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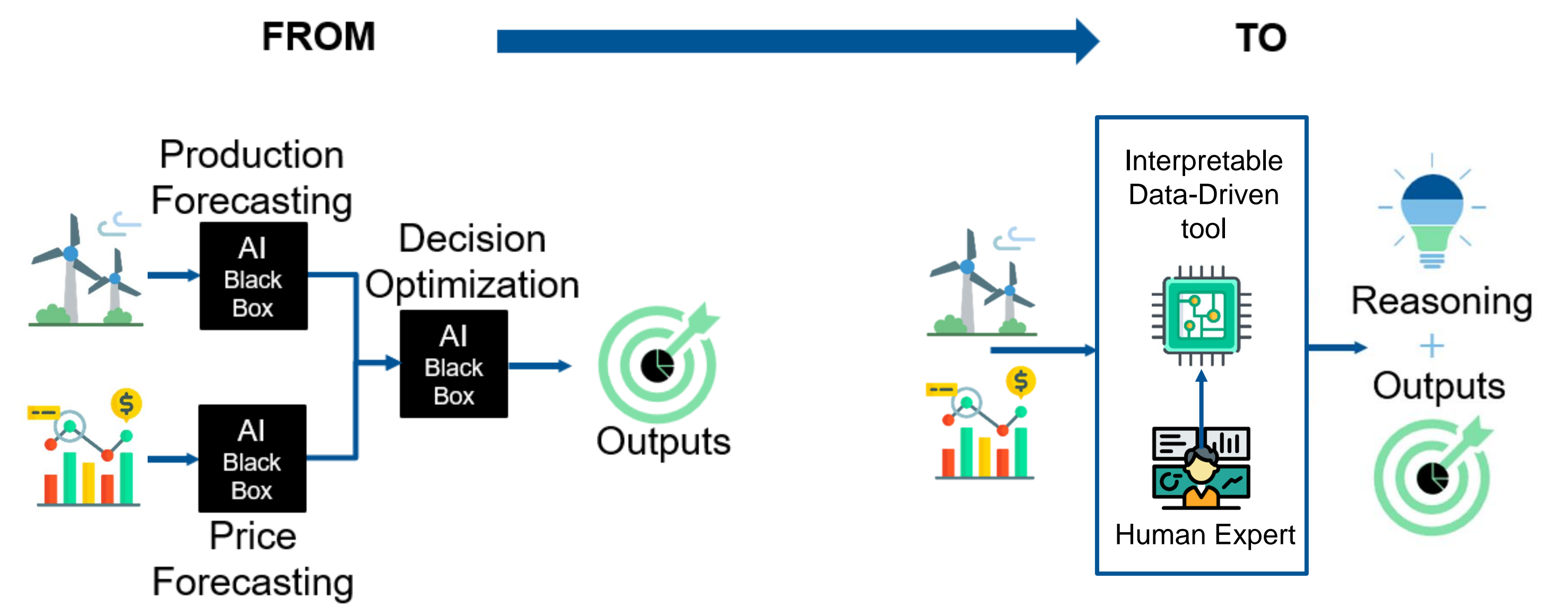


# Optimizing wind energy trading decisions using interpretable AI-based tools – the symbolic regression approach –

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## Context and Motivation

- **Artificial Intelligence (AI)** based tools have proven their efficiency in various applications in the energy sector ranging from forecasting to optimization and decision making.
- Despite the advantages of data-driven models, AI-based tools are often seen as **black-box models** and this penalizes their **acceptability** by end-users (traders, power system operators a.o.).
- **Developing interpretable of AI tools is a major challenge** for the wider adoption of AI in the energy sector.
- **Incorporating Human Expert knowledge** in such tools is expected to increase performance and facilitate better generalization of the obtained strategies.



## Objectives

### USE OF SYMBOLIC REGRESSION

Proposal and validation of a **data-driven** modelling approach that leverages genetic programming (GP) to derive **interpretable** decisions, called symbolic expressions.

### ENHANCING INTERPRETABILITY

We introduce a **penalty metric** that **reduces the complexity** of symbolic expressions by penalizing each solution with the number of operations performed.

### INCLUDE HUMAN EXPERT KNOWLEDGE

We demonstrate expert knowledge integration in the data-driven algorithm that facilitates the concept of **"Human in the Loop"** by **tailoring the grammatical space** of symbolic expressions to the expert needs.

## Methods

We are using **Symbolic Regression (SR)** from **Genetic Programming** algorithm to derive **interpretable analytical expressions** that represent our model. Those equations result according to a value-oriented reward function. The optimal solutions are selected naturally mimicking the biological theory of survival of the fittest. After the production of several individual tree structures that represent the analytical expressions, reproduction mechanisms are utilized to proceed to the next generation of analytical solutions, until we meet a determined threshold.

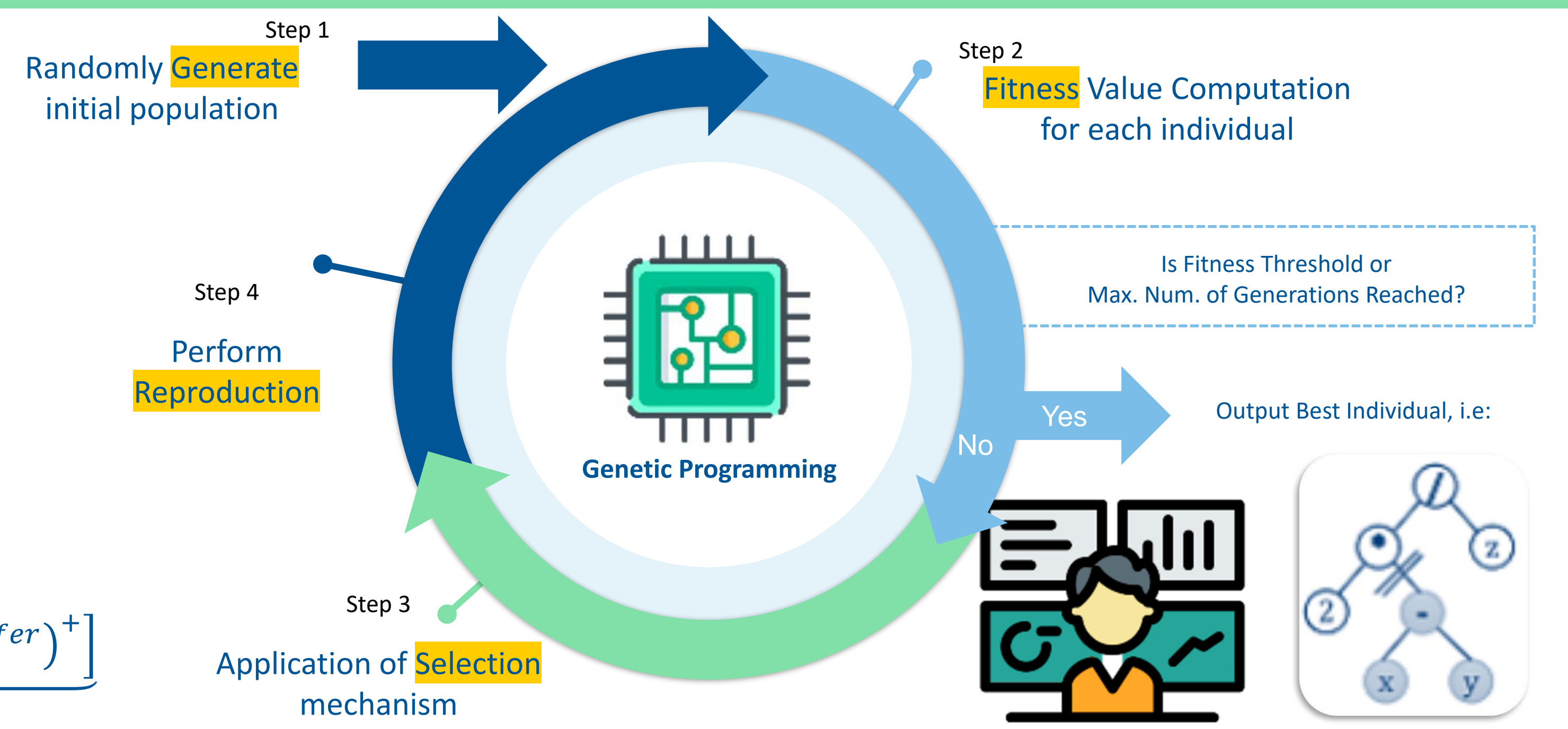
We propose a fitness metric tailored to the trading of a dual-pricing market which is formed as follows:

$$\rho^{market} = \pi^{da} p^E - \underbrace{[-\lambda^{\downarrow} (p^E - p^{offer})^{-} + \lambda^{\uparrow} (p^E - p^{offer})^{+}]}_{\text{imbalance cost}}$$

where  $\rho^{market}$  is the revenue obtained by bidding  $\rho^{offer}$  when the actual energy produced is equal to  $\rho^E$ .

The decision derived from GP is defined as  $Z$ . The objective is to **minimize the imbalance cost** of our trading decisions **as well the complexity** of the final decision. The penalty metric for complexity is defined as :

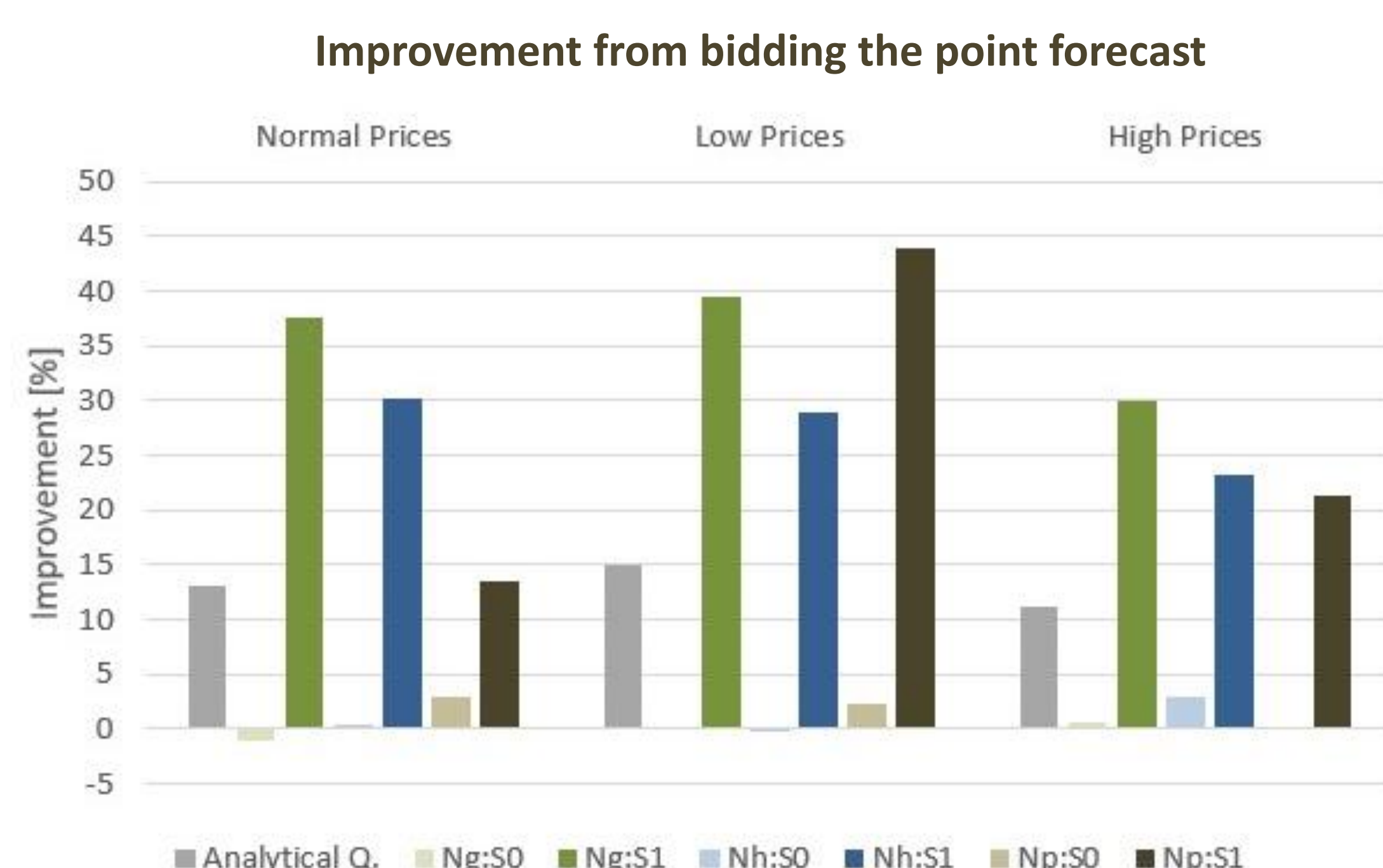
$$op(Z) = \frac{\text{len}(Z) - 1}{2} \quad \text{i.e: } op(Z) = 3$$



## Case study / Open Data:

- 17MW Wind Farm Sotavento, Portugal.
- Market prices from ENTSO-e Transparency
- Training: 11 months / Testing: 10 months
- Scenarios for Low (L), Normal (N) and High (H) Prices, global SR model (g), expert splits based on hour of the day (h), and price spreads (p)
- Grammatical Spaces:
  - S0: [+ , - , ÷ , ×]
  - S1: [G0, mean, 75%-quantile, 25%-quantile]

## Results



Our observations indicate that the interpretable strategies produced by SR are **equally effective** as the ones derived by analytical Opt. Quantile, across all three different market price scenarios. On top of that, when **expert knowledge** introduces functions in grammatic space G1, **SR performs better** than Opt. Quantile by identifying a solution that further **minimizes Imbalance Penalties**.

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