios

As DER portfolios expand, manual rule configuration and parameter tuning become operational bottlenecks. Scaling asset fleets without proportional increases in operational complexity is now a critical requirement.

As distributed generation and flexible loads expand, operators must manage increasingly complex asset portfolios. New Zealand's distributed solar capacity has already exceeded 1.1 GW (864 MW distributed solar[4] and 247 MW grid connected solar[5,6]). Growth has accelerated significantly in recent years, with total solar capacity increasing by over 50 % between 2023 and 2024, and distributed solar expanding several-fold since 2020[7]. This trajectory is expected to continue as electrification and decentralised energy systems scale.

Limitations of Traditional Rule-Based Flex Systems

Many flex platforms rely on deterministic logic such as static price thresholds, fixed time-of-use windows, and manually tuned rule groups. While effective in predictable environments, these approaches are reactive and require continual human intervention. They optimise for fixed assumptions rather than adapting to changing market conditions.

AI Capabilities to be Embedded in *robotron*eFlex*

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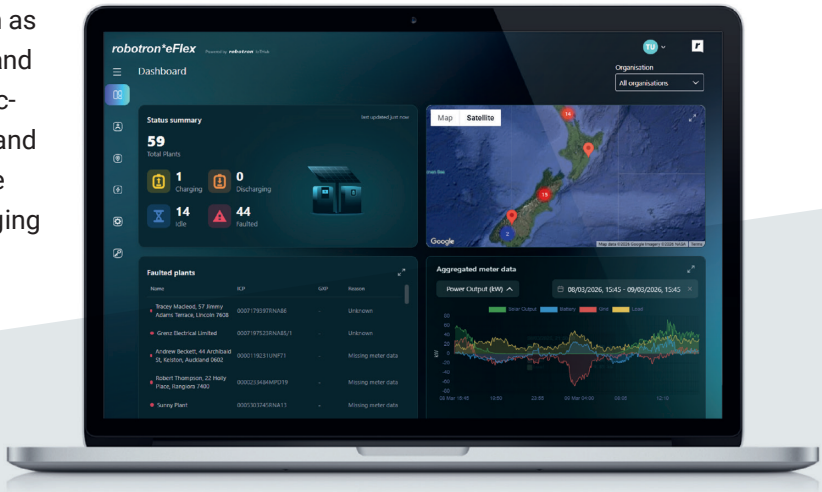

Figure 1: ***robotron e*Flex***

- **Probabilistic Forecast Integration**
  Probabilistic forecasting models predict ranges of possible outcomes rather than single deterministic values. Within ***robotron*eFlex*** probabilistic load, price, and renewable forecasts inform dispatch decisions, allowing hedge-aware and risk-adjusted optimisation under uncertainty.

  Accurate forecasting materially impacts storage performance. Several research initiatives indicate 1) that a 12.5 % electricity price forecasting error can reduce battery profitability by up to 50 %[8], and 2) that even with a 30 % forecasting error, 80 % of the optimal revenue can still be achieved[9]. This highlights the importance of probabilistic forecasting approaches that account for uncertainty in volatile electricity markets. Further research, specifically in the BESS trading market indicates that a simple AI model could achieve 90 % of max profit[10].

- **Portfolio Digital Twin Modelling**
  Digital twin modelling simulates real-world asset behaviour within a virtual portfolio environment. ***robotron*eFlex*** models asset constraints, state-of-charge behaviour, and market scenarios prior to execution, enabling strategy stress testing and revenue-risk evaluation before live dispatch.

- **Adaptive Optimisation Engine**
  The adaptive optimisation engine continuously evaluates dispatch outcomes 24/7 and recalibrates strategy parameters. This enables multi-objective optimisation across arbitrage, reserves participation, and carbon constraints while maintaining operational guardrails and compliance requirements.

  Predictive optimisation strategies have demonstrated substantial improvements in storage performance. Studies combining reinforcement learning with price forecasting have shown up to 60 %[11] improvement in arbitrage rewards, while stochastic optimisation approaches can capture 50–90 %[12] of theoretical arbitrage profit depending on market conditions.

Commercial Outcomes Enabled by AI

Scaling Flex Without Scaling Operational Complexity – Currently supported

AI-assisted rule creation, automated portfolio clustering, and continuous parameter tuning allow portfolio growth without proportional operational overhead. As asset fleets expand, optimisation remains consistent, adaptive, and manageable.

Improved Hedging Efficiency

By aligning flex dispatch with probabilistic load forecasts and hedge positions, ***robotron*eFlex*** will reduce imbalance exposure and enhance gross margin stability. Dynamic load shaping improves alignment between contracted hedges and realised demand.

Wholesale Volatility Protection

AI-enhanced dispatch will anticipate low confidence patterns and pre-position storage assets accordingly. Multiple value streams (energy arbitrage, frequency response, instantaneous reserves) co-optimisation transforms BESS fleets into active volatility management instruments, reducing tail-risk exposure.

Carbon-Aware Optimisation

By integrating carbon intensity forecasting, ***robotron*eFlex*** will enable dispatch strategies that optimise both commercial returns and emissions outcomes. Retailers can align flex operations with decarbonisation targets without sacrificing financial performance.

Implementation Approach

- Phase 1: **Currently supported: Automated Parameter Configuration**
  AI-assisted calibration reduces manual rule tuning and continuously adapts dispatch parameters to evolving market conditions.

BENEFIT: *Reduces operational overhead by automating rule calibration across large residential fleets, allowing retailers and aggregators to scale flex programmes without increasing operational complexity.*

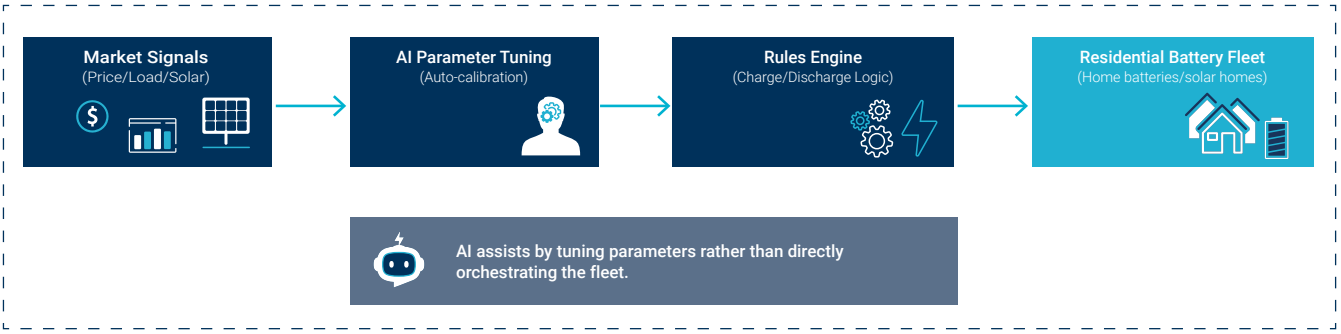

Figure 2: Automatic Rules update provides operational efficiencies

- Phase 2: **Asset-level Intelligence (Individual BESS Optimisation)**
  Individual BESS/battery assets operate using probabilistic forecasting and confidence-adjusted optimisation, improving spread capture and reserve positioning.

BENEFIT: *Improves battery performance by enabling each asset to optimise dispatch using probabilistic forecasts and asset constraints, increasing revenue capture while protecting battery health.*

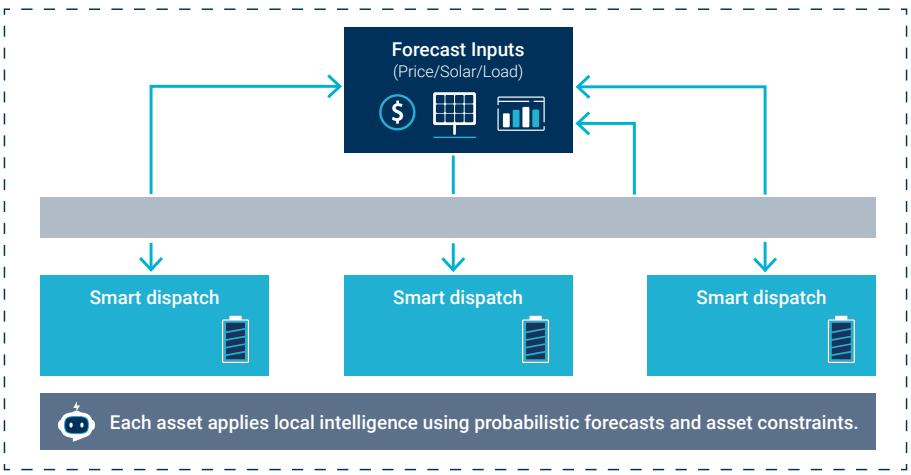

Figure 3: BESS optimisation and self learning

- Phase 3: **Portfolio Simulation and Digital Twin Modelling**
  Fleet-level modelling enables stress testing and hedge-aligned optimisation prior to live execution.

BENEFIT: *Reduces financial and operational risk by allowing dispatch strategies to be stress-tested in a simulated portfolio environment before being deployed in live market.*

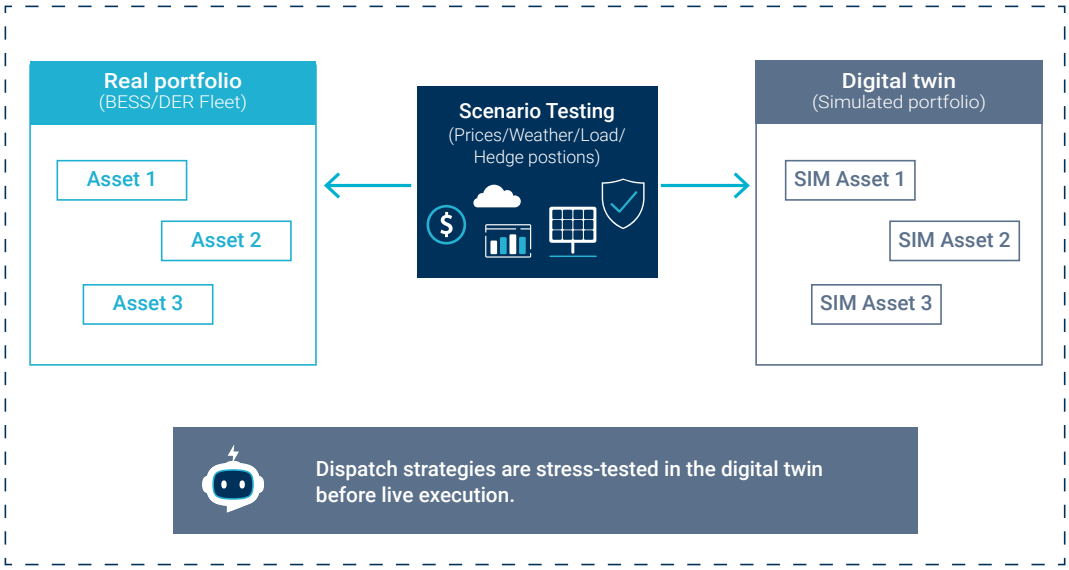

Figure 4: Portfolio Simulation and Digital Twin Modeling

- Phase 4: **Bespoke C&I Asset Management**
  Asset-specific optimisation supports complex industrial loads such as thermal systems, plant nurseries, and scaled EV fleets, incorporating operational constraints and customer safeguards.

BENEFIT: *Unlocks flexibility from complex commercial and industrial loads by incorporating operational constraints, ensuring participation in flex markets without disrupting core business operations.*

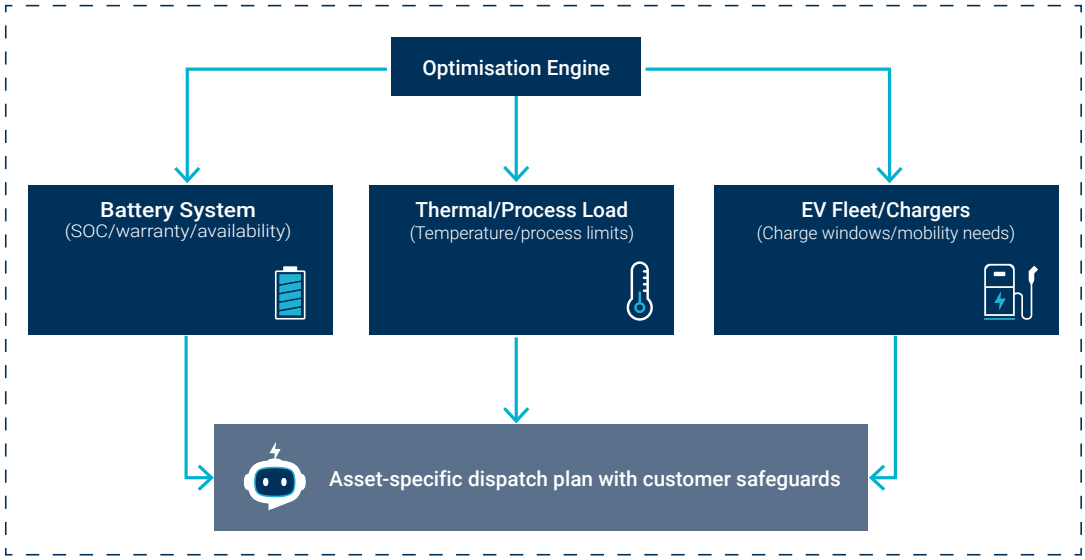

Figure 5: Bespoke C&I Asset Management

- Phase 5: **Multi-Device Orchestration**
  Coordinated optimisation across heterogeneous assets enables revenue stacking, volatility protection, and carbon-aware dispatch at portfolio scale.

BENEFIT: *Maximises portfolio value by coordinating heterogenous assets (batteries, distributed generation, and flexible loads) to respond collectively to wholesale market conditions and hedge exposure.*
Each phase builds capability incrementally while maintaining operational control and transparency.

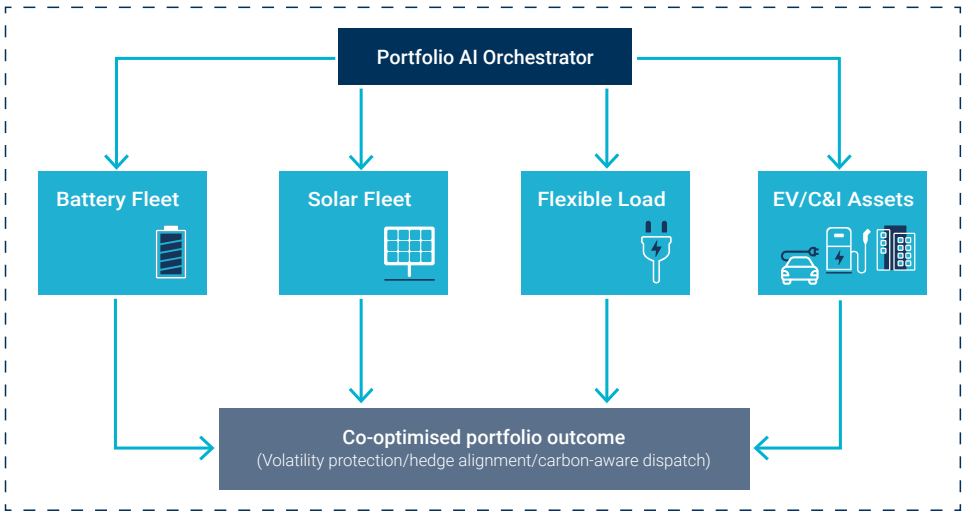

Figure 6: Multi-Device Orchestration

Governance, Control and Explainability

robotron*eFlex is being built to incorporate operator override capabilities, dispatch guardrails, strategy transparency, and full auditability. AI-driven optimisation operates within defined compliance and risk parameters, ensuring alignment with market regulations and internal governance standards.

Conclusion

Flexibility is evolving into a core financial and operational instrument within modern electricity markets. Rule-based optimisation approaches are insufficient in environments characterised by volatility, uncertainty, and portfolio scale. Gas shortages and oil price rises, as well as constantly decreasing price of renewable energy will steer the energy market towards more imbalanced and unpredictable grids. AI capabilities embedded within ***robotron*eFlex*** enable adaptive, hedge-aware, carbon-aligned orchestration designed for next-generation energy markets.

Organisations seeking to enhance flexibility value, improve hedge alignment, and manage wholesale volatility are invited to engage with Robotron to explore how AI-enabled orchestration can be applied to their portfolios.

Robotron offers collaborative workshops and targeted assessments to identify high-value flexibility opportunities and define a practical pathway toward implementation using ***robotron*eFlex***.

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