



Towards a paradigm of explainable AI applied in energy meteorology.

EGU23, 25th April, Vienna

Konstantinos Parginos¹, Georges Kariniotakis¹,
Ricardo Bessa², and Simon Camal¹

¹ Mines Paris - PSL, France

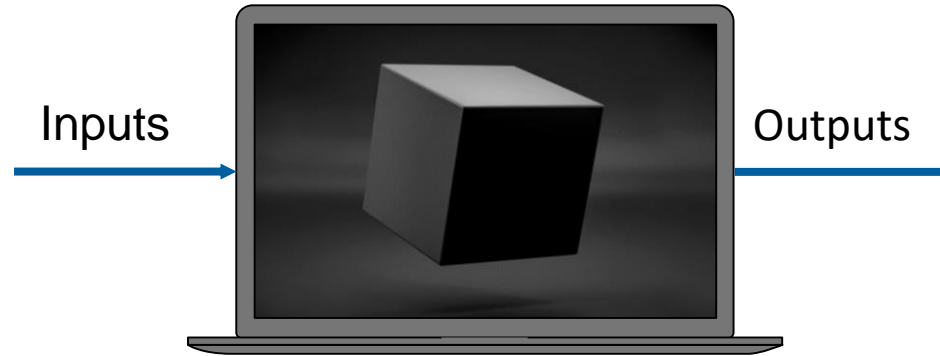
² INESC TEC, Portugal



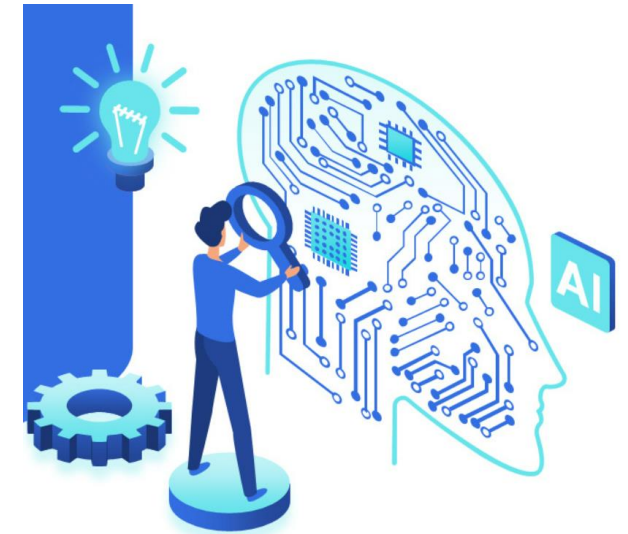
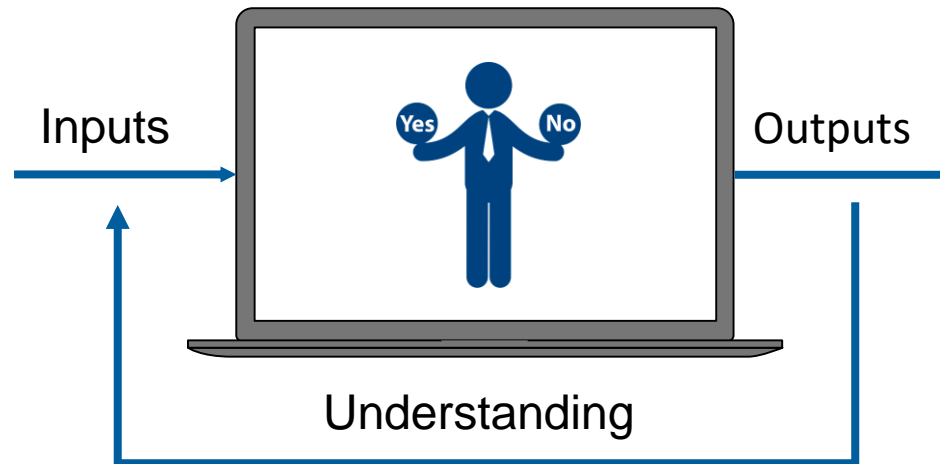
OVERVIEW

Difficulty to assess output in **High Dimensional** and **Non Linear** Problems

FROM



TO



“The ability to **explain** or to present a model output in **understandable** terms to a human”

Doshi-Velez & Been Kim, 2017

WHO NEEDS INTERPRETABILITY?



AI Model Builders:

- Why is the model not performing?
- How can I improve it?

End Users of AI systems:

- Should I trust the model's output?
- How should I respond to the predictions?

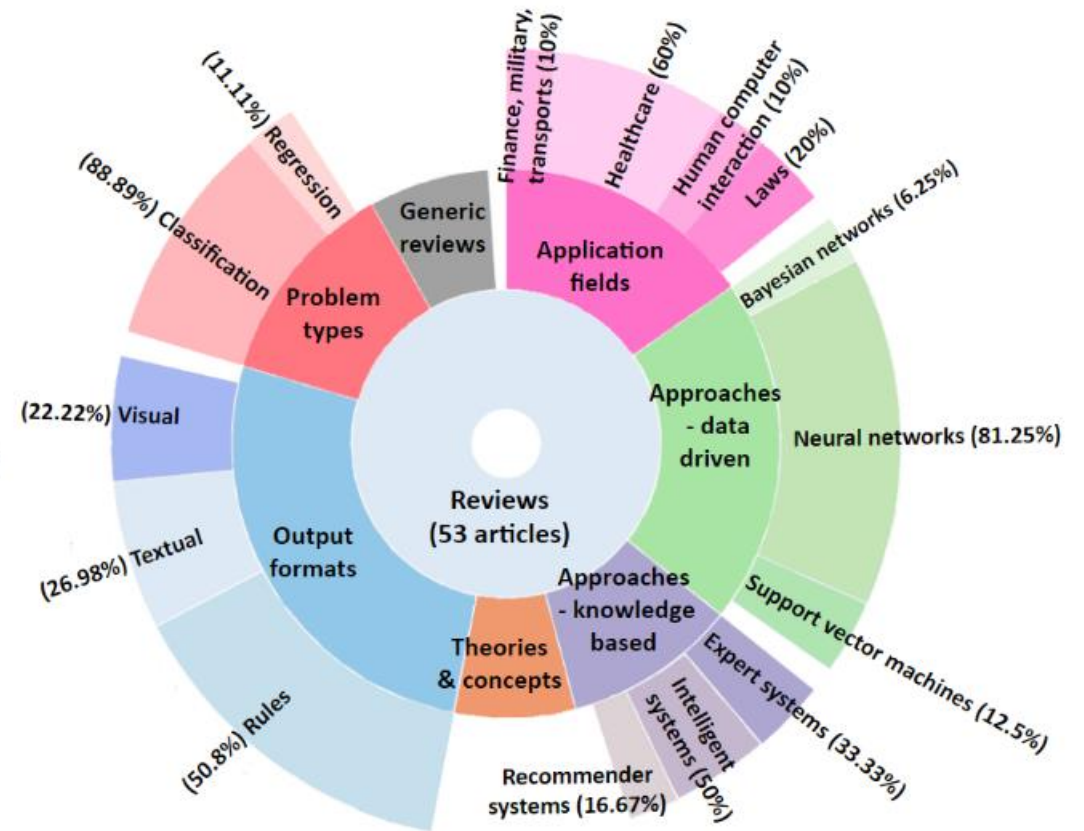
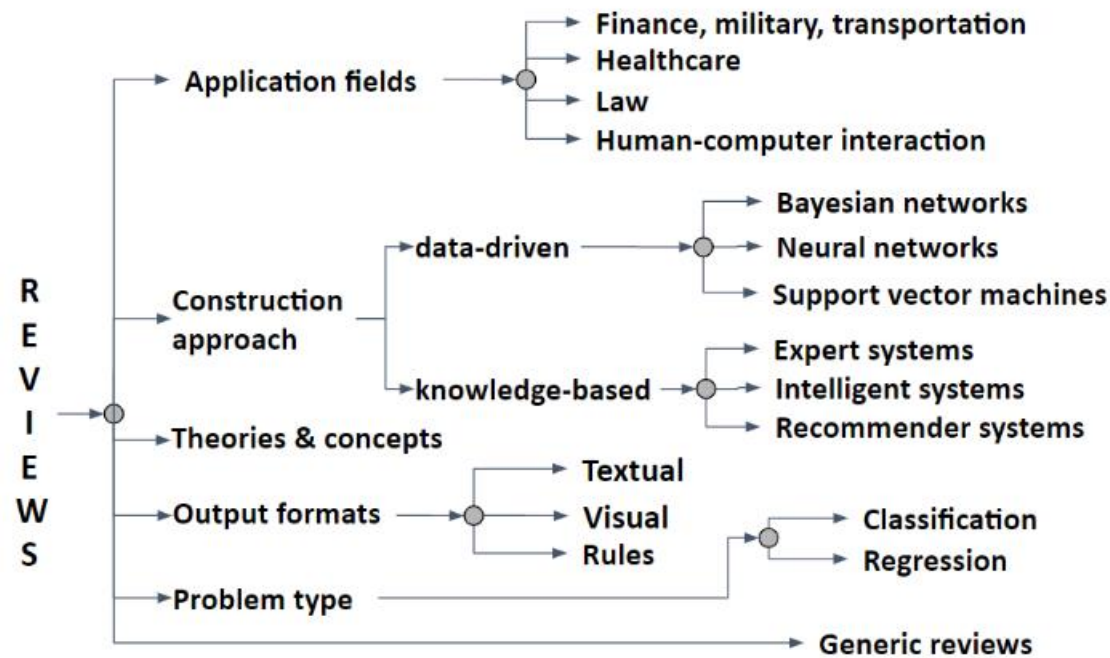
Public stakeholders:

- Is the model safe and fit for purpose?
- Does it comply with regulations?



WHERE IS INTERPRETABILITY BEING USED?

Despite the numerous interpretable methods developed, there are limited applications in the Energy Sector



ARTIFICIAL INTELLIGENCE APPLICATIONS TO THE ENERGY SECTOR

Demand & RES Forecast



Anomaly detection



Predictive Maintenance



Power Trading

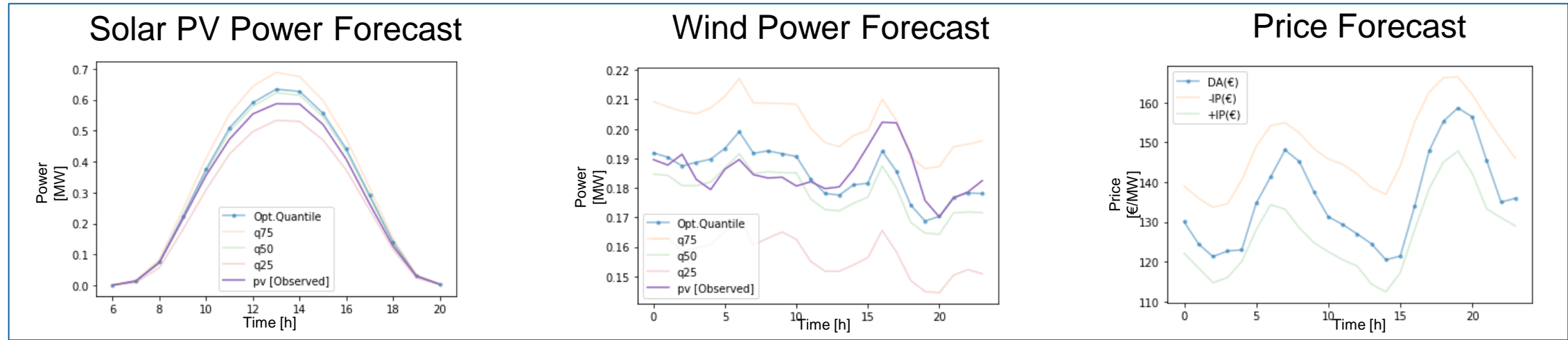


Demand Profiling

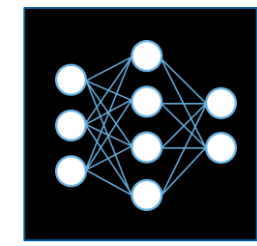


BRIEF INTRODUCTION TO POWER TRADING

Input Data

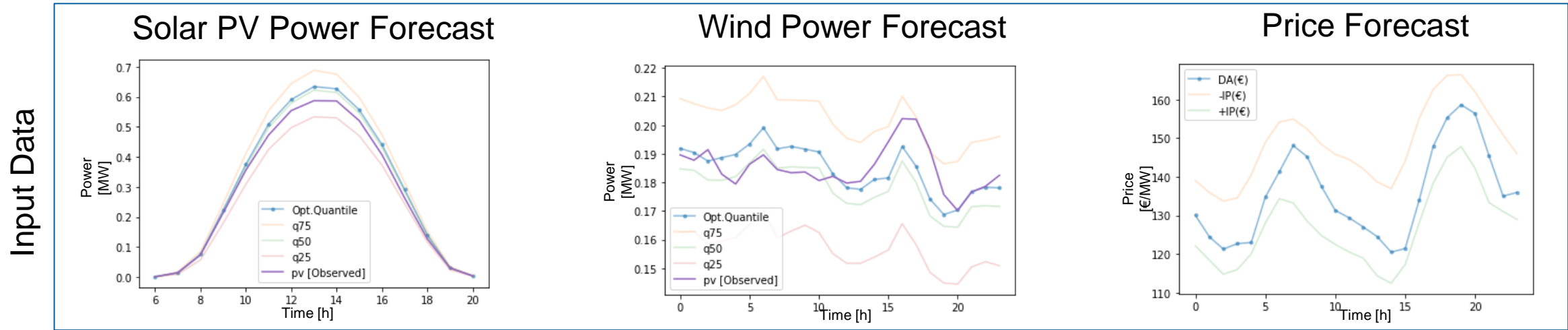


AI Tool (ANN)



Power Trading

BRIEF INTRODUCTION TO POWER TRADING

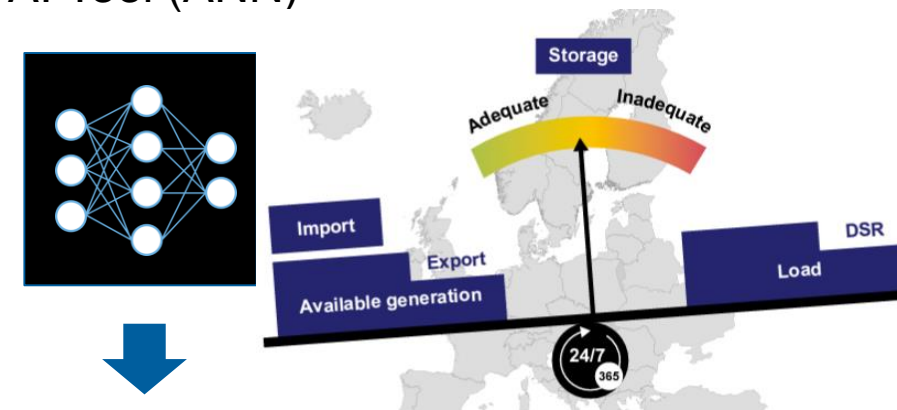


Dual Pricing Market:

- Day-Ahead Price (spot price) Π_{DA} determined in advance for planning adequacy
- Real-Time Price (balancing price) Π_{Bal} determined based on the actual supply and demand

The imbalance penalty is a fee charged to market participants who do not balance their positions

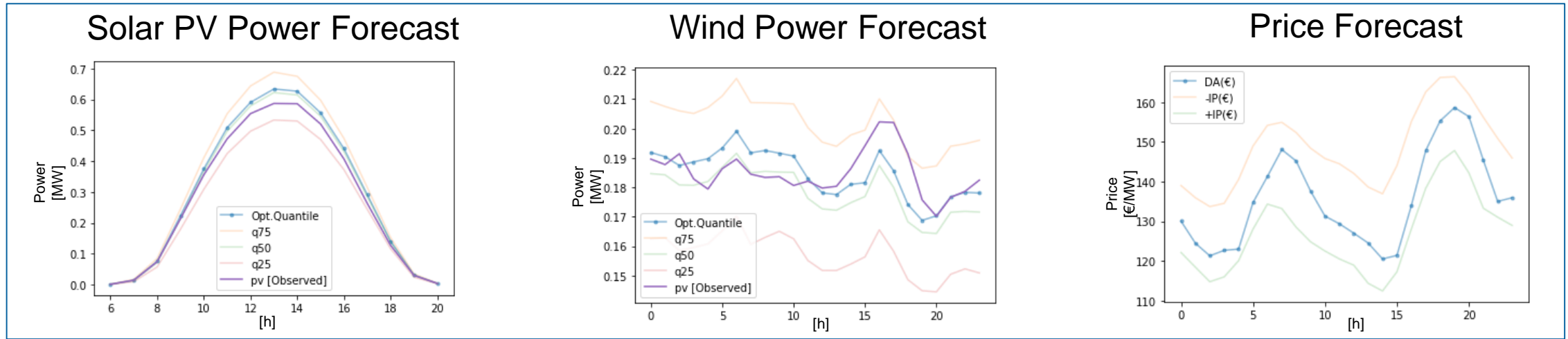
AI Tool (ANN)



Trading decisions

AI INTERPRETABLE APPROACH IN RES TRADING

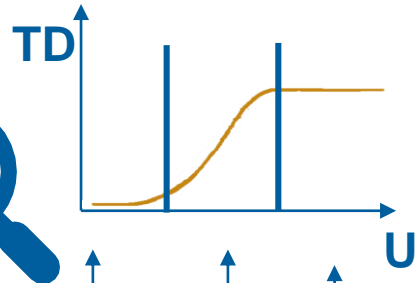
Input Data



Interpretable AI tool

Library of Analytical Functions

- $TD = U^3$
- $TD = 4T$
- $TD = U^2/3$
- $TD = U^3 + TCC$



- $TD = 0$
- $TD = U^3$
- $TD = 1$

Trading decisions



+



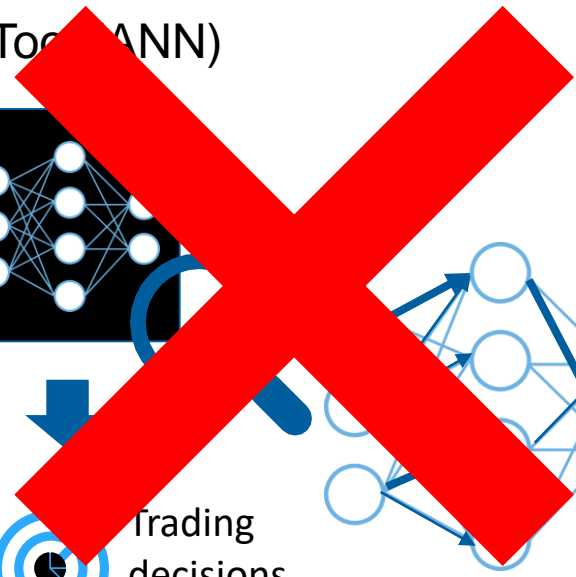
Reasoning



AI Tool (ANN)

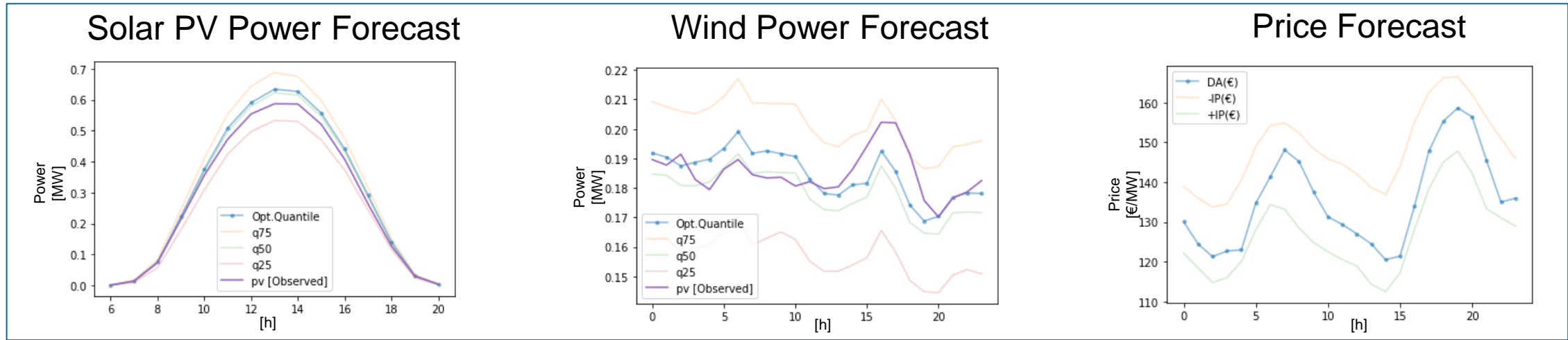


Trading decisions



AI INTERPRETABLE APPROACH IN RES TRADING

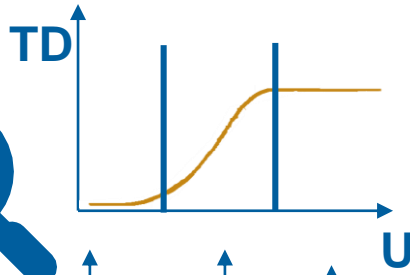
Input Data



Interpretable AI tool

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Trading decisions



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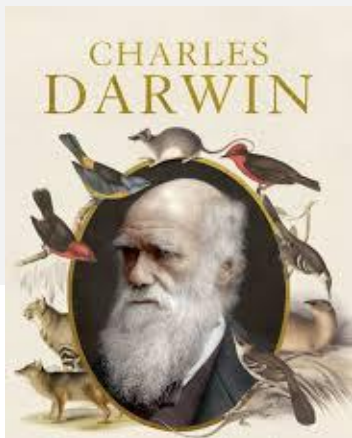
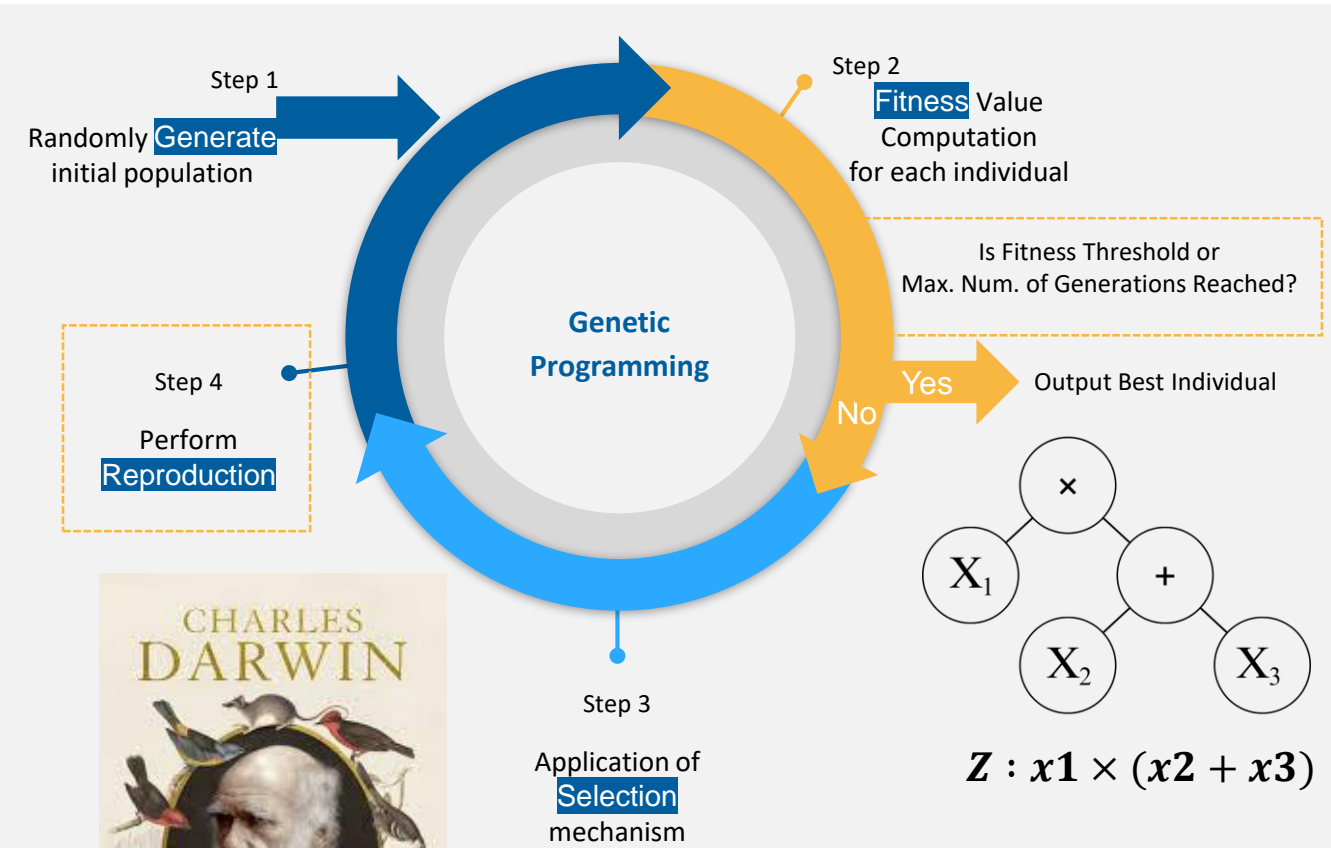


Reasoning

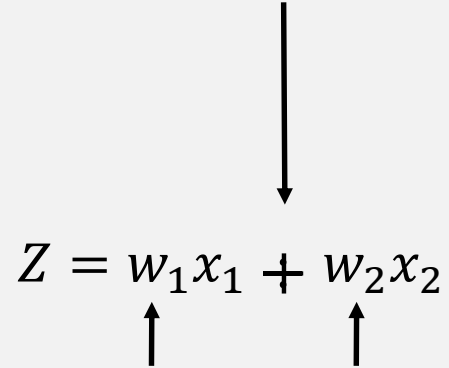
Key questions:

- Which features are important to the model?
- How features interact for a particular decision?

EVOLUTIONARY STRATEGIES DERIVED BY GENETIC PROGRAMMING [GP]



BENEFITS OF GENETIC PROGRAMMING

$$Z = w_1 x_1 + w_2 x_2$$


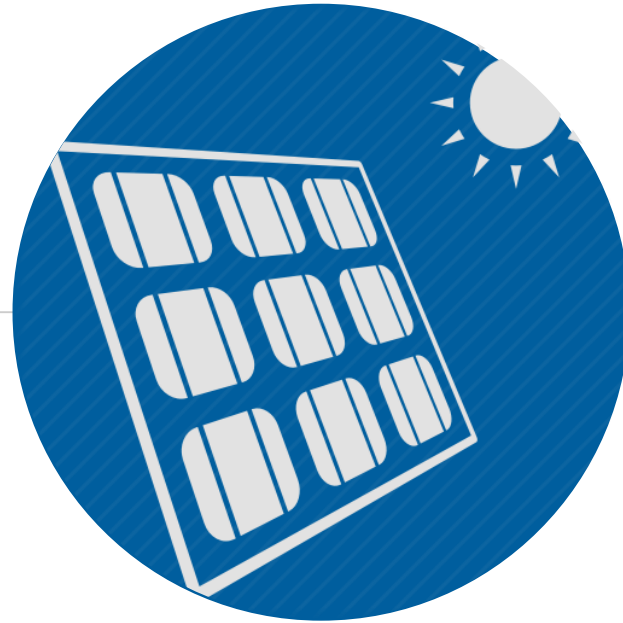
$$f_{w_1, w_2}(x_1, x_2)$$

y = output

$x_{1,2,\dots}$ = input

$w_{1,2,\dots}$ = weight

- Data-Driven simple analytical solutions
- Optimize both weights and feature relations
- Could be used both as Post-Hoc and Ad-Hoc tool



CASE STUDY

Optimizing Bidding Decision of Solar PV Plant
in Day-Ahead Electricity Market

PROBLEM FORMULATION

Definitions

$$p^{offer} = Z_{E,\theta}$$

$$Z_{opt} = \underset{\{Z_{E,\theta} \in \Phi\}}{\operatorname{argmin}} G(Z_{E,\theta}, X)$$

Formulation of Fitness Function G to optimize Trading Value:

p^E : Actual Energy Produced

$\lambda^\uparrow, \lambda^\downarrow$: Imbalance Prices

$$\underbrace{\left[-\lambda^\uparrow (p^E - p^{offer})^- + \lambda^\downarrow (p^E - p^{offer})^+ \right]}_{G = \text{imbalance cost}}$$

Benchmark

$$\text{Analytical } Q. = \hat{F}^{-1}(\tau)$$

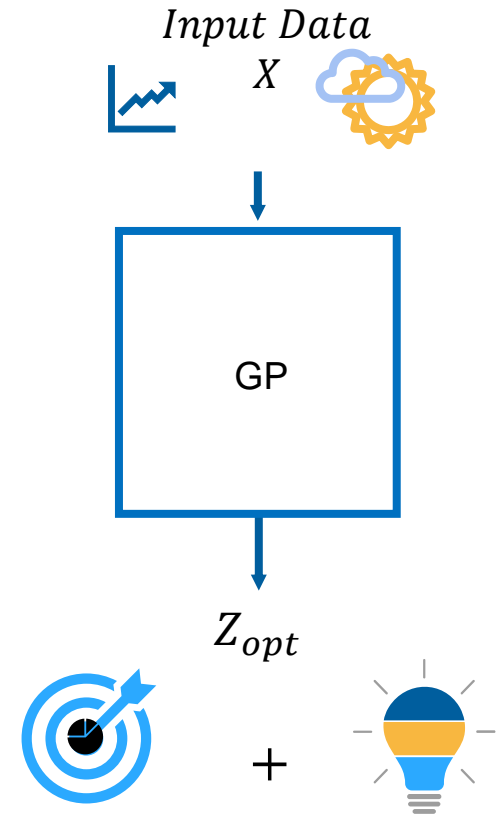
\hat{F}^{-1} : predicted inverse cumulative distribution function (c.d.f.) of p^E

$$\tau = \frac{\hat{\lambda}^\downarrow}{\hat{\lambda}^\downarrow + \hat{\lambda}^\uparrow}$$

Π_{DA} : Day Ahead Market Price

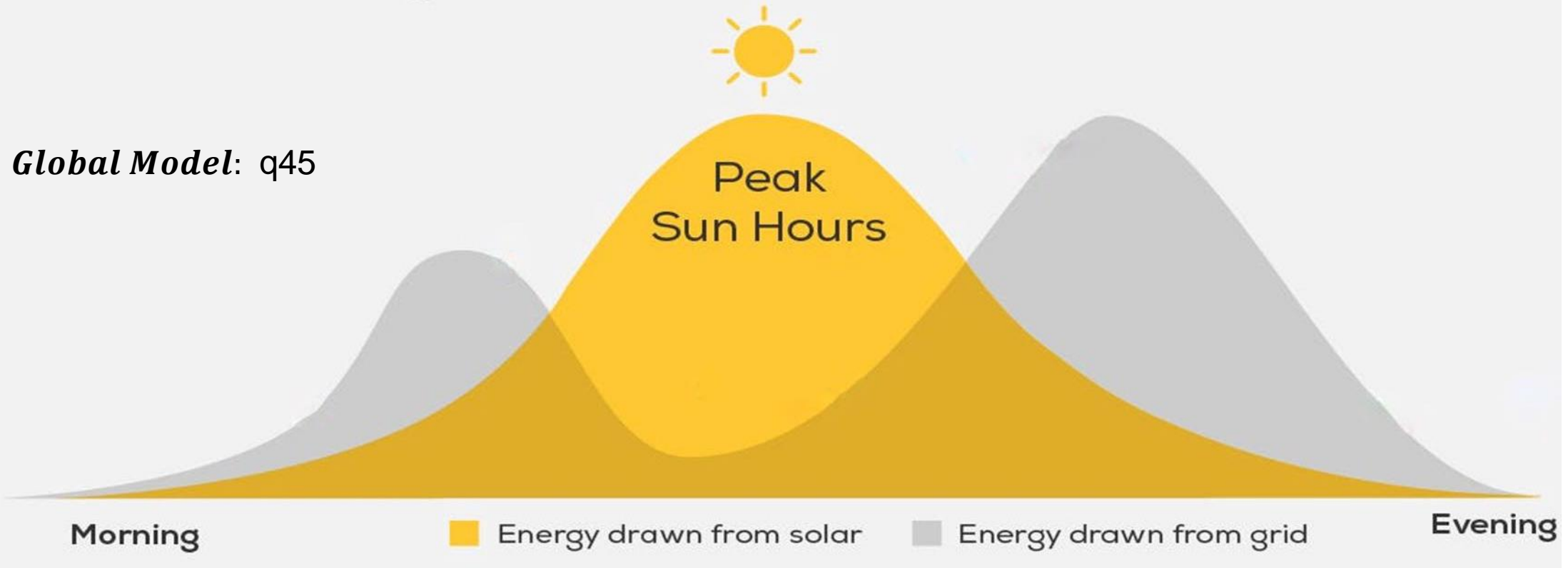
Revenue :
 $\Pi_{DA} \times p^E - \text{imbalance cost}$

Direct Approach



RESULTS - POLICIES

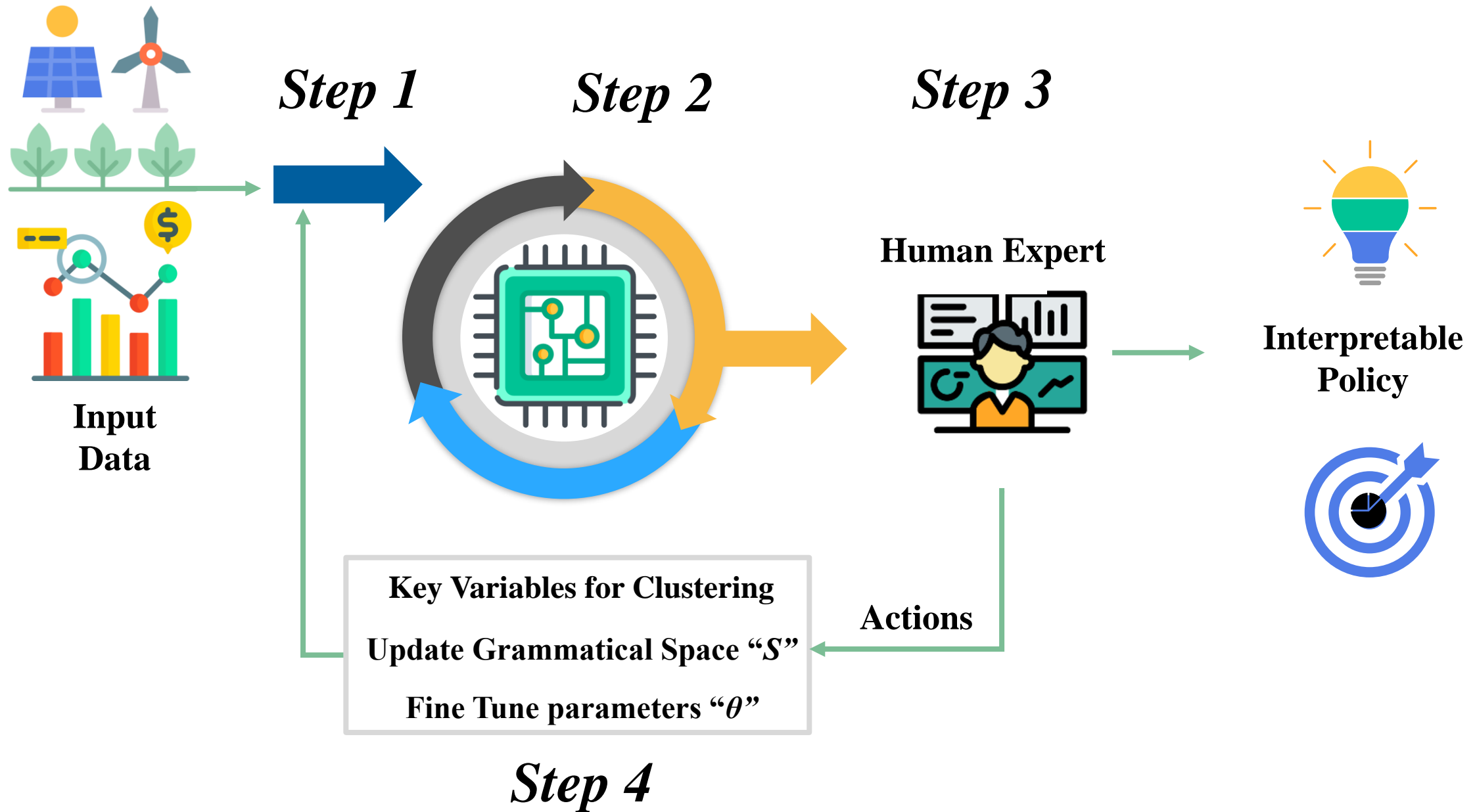
Energy Production vs Consumption



Local Model:

6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00
q60	q65	q65	q60	q45	q35	q40	q35	q30	q35	q65	q80	q85	q75	q55

RESULTS WITH HUMAN IN THE LOOP

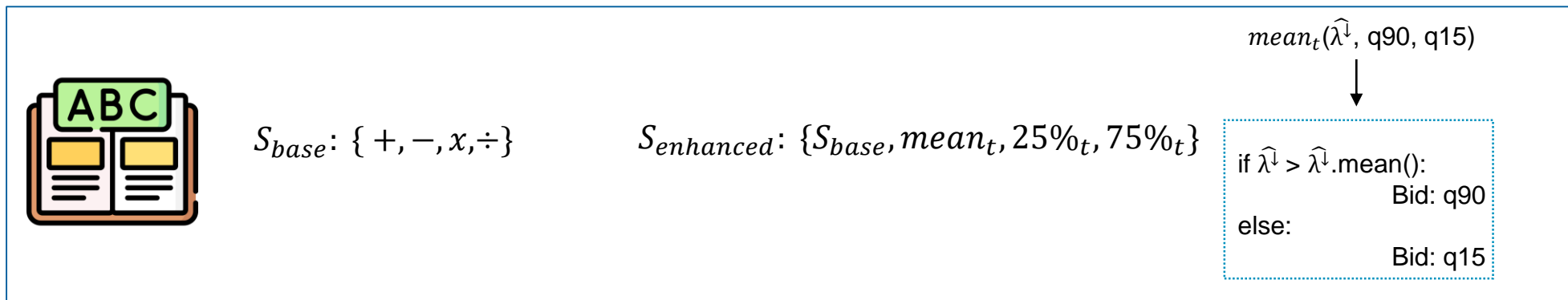
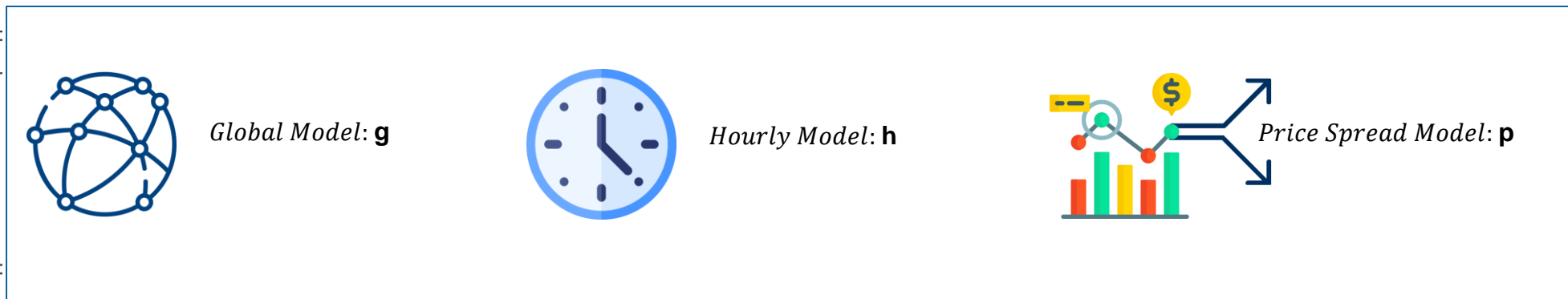


RESULTS WITH HUMAN IN THE LOOP

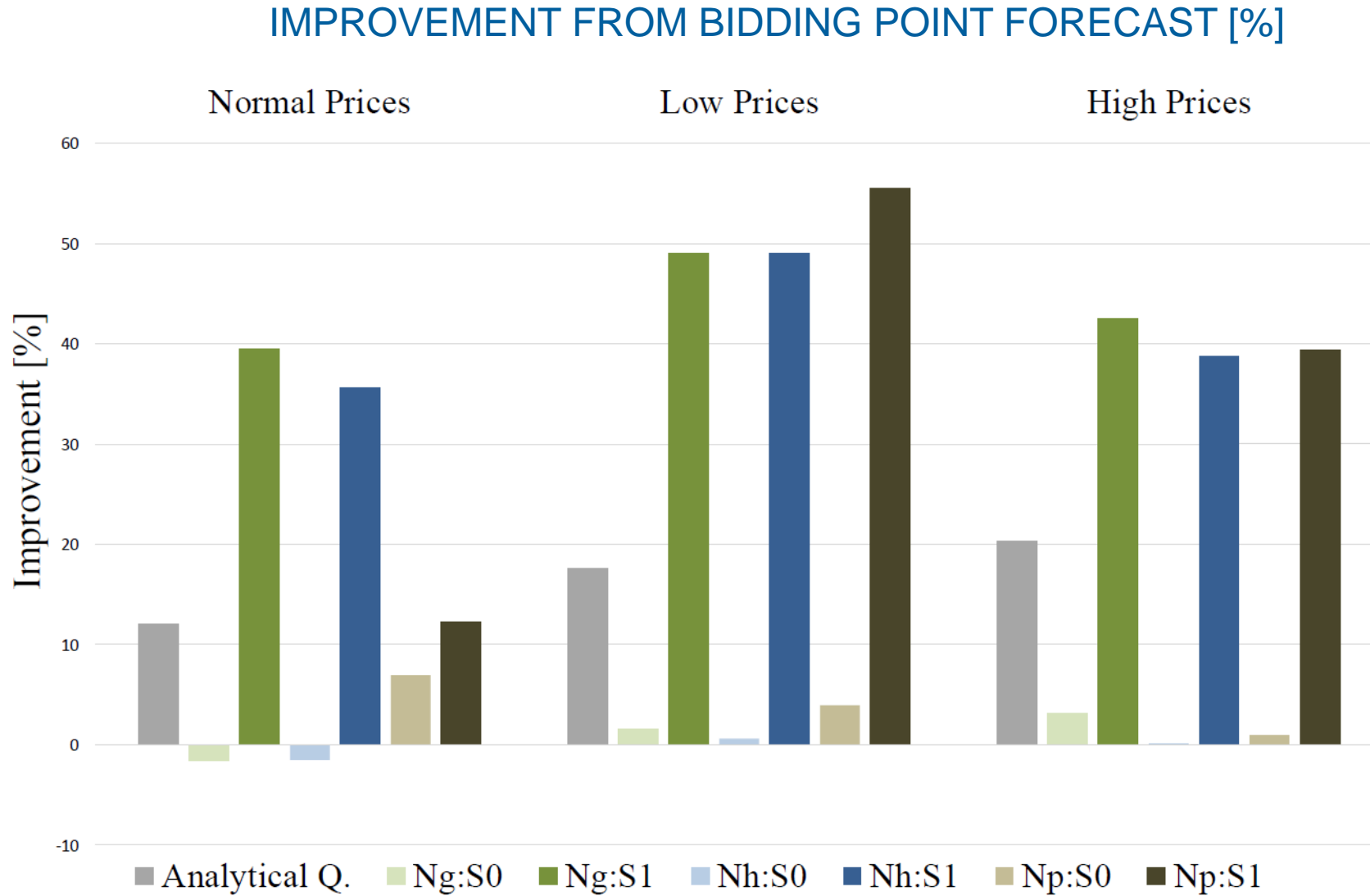
π^{da} METRICS FOR PRICE SCENARIOS [€/MWH]

	train			test		
	N	L	H	N	L	H
$\overline{\pi^{da}}$	54.15	44.22	169.91	62.90	47.04	142.08
$\sigma_{\pi^{da}}$	10.2	9.79	85.87	10.00	8.49	76.70

N Price	L Price	H Price
NgS0	LgS0	HgS0
NgS1	LgS1	HgS1
NhS0	LhS0	HhS0
NhS1	LhS1	HhS1
NpS0	LpS0	HpS0
NpS1	LpS1	HpS1

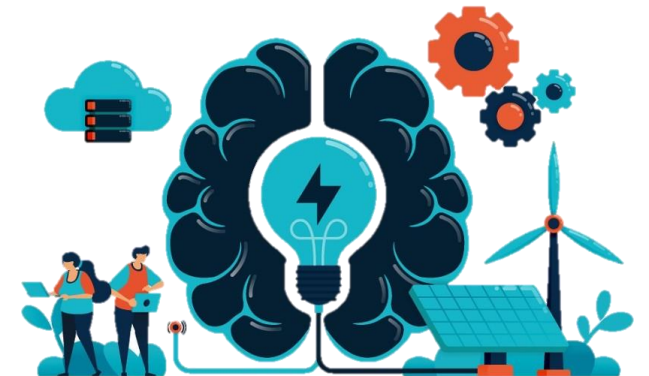


RESULTS - PERFORMANCE



CONCLUSIONS

- Interpretability of AI tools is an essential enhancement for applications to the energy sector
- EU regulation on AI will impose a dedicated framework for high-risk sectors such as energy systems
- A knowledge transfer of interpretability tools from other sectors to energy applications is needed
- We proposed an Interpretable method to the DA Trading Case study



THANK YOU!

Any questions ?

You can find me at:



[linkedin.com/in/konstantinos-parginos](https://www.linkedin.com/in/konstantinos-parginos)



konstantinos.parginos@minesparis.psl.eu



- [1] [K. Parginos](#), R. Bessa, S. Camal, G. Kariniotakis, **Interpretable data-driven solar power plant trading strategies**, IEEE ISGT, 2022
- [2] [K. Parginos](#), R. Bessa, S. Camal, G. Kariniotakis, **Towards increased interpretability of AI-tools in the energy sector with focus on the wind energy trading application**, poster and oral presentation at Wind Europe, 2022
- [3] F. Heyman, [K. Parginos](#), R. Bessa, M. Galus, **Operating AI systems in the electricity sector under European's AI Act – Insights on compliance costs, profitability frontiers and extraterritorial effects**, submitted to SEGN, 2022
- [4] F. Heyman, R. Bessa, [K. Parginos](#) et al., **Scarcity events analysis in adequacy studies using CN2 rule mining**, Energy and AI journal, 2022