Advancing Lead Oxide Battery Production

Integrating Machine Learning with Barton Reactor Operations

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Milan, Italy | 18.09.2024

BETTER BATTERY
BETTER WORLD

Continuous improvement is our core value, inspiring us every day to create a better tomorrow.

Jacek Bak

1950-2022
Founder of Autopart
Visionary Entrepreneur, Philanthropist,
Fascinator of Energy and Technology

AGENDA

The Next Generation

1. Company Presentation
2. Digitalization of Business, The Role of AI in Industry
3. Lead Oxide Production Journey
4. Lead Oxide Development Project
5. Further Implementations of Intelligent Solutions
6. Conclusions
7. Sources

Monika Bak

The Owner and President of the Board

COMPANY PROFILE

- A battery producer with **40 years of tradition**. **100%** Polish-owned, **100%** family-operated
- A major exporter in the battery industry, with **65%** of production being shipped to multiple continents
- A leading player in the domestic market, supplying **20%** of the batteries in Poland from the factory in Mielec
- Member of industry and business associations; laureate of awards for development and achievements

East Automotive Alliance

SPIAB Association of Producers and Importers of Accumulators and Batteries in Poland

BCC

Łukasiewicz Research Network

SCIENTIFIC COOPERATION:

Politechnika Poznańska

AGH

ICAN INSTITUTE

RZESZOW UNIVERSITY OF TECHNOLOGY

LA

KOZMINSKI UNIVERSITY

PRODUCTS OVERVIEW

BATTERIES

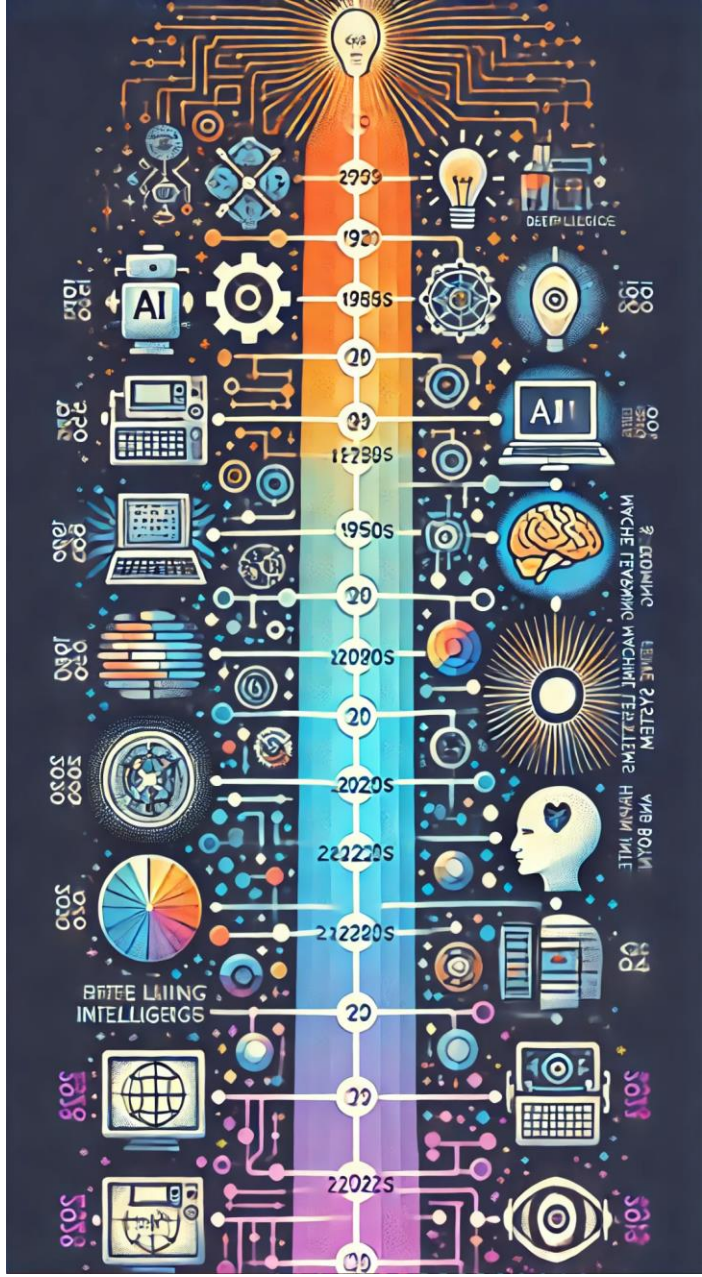
CAPACITY	TECHNOLOGIES	APPLICATIONS
26 Ah – 230 Ah	EFB, AGM, Deep Cycle, DUAL, GEL, SHD, EVR	Passenger cars, trucks, campers, boats, agro devices, tanks

ENERGY STORAGE SYSTEMS

TECHNOLOGIES	APPLICATIONS
Bipolar batteries, Bidirectional energy conversion module	Energy instalations (*photovoltaic, wind energy etc.)*

DIGITALIZATION OF BUSINESS, THE ROLE OF AI IN INDUSTRY

1950	**Early AI Foundations** Development of the first algorithms, such as those by Alan Turing, and work on symbolic AI, laying the groundwork for future AI research.
1960	**Machine Learning & Expert Systems** Rapid advancements in machine learning, including the creation of foundational algorithms and the rise of expert systems. These systems applied complex rules for decision-making in specific fields, such as medical diagnosis, and laid the foundation for future deep learning innovations
1990	**Deep Learning (DL)** Expansion of deep learning, driven by breakthroughs in neural networks and large datasets with multiple layers to model and understand complex patterns and relationships in data. It excels in tasks like image and speech recognition, natural language processing, and generative tasks by automatically learning features from raw data**.**
2020	**Generative AI** Development of generative AI models, such as GPT, capable of creating text, images, music, and other forms of art based on learned data.
2025	**Early AGI (Artificial General Intelligence)** Initial steps toward developing AGI, capable of understanding and performing tasks at a human level across multiple domains. Progress in context understanding, creativity, and adaptability. Fully developed artificial general intelligence will be capable of independent learning and performing a wide range of tasks at a human-like level.



Source: McKinsey & Company 2022, 2024; Calls9; Iqbal H. Sarker 2021

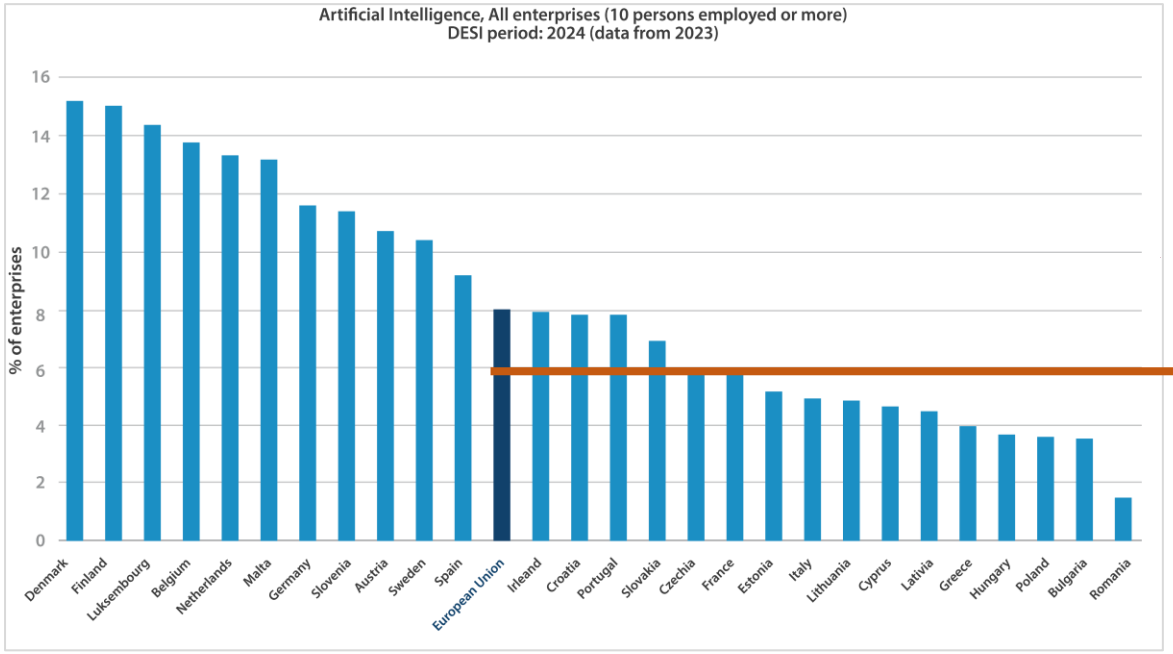
DIGITALIZATION OF BUSINESS, THE ROLE OF AI IN INDUSTRY

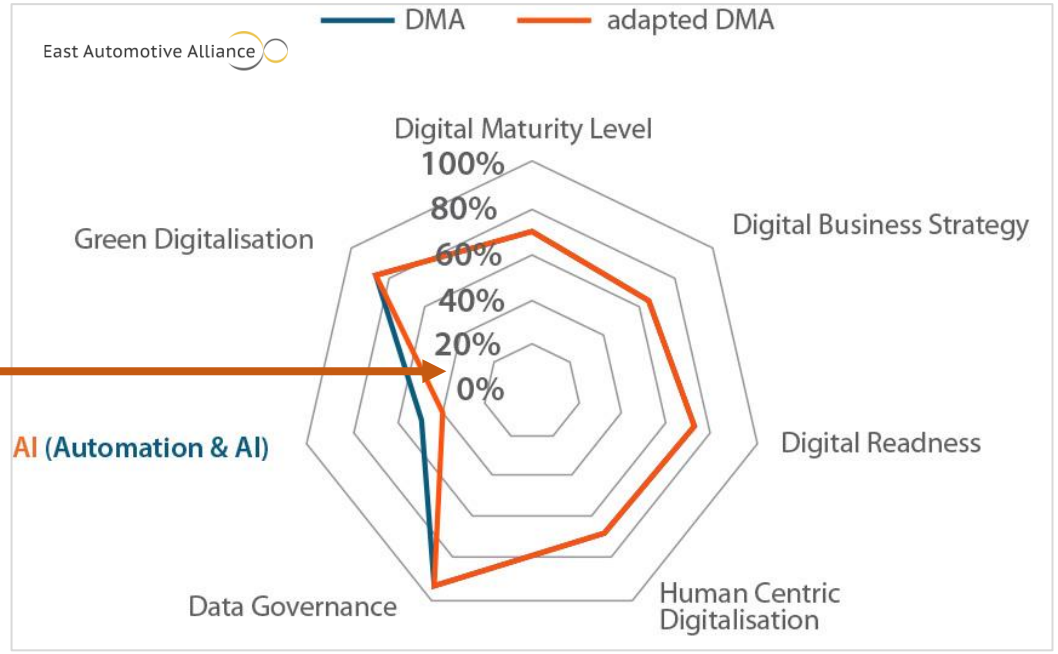
Europe's Digital Decade Program

- average: 8%
- target 75% → updated trajectory 17%

Digital Maturity in Automotive Companies within the East Automotive Alliance Cluster (Poland)

- average 38%





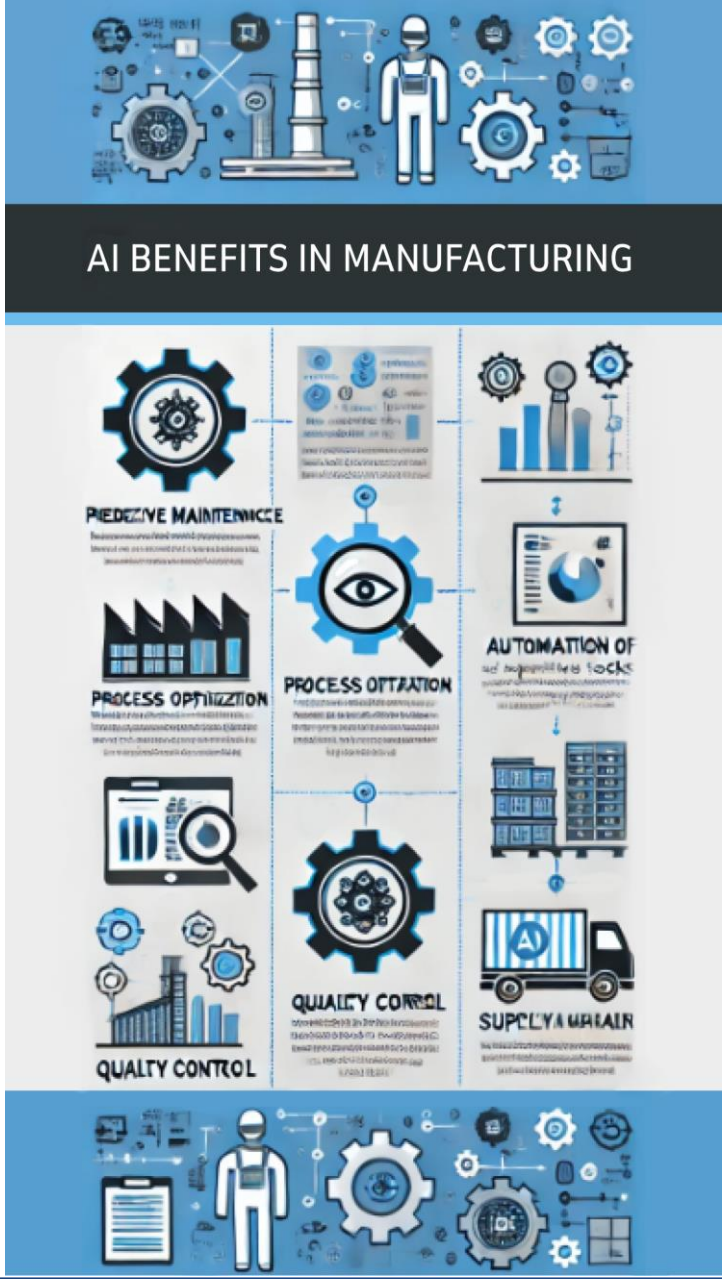
Definition: *Enterprises with 10 or more persons employed. All manufacturing and service sectors, excluding the financial sector. Measured as the percentage of enterprises using at least one AI technology, such as text mining; speech recognition; natural language generation; image recognition and processing; machine learning.*

Source: European Commission, Digital Decade in 2024

Source: Own research based on a survey using the Digital Maturity Assessment (DMA) Tool, 2024

DIGITALIZATION OF BUSINESS, THE ROLE OF AI IN INDUSTRY

Predictive Maintenance	AI predicts equipment failures by analyzing sensor data, allowing for proactive maintenance, reducing downtime, and cutting costs.
Process Optimization	AI optimizes manufacturing processes in real-time, improving efficiency, reducing costs, and enhancing resource utilization. Accelerates problem-solving by automating data analysis, unlocking 10-20% productivity gains in engineering teams.
Quality Control	AI enhances quality control by detecting defects more accurately than human inspectors, ensuring higher product standards and reducing waste.
Automation of Repetitive Tasks	AI automates repetitive tasks, increasing production speed, reducing errors, lowering labor costs, and improving workplace safety.
Supply Chain Management	AI improves supply chain efficiency by predicting demand, optimizing inventory, and enhancing logistics, leading to a more agile and responsive supply chain.
Improving Sustainability	AI helps reduce emissions by predicting energy consumption and emissions and identifying devices responsible for excessive consumption. It also optimizes process parameters and production sequences, which contributes to reducing emissions.
Financial Efficiency	Digitally mature companies achieve 6% more EBIT.



Source: Deloitte 2023; McKinsey & Company 2022; CTG 2023; West Monroe Partners 2024; Digitopia Research Team 2023; PWC 2022; World Economic Forum 2023; Deloitte 2023; DMA Tool, European Digital Innovation Hubs Network

AUTOPART'S LEAD OXIDE PRODUCTION JOURNEY

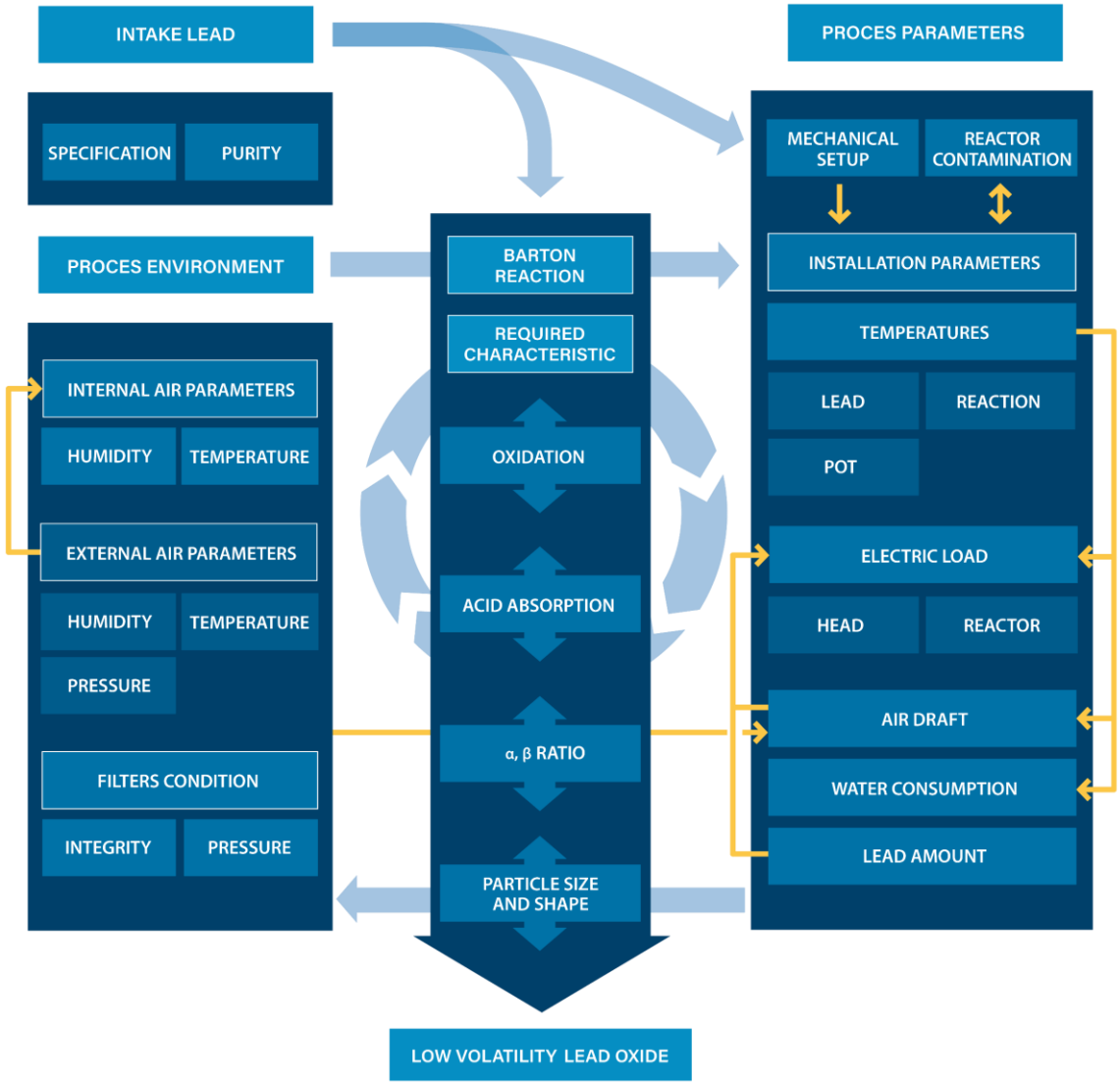
1995	**INITIAL INSTALLATION OF THE BARTON REACTOR**
2009	**CONSTRUCTION OF A NEW PRODUCTION HALL DEDICATED TO THE LEAD OXIDE MANUFACTURING**
2010	**INSTALLATION OF A NEW BARTON REACTOR (1200 KG/H)** Challenges: • unstable reactor operation • Insufficient (too low) absorption
2015	**INSTALLATION OF THE NEXT BARTON REACTOR (1200 KG/H)**

Source: Author's own sources

LEAD OXIDE PRODUCTION DEVELOPMENT PROJECT

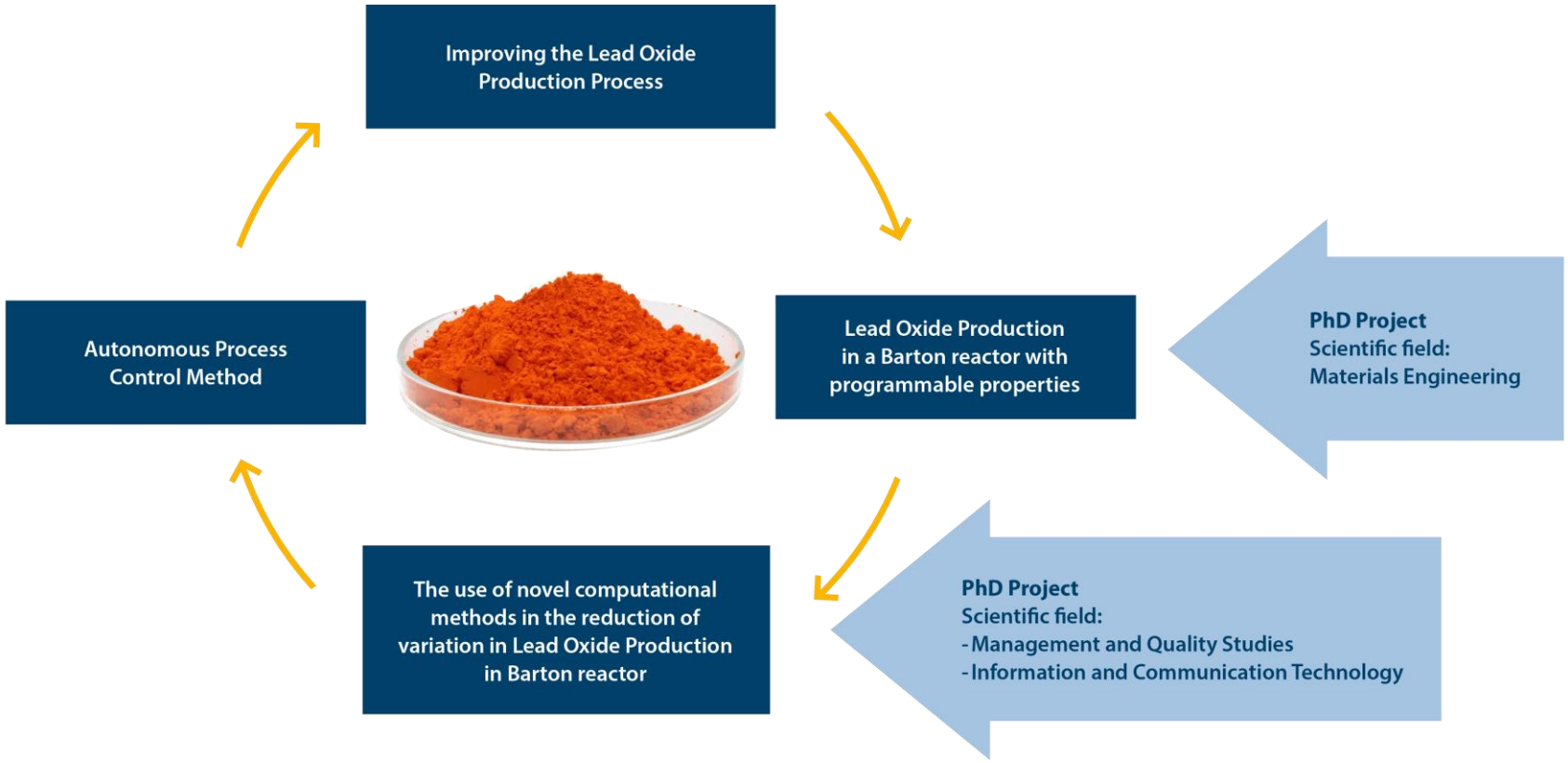
Challenges in reactor control:

- Nonlinear process
- Conjugate interactions between variables
- Sensitive to Environmental Changes
- Challenges in Ensuring a Consistent Supply of Homogeneous Alloy Raw Materials Over the Long Term
- The complexity of the variables makes it impossible to make quick decisions on settings without the aid of modern computational methods



Source: Author's own sources

LEAD OXIDE PRODUCTION DEVELOPMENT PROJECT

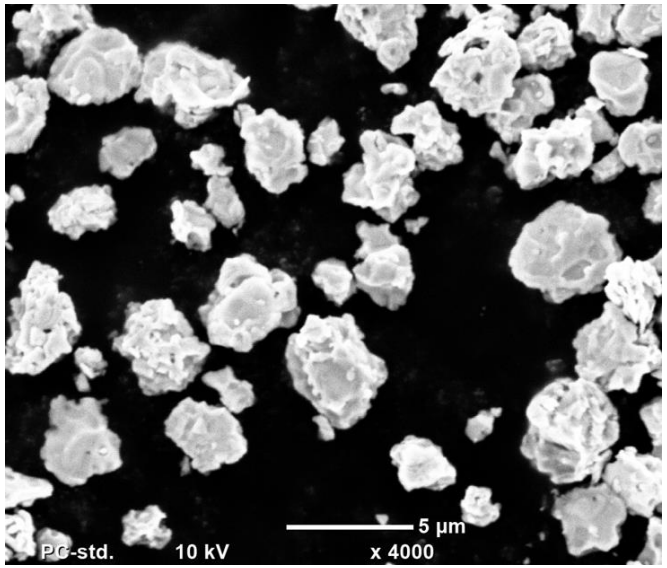


Source: Author's own sources

LEAD OXIDE PRODUCTION DEVELOPMENT PROJECT

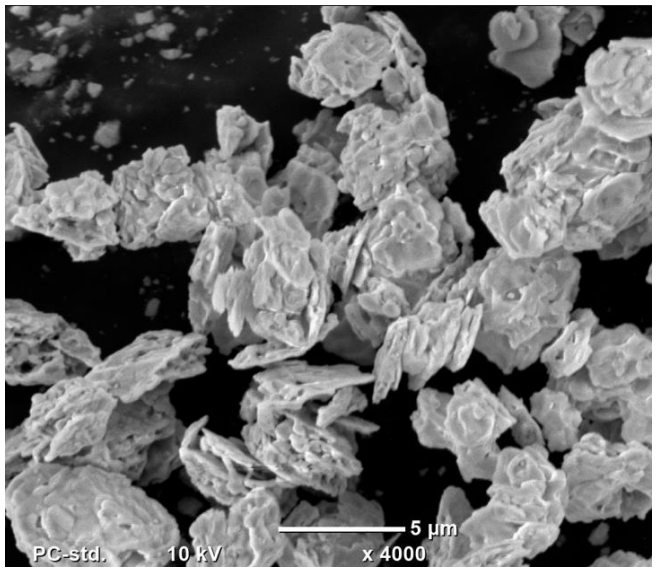
The impact of humidity lead oxide production process

- The particle size of the oxide produced under high humidity conditions is significantly smaller than when using low humidity air.



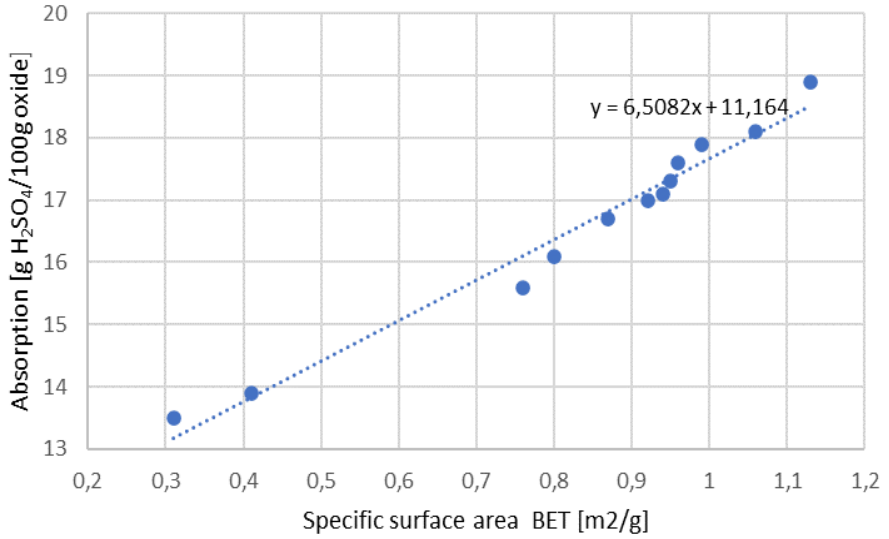
The structure of lead oxide at different humidity levels 59 – 61 %

- The oxide grains produced under elevated humidity conditions have a more developed specific surface area.



The structure of lead oxide at different humidity levels 19 – 21 %

- The specific surface area of the obtained lead oxide is closely related to absorption. As absorption increases, the specific surface area increases.

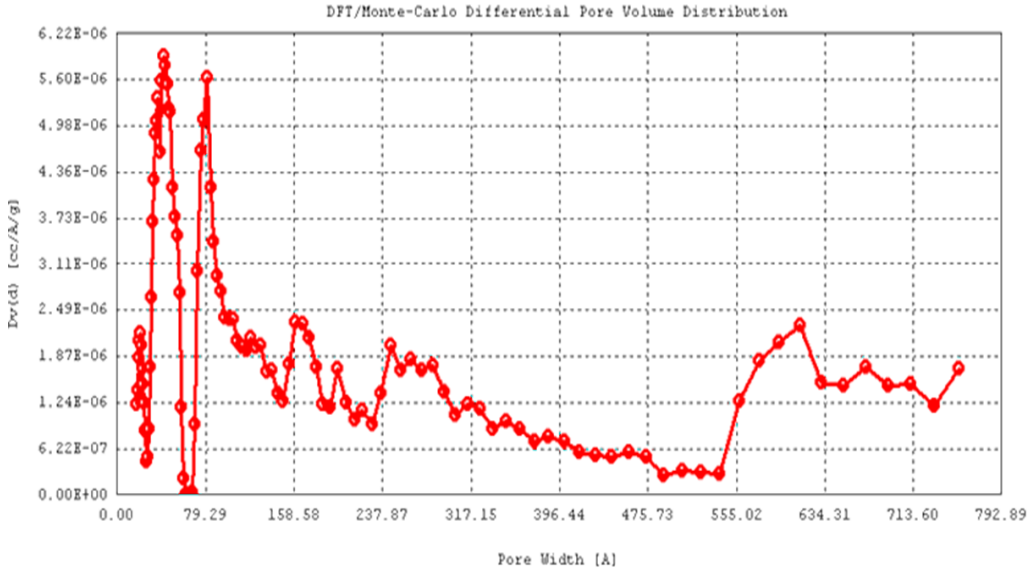


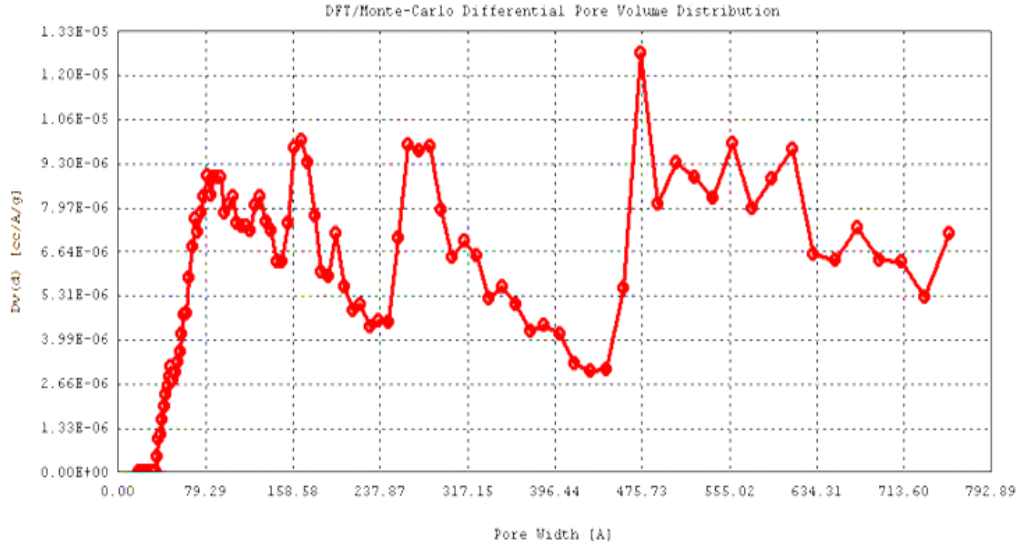
Source: R. Szela 2024

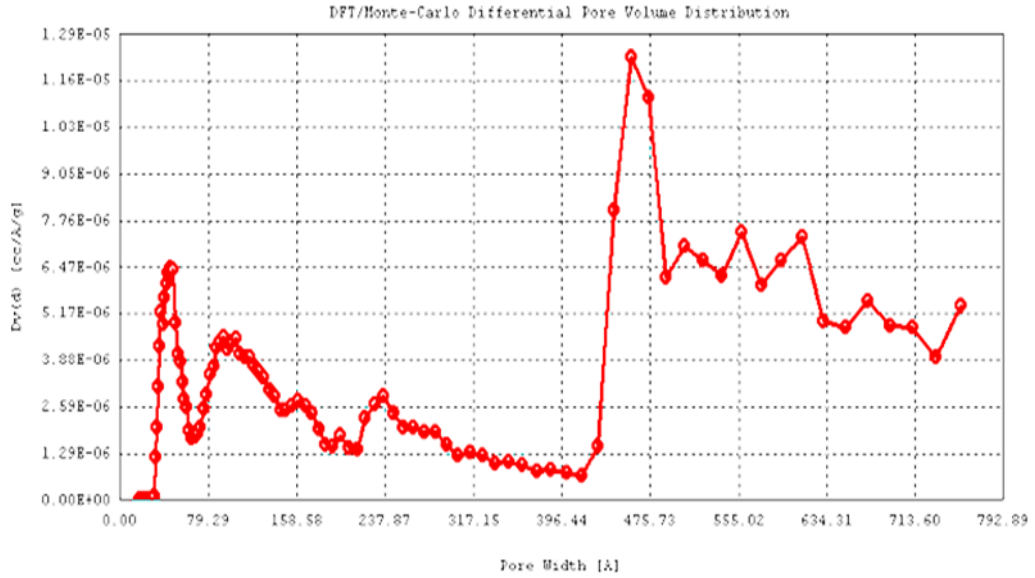
LEAD OXIDE PRODUCTION DEVELOPMENT PROJECT

The largest quantity of pores in lead oxide particles

For the analyzed samples, multiple peaks are observed on the pore size distribution graphs, indicating the presence of pores of varying sizes. This suggests that the samples are heterogeneous with respect to pore size. The quantity and size of these pores influence the shape and specific surface area of the lead oxide particles.







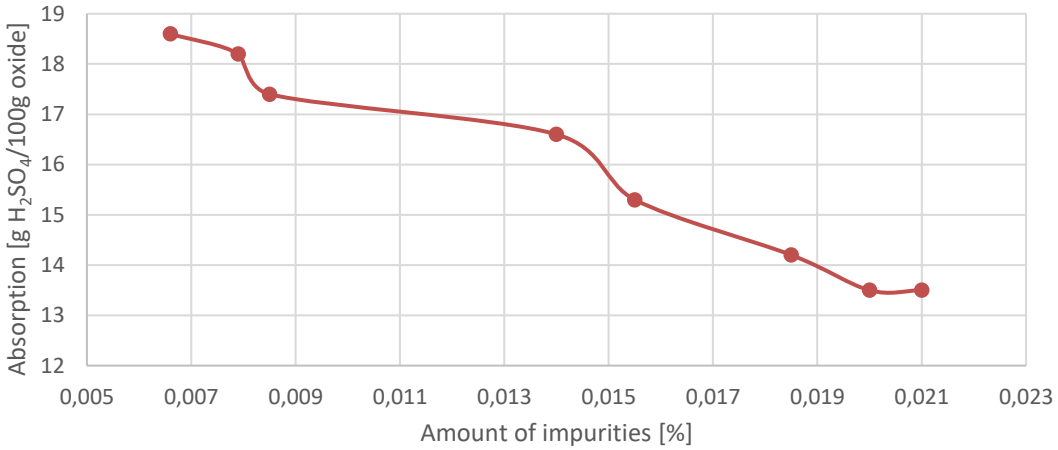
Graphs of the dependence of the number of pores on the particle size [own work]

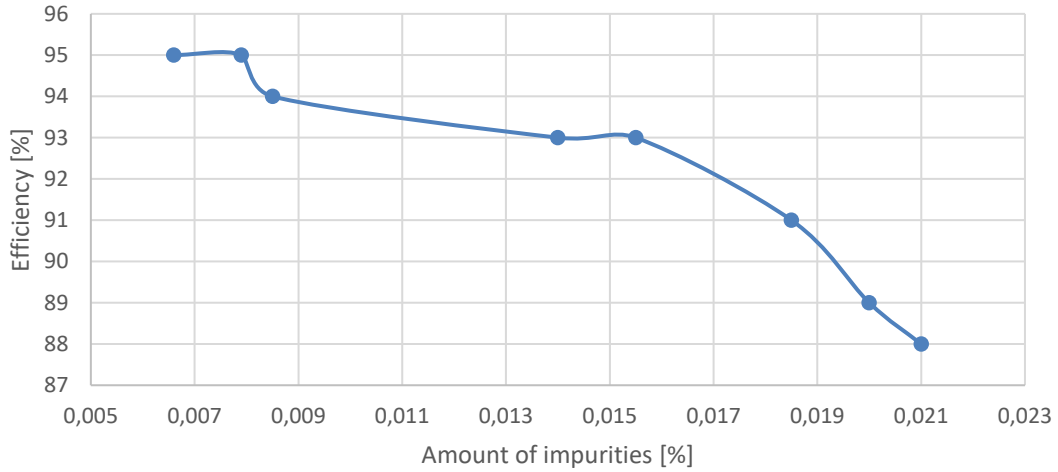
Source: R. Szela 2024

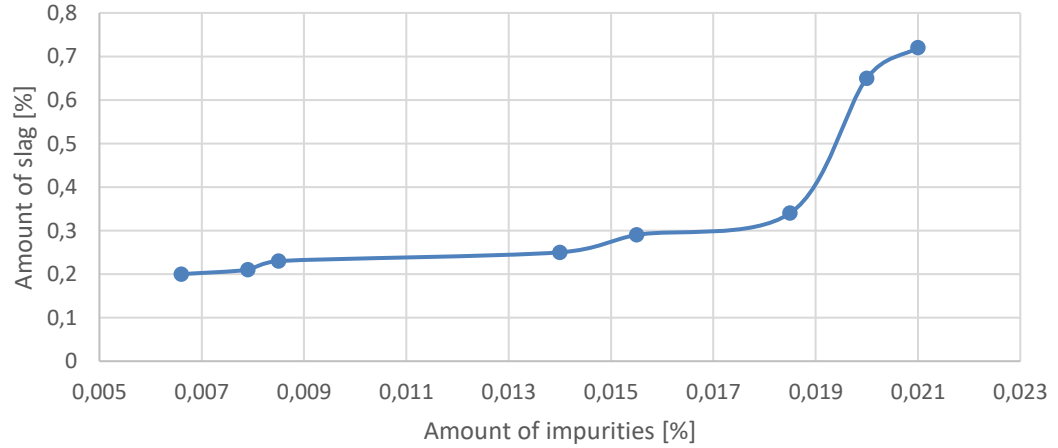
LEAD OXIDE PRODUCTION DEVELOPMENT PROJECT

The impact of lead purity on the production process

- Reduction in process efficiency
- Decrease in the specific surface area of the produced oxide
- Absorption decline
- Increased reactor load during production (=higher costs)
- Unstable reactor operation
- Increase in slag quantity

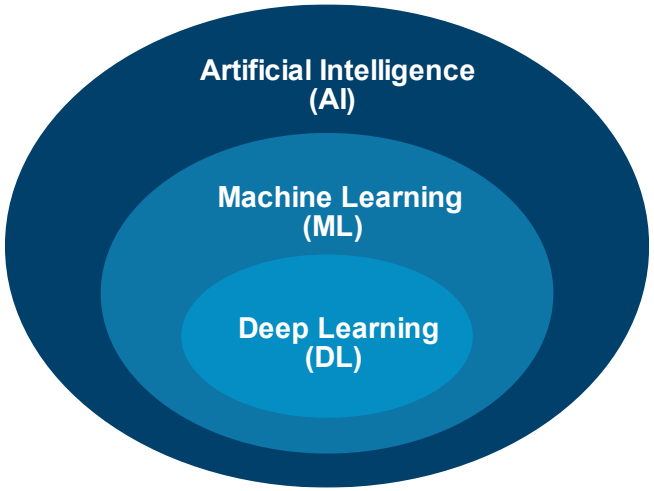






Source: R. Szela 2024

LEAD OXIDE PRODUCTION DEVELOPMENT PROJECT



Machine Learning

is a subset of Artificial Intelligence tht enables systems to automatically learn and improve from experience without being explicity programmed

Key applications

- Value prediction
- Forecasting
- Pattern recognition
- Feature engineering

Types

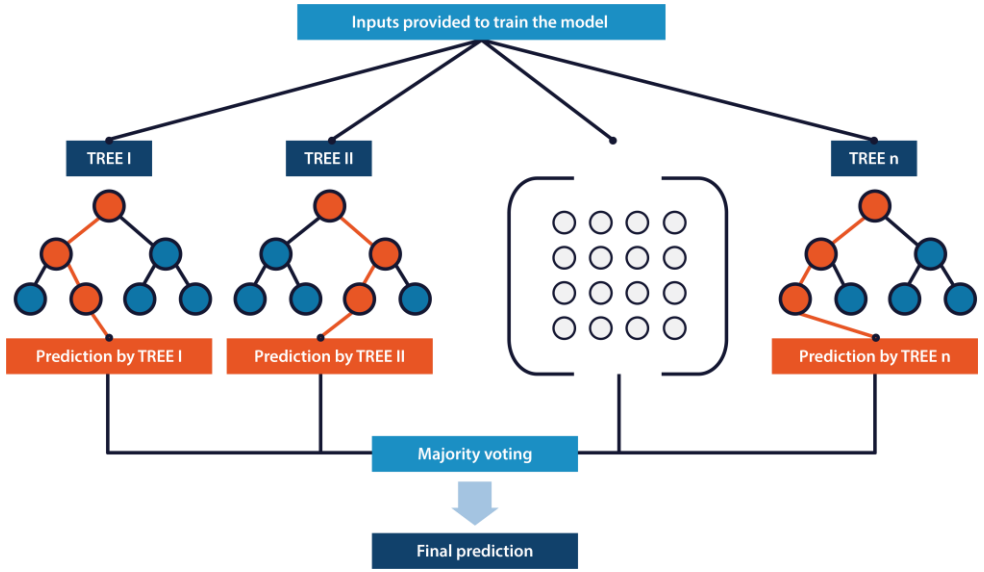
- **Supervised** — Learns from labeled data
- **Unsupervised** — Identifies patterns in unlabeled data
- **Reinforcement** — Learns through rewards and penalties

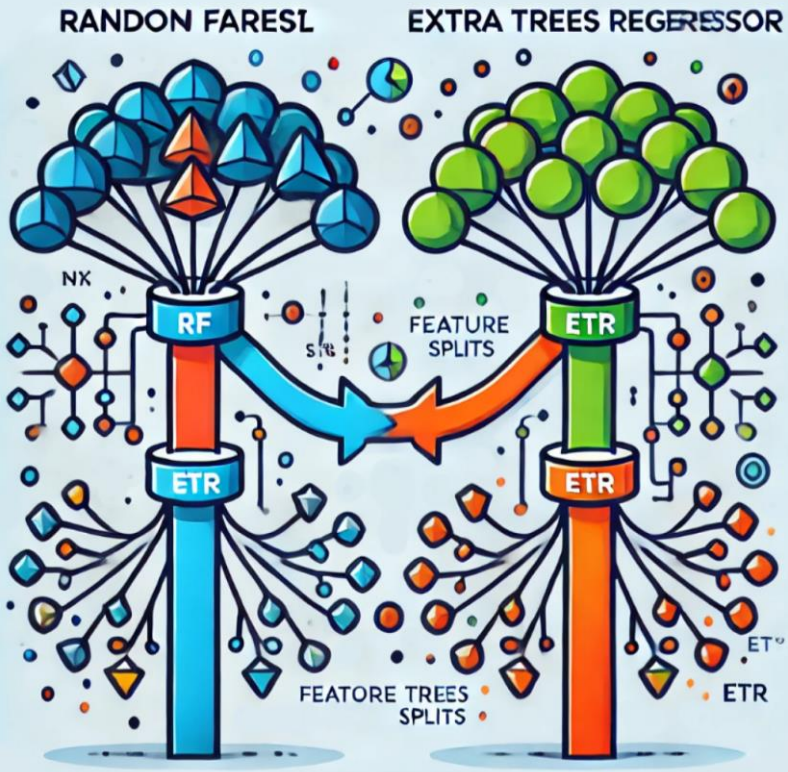
Source: R. Mazur 2024, Iqbal H. Sarker 2021

LEAD OXIDE PRODUCTION DEVELOPMENT PROJECT

AUTOPART Machine Learning Combined Model

SVM, Random Forest (RF) – Extra Trees Regressor (ETR)





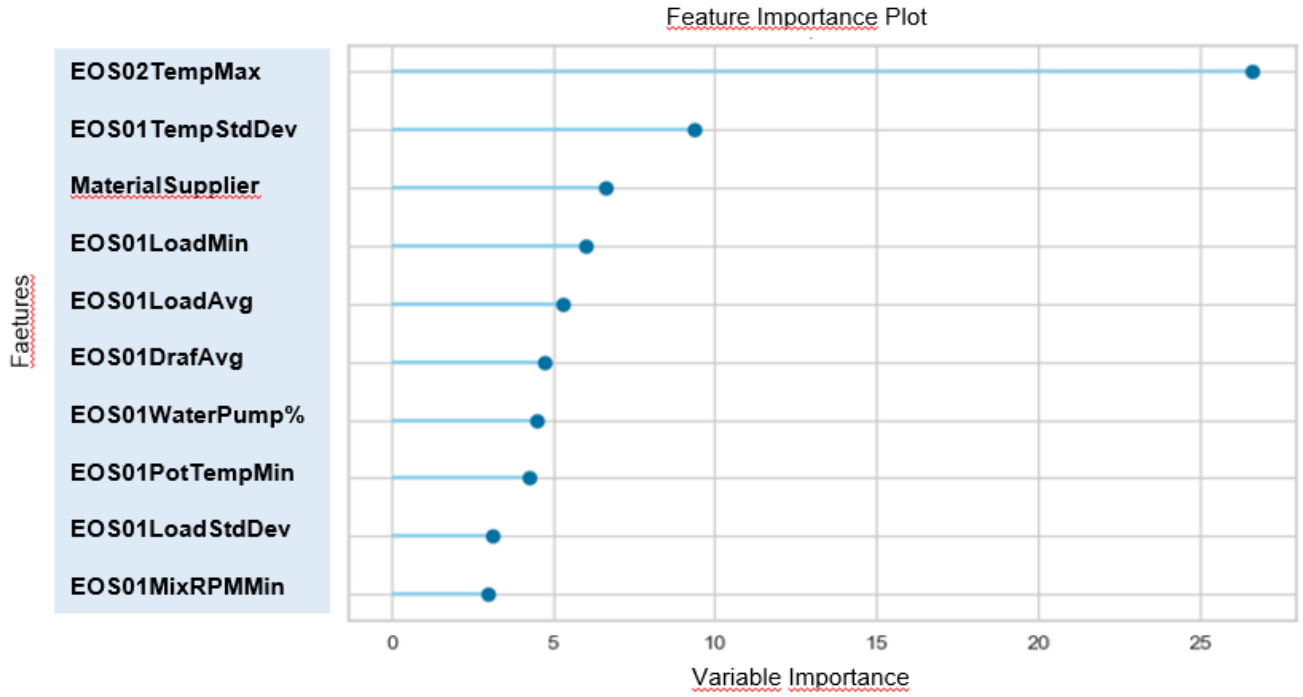
The combination of models enables:

- Combining models for parallel prediction to reduce model errors
- Ability to use models independently

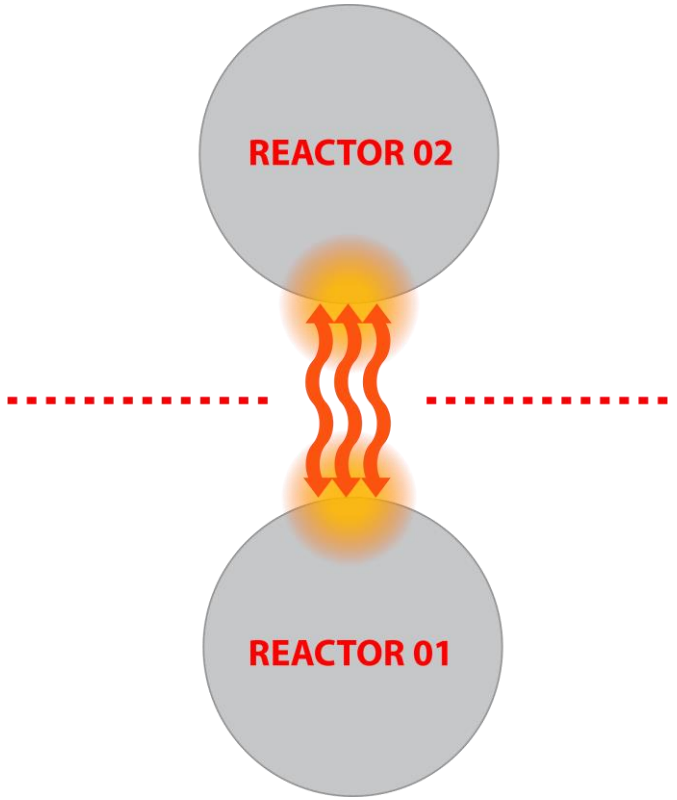
- Many implemented models enable predictions based on the available data and dependent variables

LEAD OXIDE PRODUCTION DEVELOPMENT PROJECT

Feature selection – Chosen elements



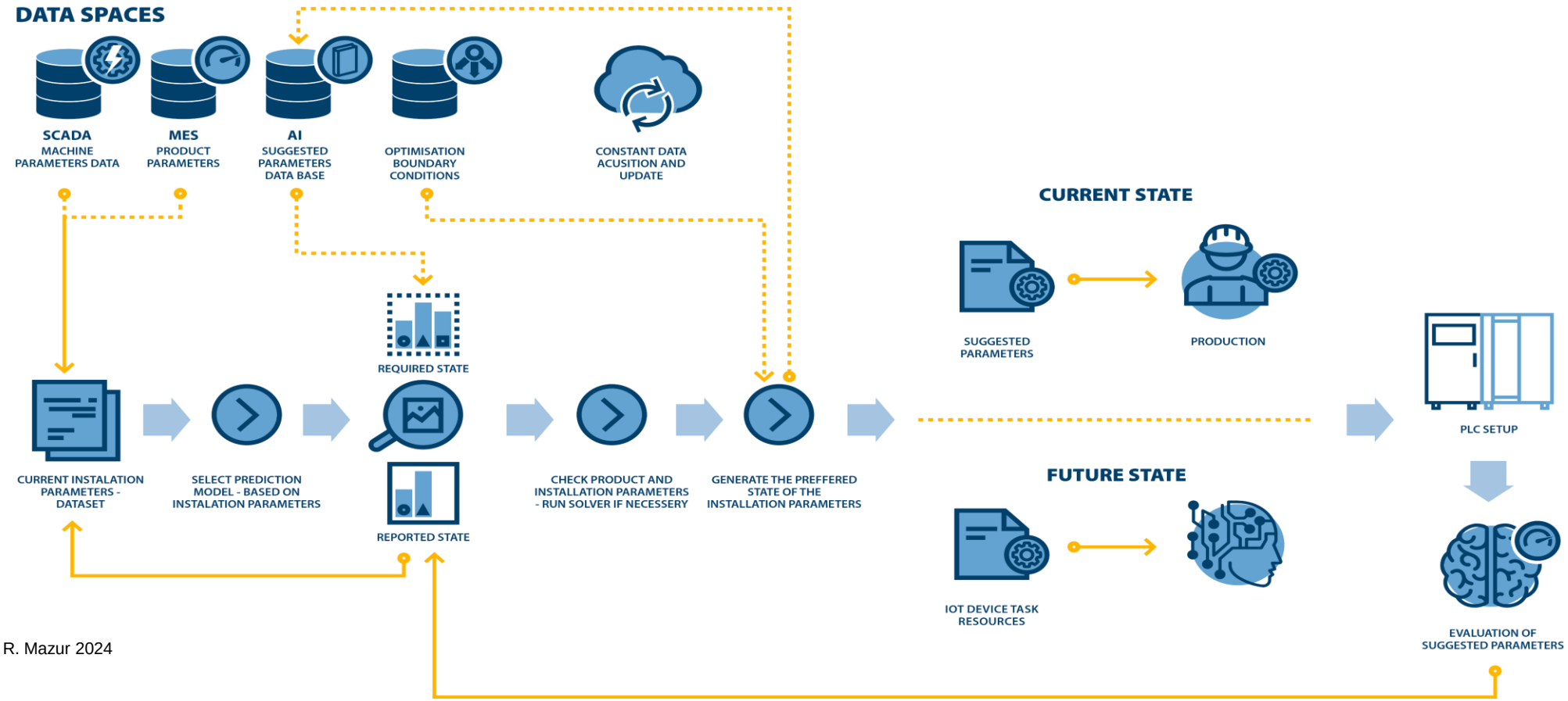
Source: R. Mazur 2024



Advanced feature engineering enables the identification of variables that may not be immediately obvious but are crucial.

LEAD OXIDE PRODUCTION DEVELOPMENT PROJECT

Simplified Decision process for Barton Reactor Setup



Source: R. Mazur 2024

LEAD OXIDE PRODUCTION DEVELOPMENT PROJECT

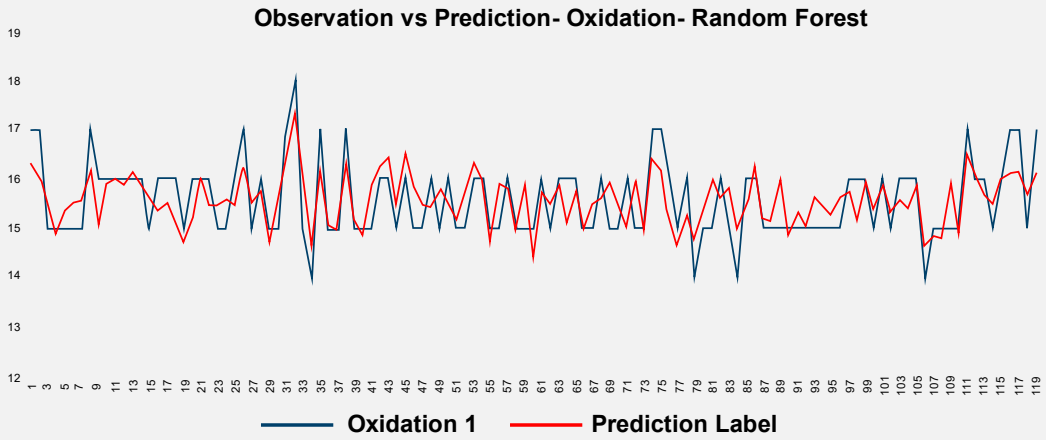
EXAMPLE OF MODEL FITTING RESULTS – OXIDATION EOS01

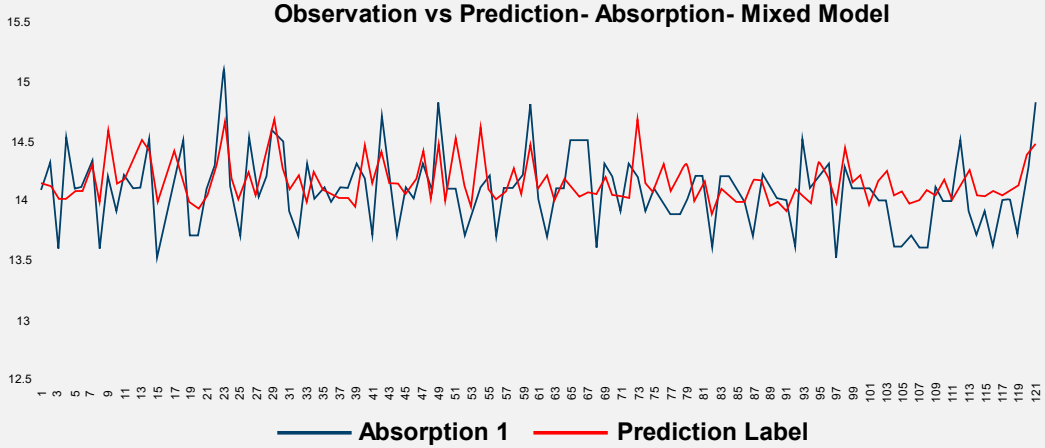
Model	MAE	MSE	RMSE	R2	RMSLE	MAPE
Random Forest Regressor	0.9969	1.575	1.2518	0.7358	0.0166	0.0133
CatBoost Regressor	1.02	1.6004	1.2592	0.7261	0.0166	0.0136
Extra Trees Regressor	1.0064	1.5794	1.2532	0.7251	0.0166	0.0134
Orthogonal Matching Pursuit	1.0228	1.7127	1.3017	0.673	0.0172	0.0136
Bayesian Ridge	1.0219	1.7152	1.3024	0.6723	0.0172	0.0136
Lasso Regression	1.0271	1.7249	1.3062	0.6663	0.0173	0.0137

OVERALL SUMMARY OF DEVELOPED MODELS:

MAPE – LESS THAN 1,5 %
R^2 – MORE THAN 73 %
MODELS FOR ABSORPTION AND OXIDATION WELL
ADOPTED FOR MAJOR CHANGES IN PROCESS
HIGH-LEVEL GENERALIZATION -
AVOIDING OVERFITTING

Source: R. Mazur 2024





FURTHER IMPLEMENTATIONS OF INTELLIGENT SOLUTIONS – PROPRIETARY DESIGN PROJECTS

1

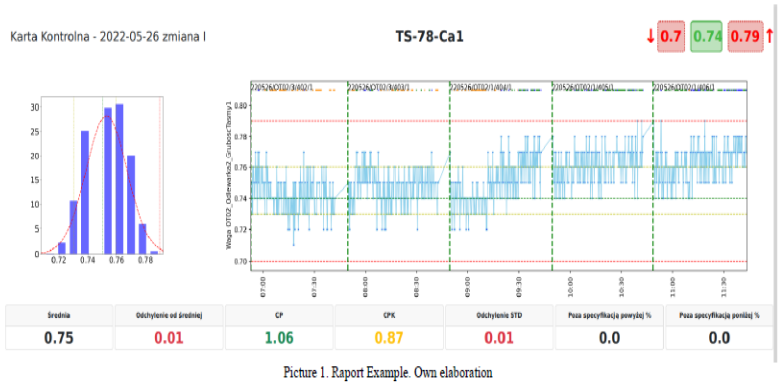
The use of the DNN YOLO architecture in analyzing transport operations within intralogistics processes

Figure 6: Sample frames saved by application

Source: Own elaboration

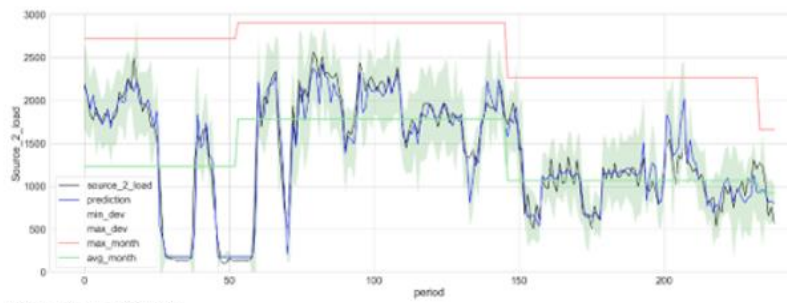
2

Automation of the SPC reporting process using data from industrial automation collected in MES/SCADA database systems



Picture 1. Raport Example. Own elaboration

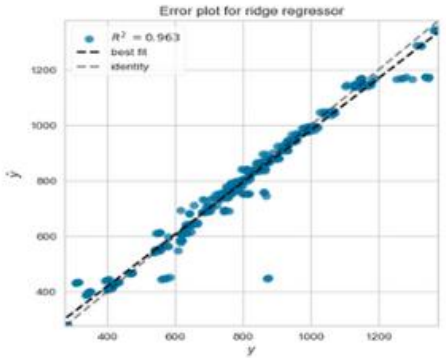
SOURCE_2 average load prediction with confidence interval



Source: Own elaboration

3

Computational methods for forecasting electrical power demand



4

Prediction of CCA based on measurements obtained from the HRD test

Source: Author's own sources

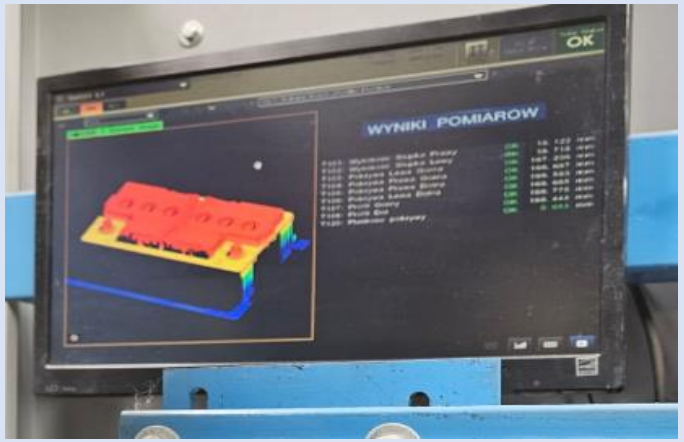
FURTHER IMPLEMENTATIONS OF INTELLIGENT SOLUTIONS

1

Visual assessment of the accuracy of enveloping

2

Profilometric assessment of the accuracy of lid assembly and terminal welding



3

Visual inspection of the linearity of the box edges

4

The use of industrial cameras to monitor the proper use of personal protective equipment

CURRENT PROJECT

Source: Author's own sources

CONCLUSIONS

1.One of the key parameters influencing the lead oxidation process and the properties of the resulting lead oxide is air humidity. High humidity plays a crucial role in achieving high-quality oxide and positively impacts the technological parameters of the process.

2. The influence of lead impurities on the oxidation process and the quality of the resulting product has been observed. Within the studied range of impurity levels, these impurities significantly affect the reactor load, process efficiency, the amount of lead processed per unit of time, and the quantity of slag produced.

3.The hybrid model used to predict absorption and oxidation results, considering factors such as humidity and lead type, achieved high accuracy rates (MAPE < 1.5%, R^2 > 73%). This demonstrates its effectiveness in adapting to process changes and minimizing errors.

4.AI tools offer opportunities to enhance various operational processes within a company and can serve as a significant source of competitive advantage.

5.The development of AI-related competencies requires incorporating the company's digitalization roadmap into the organizational strategy.

6.The primary focus for minimizing the risk of modeling ineffectiveness should be on automating the processes for acquiring prediction object values.

7.One of the barriers to AI development in the industry is the anticipated high investment costs. However, the example of AUTOPART demonstrates that leveraging existing infrastructure and proprietary solutions can enable the cost-effective development of AI tool

SOURCES

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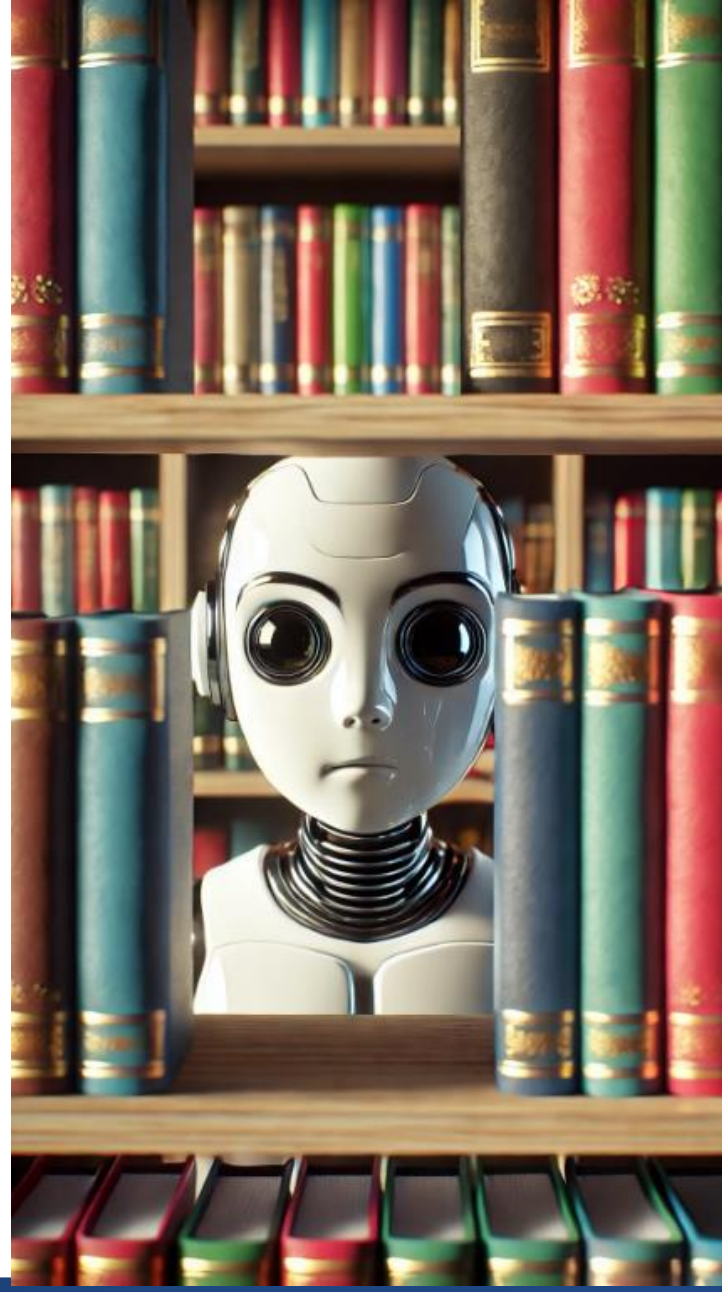

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