

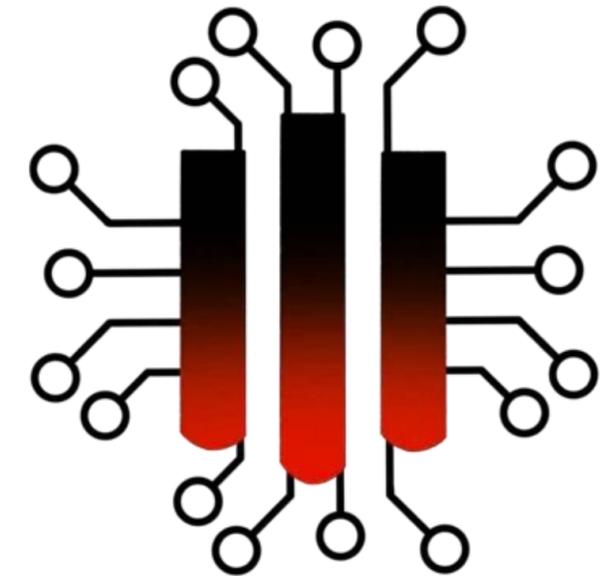
ESTEP 2025 Annual Event

28-30 October 2025
Udine (ITALY)

How decarbonisation, digitisation
and circular solutions forge the
sustainable European steel future?

Philemon Adeyemi
Ahmed Alduwayb
Julia Kulpa
Leonidas Spandagos

DI-TRODE: AN AI-POWERED APPROACH TO SECURING THE FUTURE OF ELECTRODES IN THE STEEL INDUSTRY



DI-TRODE: SECURING 1ST PLACE AT THE 2025 RACE EVENT AND THE AUDIENCE AWARD



The Di-Trode team



Philemon

- Bsc Mechanical Engineering
- 2nd year META 4.0 student
- Aim: to apply data-driven approaches and Industry 4.0 technologies to improve the efficiency of the steel industry

Duwayb

- BSc in Materials Science and Engineering, currently
- MSc Smart Industry Engineering
- Materials, Metals & Data

Julia

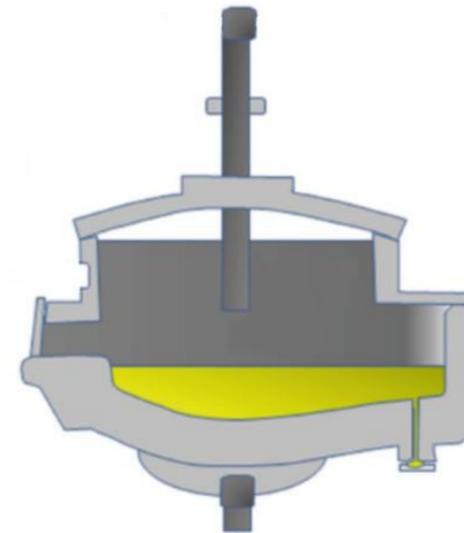
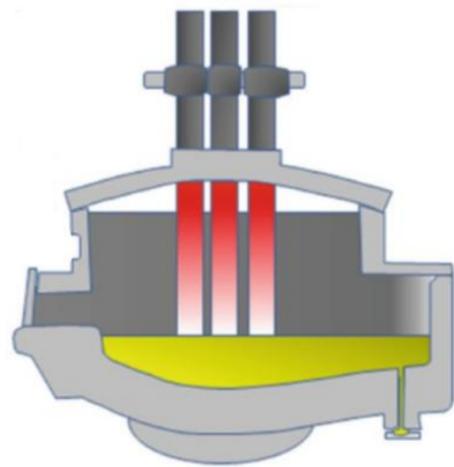
- BSc Chemistry, currently 2nd year SINReM student
- Innovation Consultant intern at PNO Innovation
- Aims to use data-driven solutions to improve steel industry

Leonidas

- Bsc Industrial Engineering
- ML engineering at Sense Space informatics
- Wants his steel to be greener and cheaper

Steel Industry in 2050

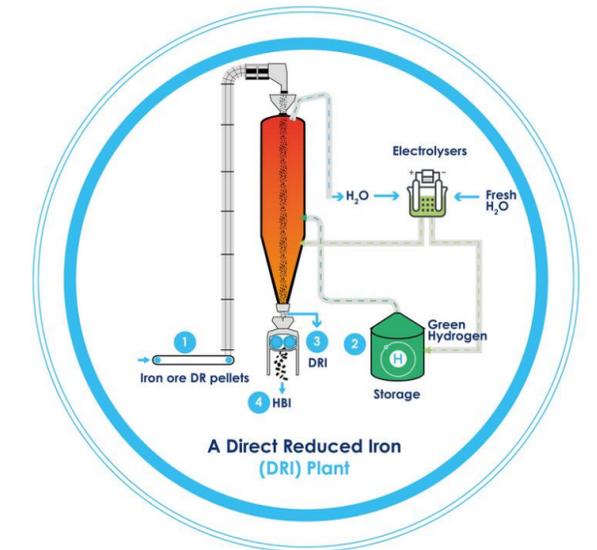
Will the Electric Arc Furnace (EAF) be the future of steelmaking?



EAF ~ 60 %¹



Scrap



DRI



Electrodes

1. Net Zero Steel Initiative transition strategy model (2021). Steel production by technology – feasible decarbonization scenario

Graphite electrodes

Synthetic graphite demand



EAF ~ 60%
by 2050

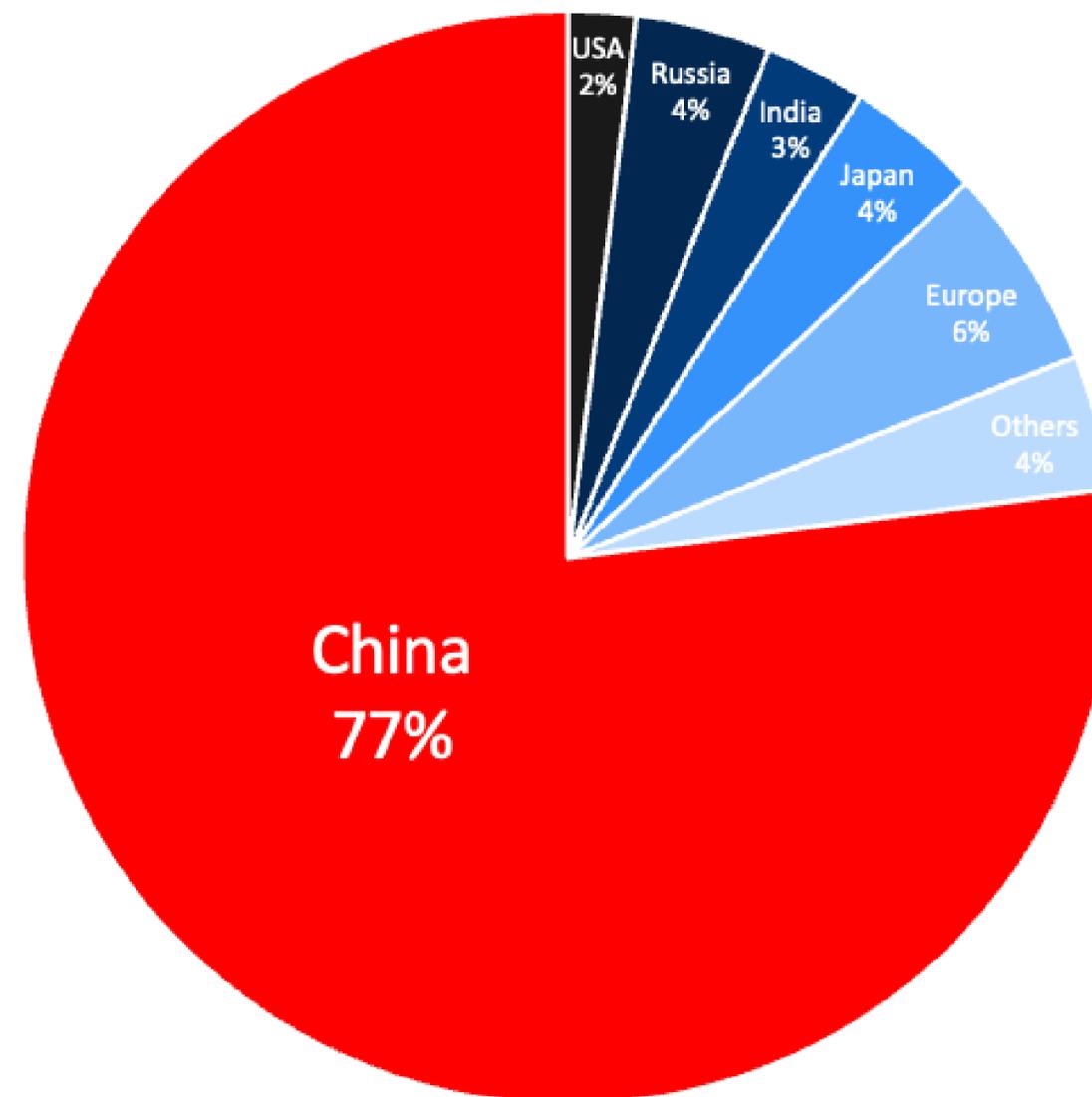


500 %
increase in
graphite
demand for
EAF by 2050¹



Competition
from other
industries
(batteries)

Synthetic graphite supply forecast 2028²



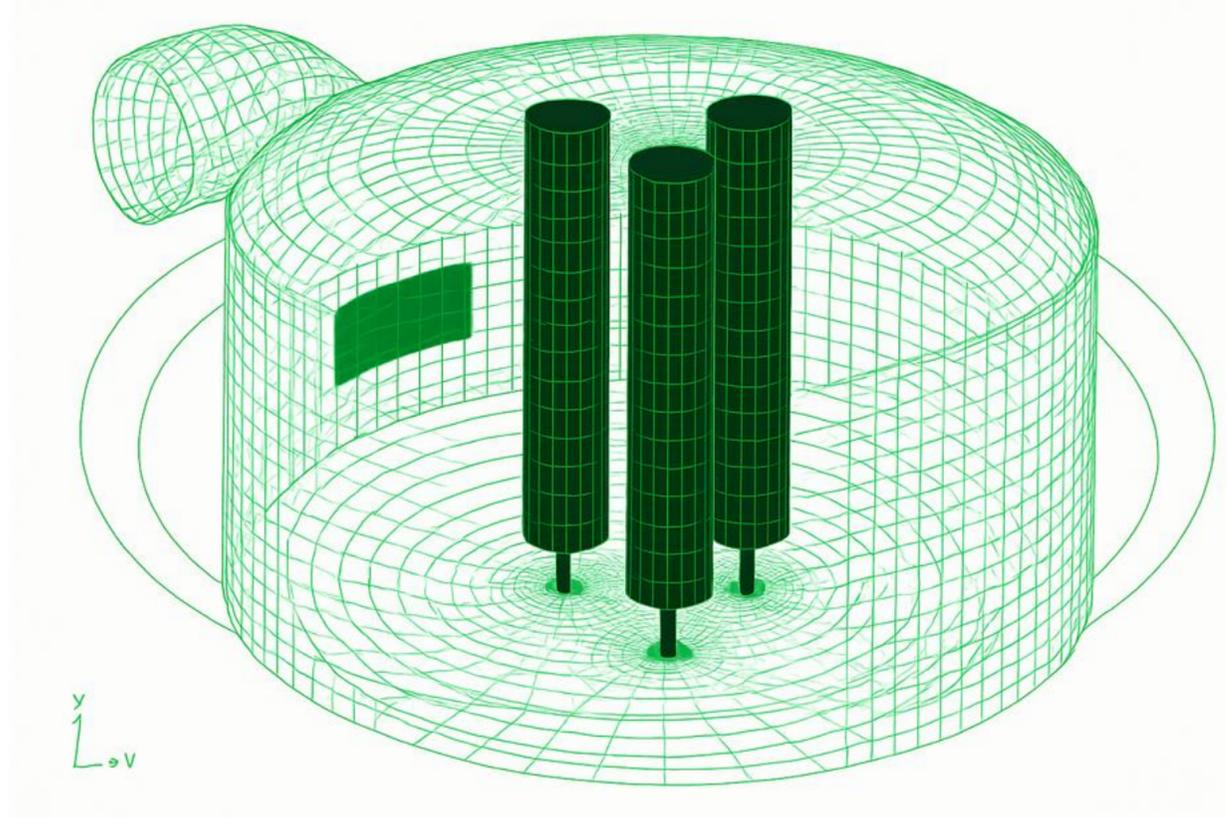
1. Ritoe et al. (2022). Graphite. Supply chain challenges & recommendations for a critical mineral

2. ECGA (2025). Safeguarding Steel Technology in Europe: The Case of Synthetic Graphite.

Graphite electrodes

How to secure the future of the electrodes in the steel industry by 2050 using novel AI-solutions?

Electrode Digital Twin Platform: Di-Trode



Digital Twin of the Electrode

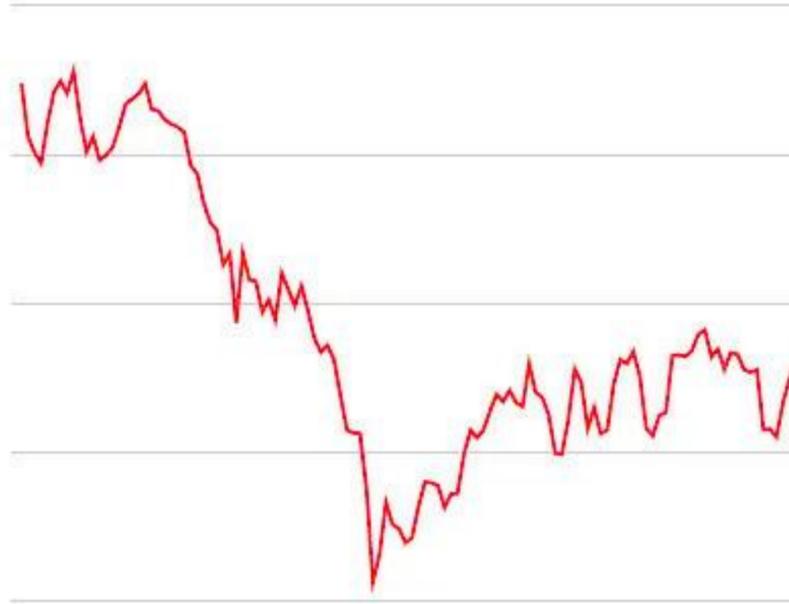
- A simulation of the electrode
- Models price, consumption & failure



Agent training

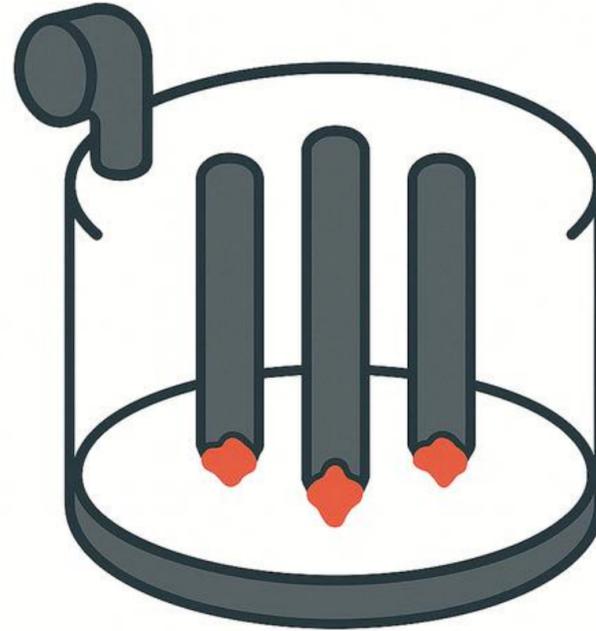
- Agent tries millions of strategies
- Find trends
- Suggest optimizations

Implementation Stages



Stage 1: Scarcity Estimation

- TRL3
- Price prediction
- Lstm NN architecture
- Historic price data
- Stock market data (coke, oil)



Stage 2: Consumption Prediction

- TRL2
- Sensor data
- Physics model
- NN architecture



Stage 3: Failure Prediction

- TRL2
- Similar pipeline
- Focus on historical data

Electrode Consumption

2.3 kg/t

-8.2% vs target

Energy Consumption

485 kWh/t

+3.1% vs target

Failure Probability

12%

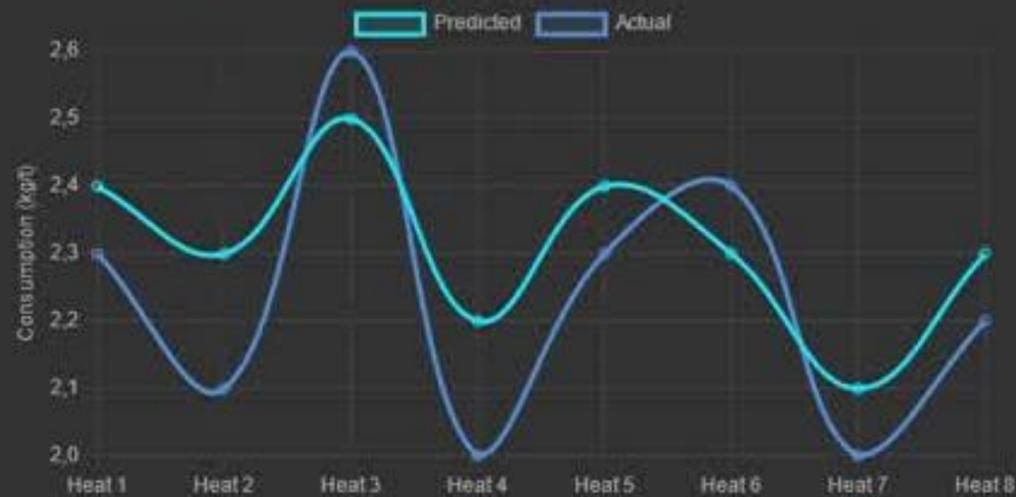
-2.8% vs last week

Cost per Ton

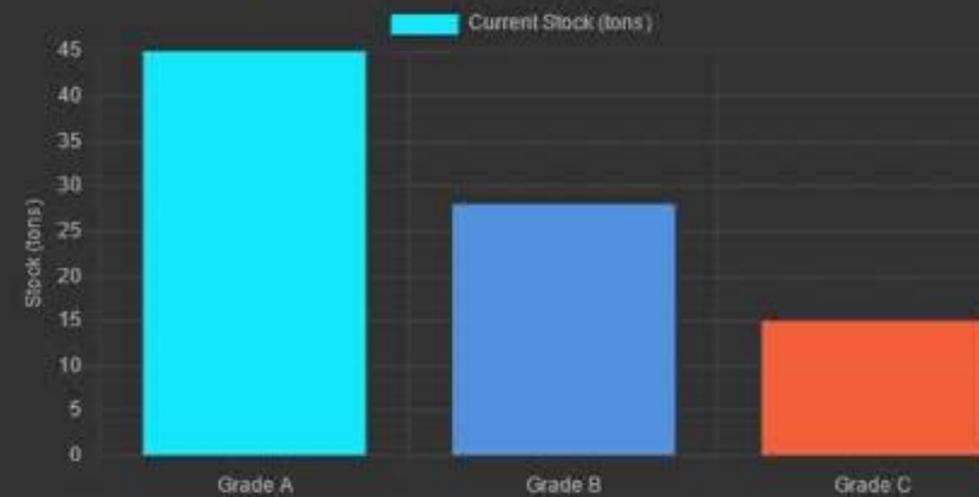
€18.4

-€1.2 vs target

Predicted vs Actual Consumption

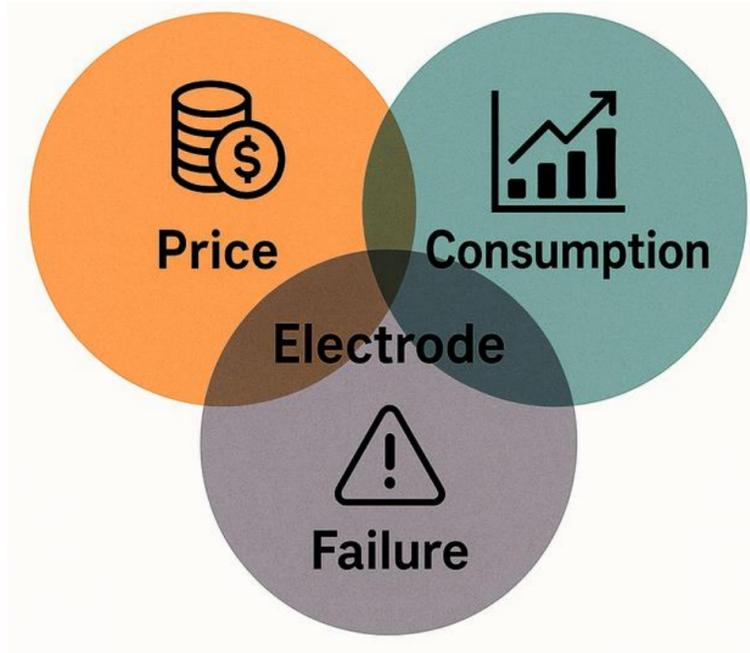


Inventory Snapshot

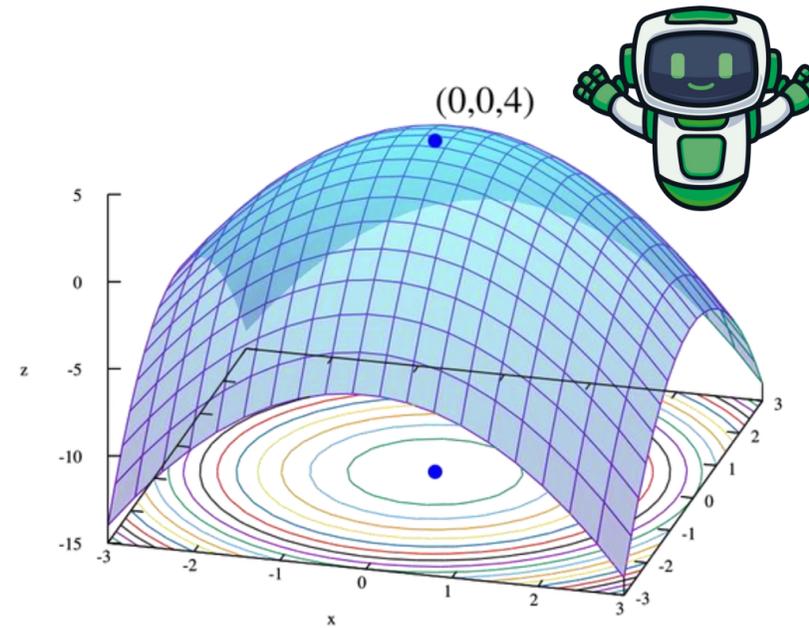


Quick Insights

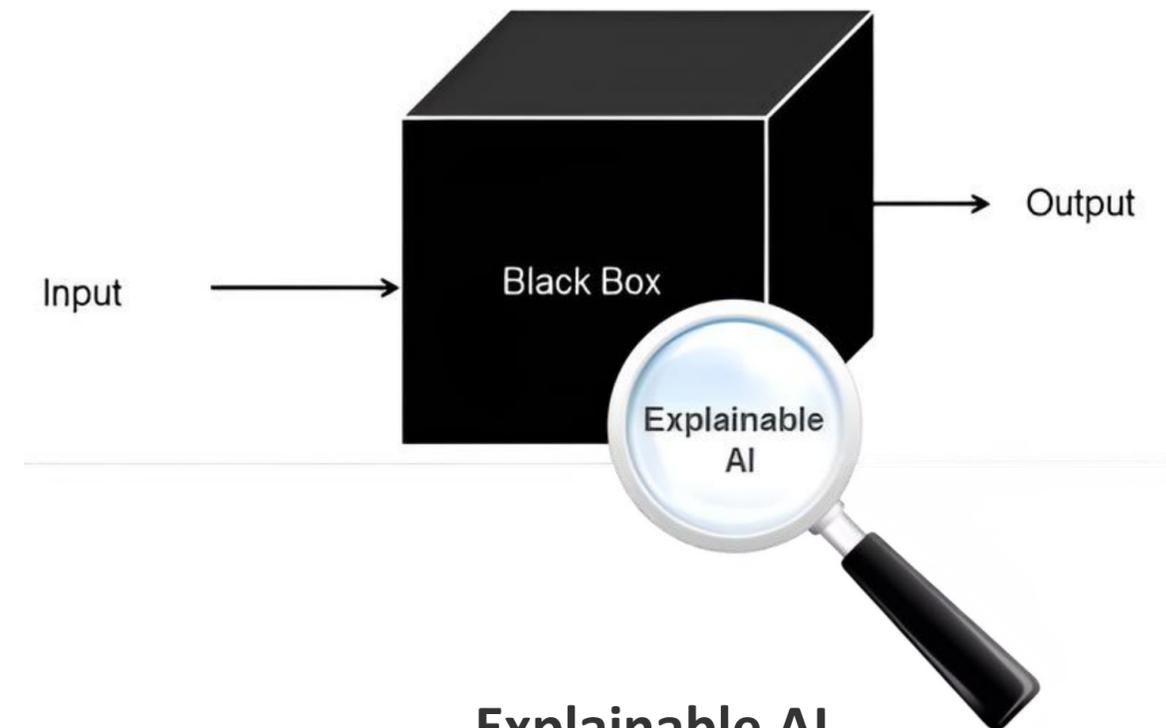
Innovative Edge



Holistic electrode simulation



Not just a digital twin:
optimization agent



Explainable AI

Value proposition



**Resilience to the
supply crisis and
market
competition**



**Advanced
optimization**



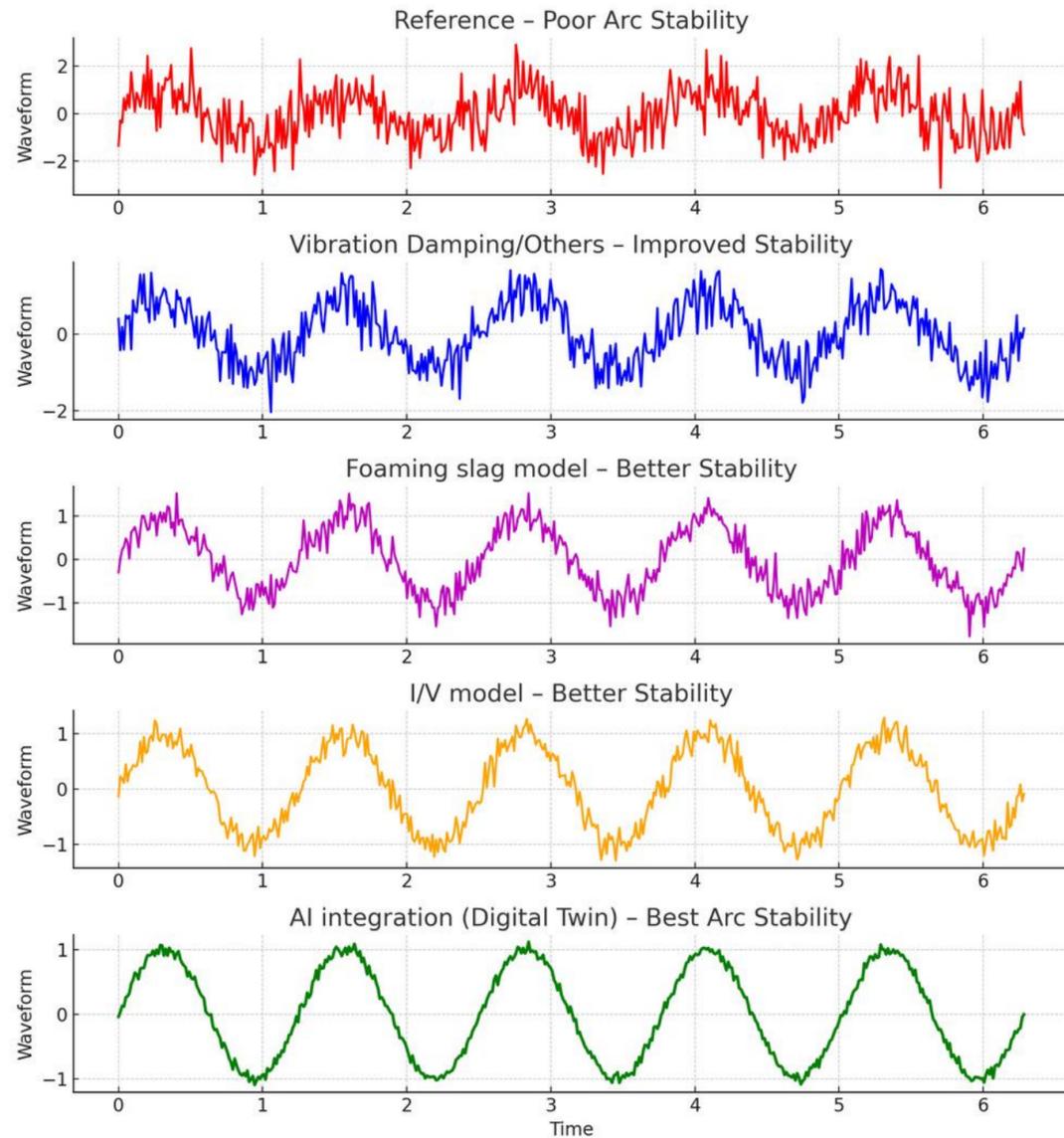
**Cost
reduction**



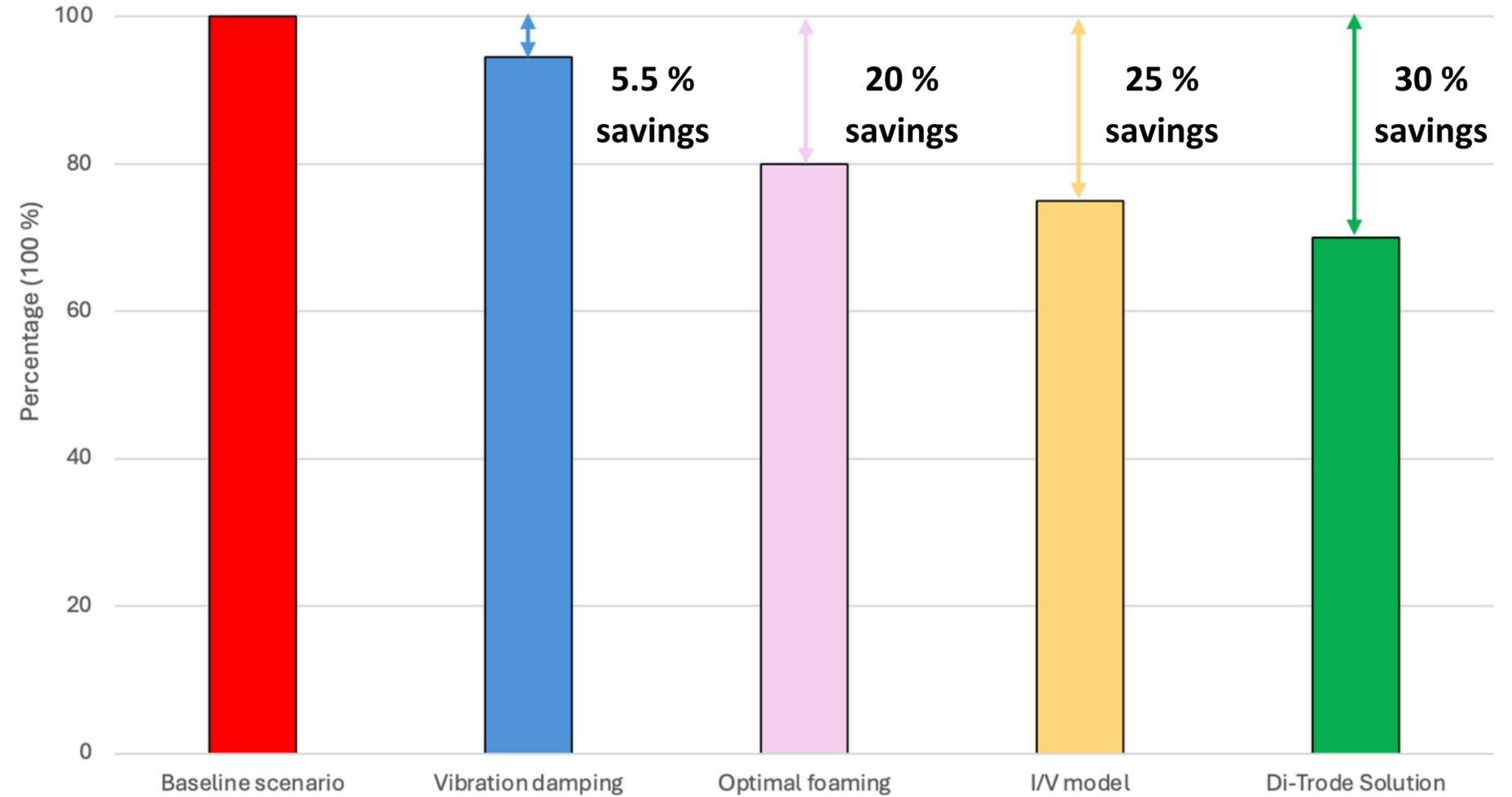
**Reduced
environmental
impact**

Competitive advantage

Electric Arc Furnace Waveform Stabilization

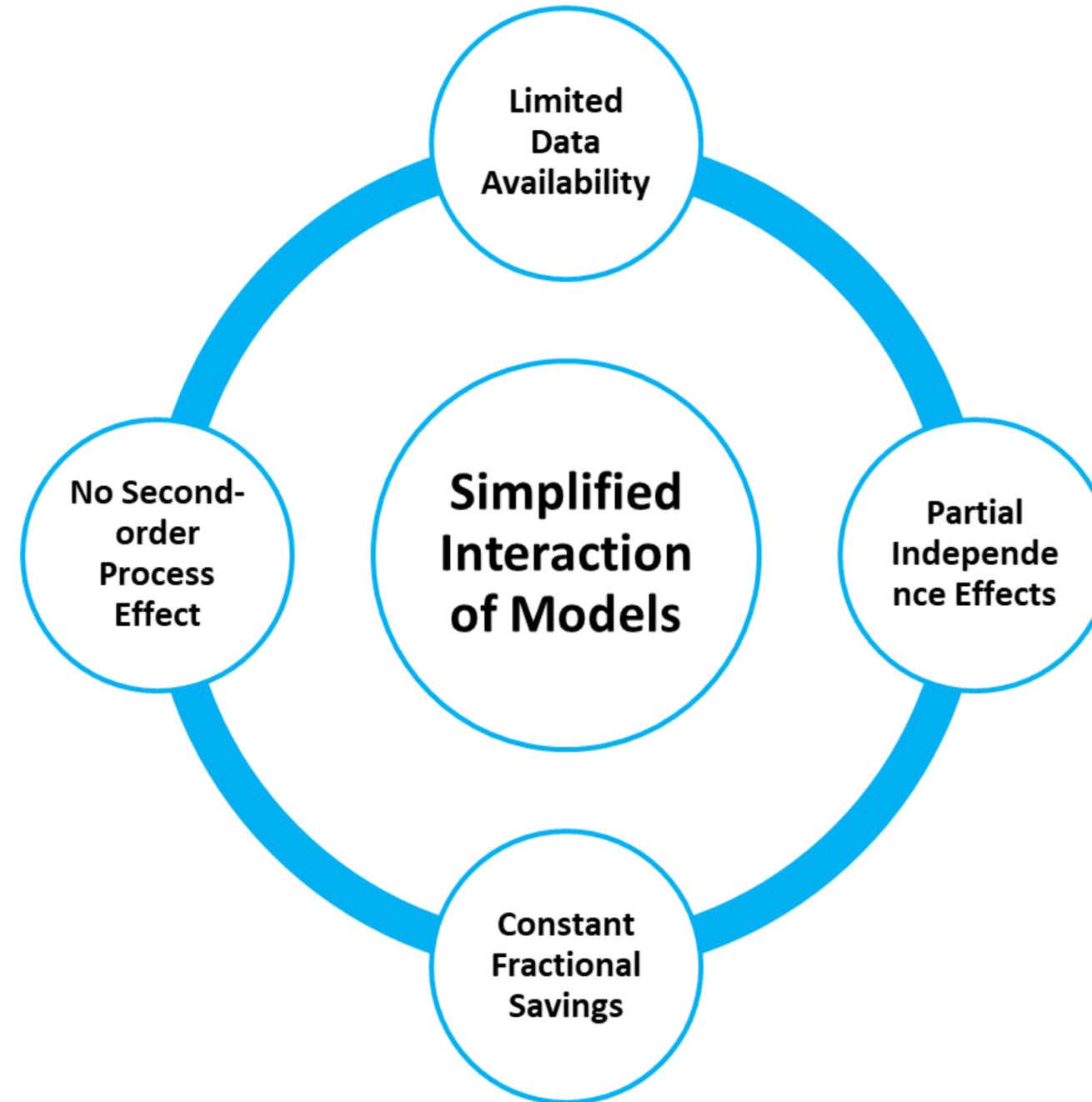


Estimated electrode consumption



1. RD, M., Rubén, L. G., López, F., Camacho, J., & JA, R. (1995). The slag foaming practice in EAF and its influence on the steelmaking shop productivity. ISIJ International, 35(9), 1054–1062.
2. Aguirre Ortiz, F. R., Hernández Paredes, P. E. (2019). Tenaris Tamsa's Ladle Furnace Electrode Consumption Reduction. Proceedings of the Iron & Steel Technology Conference, 6-9

Drawback & Assumptions



Arc Stability = Electrode Efficiency

Data we Can Already Use:

- Power consumption patterns
- Scrap composition data
Weight & percentages by grade/element
- Voltage tap changer positions
- Three-phase current measurements
- Operating time data
Tap-to-tap times, melting durations
- Temperature readings
Water-cooled panel & furnace bottom

Critical Missing Data need to Obtain:

- Electrode consumption tracking
Weight before and after each heat, or diameter measurements
- Real-time current balance
millisecond-level measurements showing arc stability
- Electrode position data
Hydraulic cylinder movements indicating gap adjustments
- Power quality metrics
Harmonic distortion, power factor variations

EXISTING DATA ANALYSIS

- Identify electrode wear patterns from available data

Phase 1

BASIC MONITORING INSTALLATION

Simple before/after weight measurements

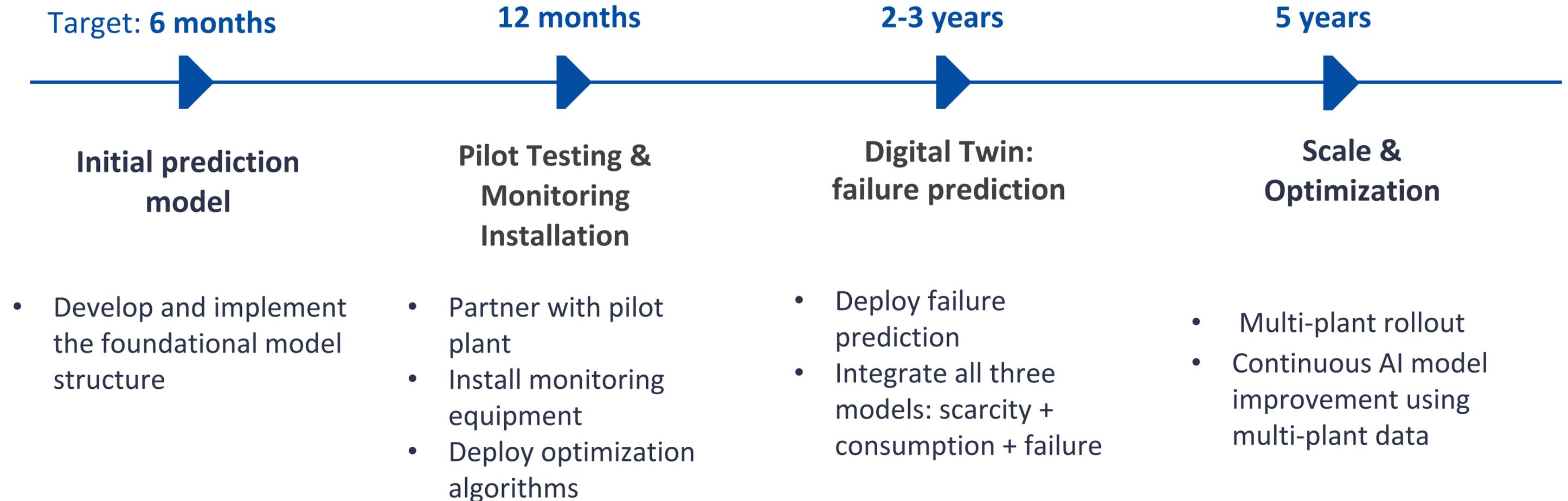
Phase 2

CORRELATION STUDIES

Link power patterns to electrode consumption

Phase 3

Development roadmap and time to market



Financial aspect

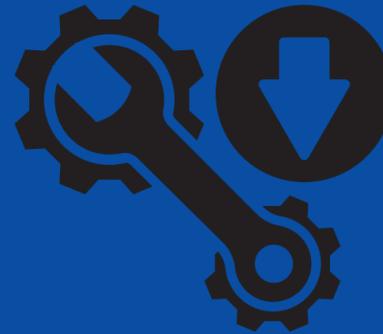
Company and service costs

- Initial investment:
 - Capital €30,000
 - high-performance computers
 - servers
 - Operational cost €160,000/y
 - software licenses, electricity and personnel (4 people)
- Revenue stream of Di-Trode: subscription model based on the company needs

Financial benefits

Reduce electrode consumption
from 2.25 to 1.87 kg/tonne

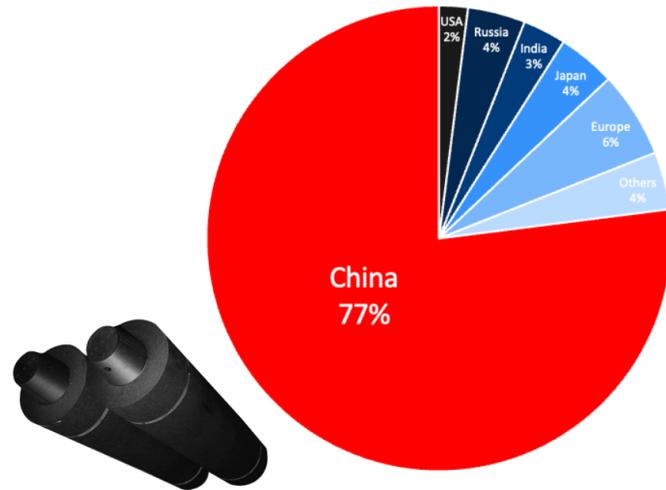
~ €1 million annual savings



Estimated savings of ~€1 per tonne (≈€1M annually for 1M tonne/year) based on average market prices and may vary.

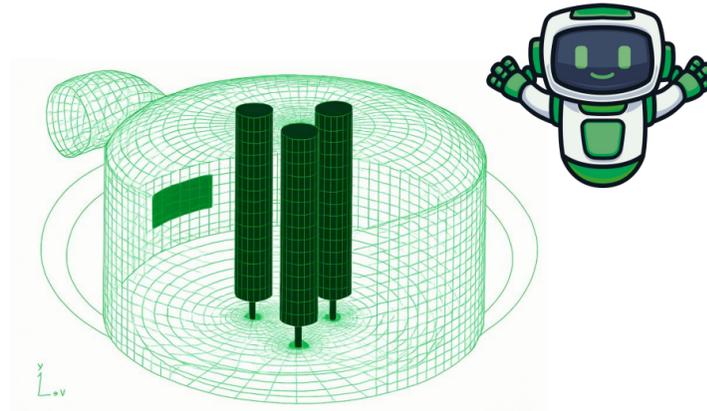
Our Di-Trode project:

Issue



- Supply vulnerability
- Unpredictable geopolitics disruptions
- Graphite demand surge

Solution



- Forecast
- Optimize
- Prevent
- Advice

Benefits



- Supply Intelligence
- Resilience
- Cost reduction
- Sustainability

Thank You
For Your Attention.
Reach us at

ditrode.race@gmail.com

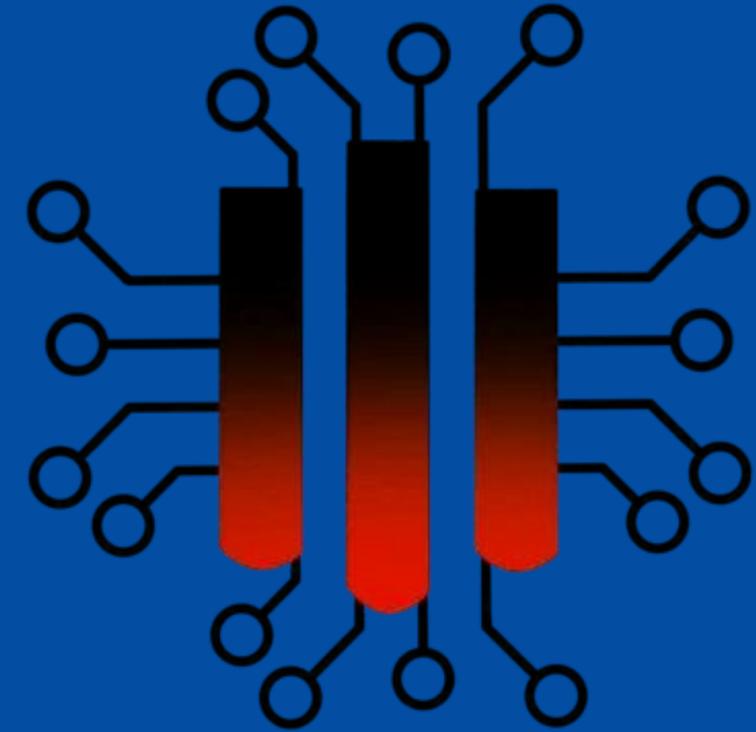


SCAN ME

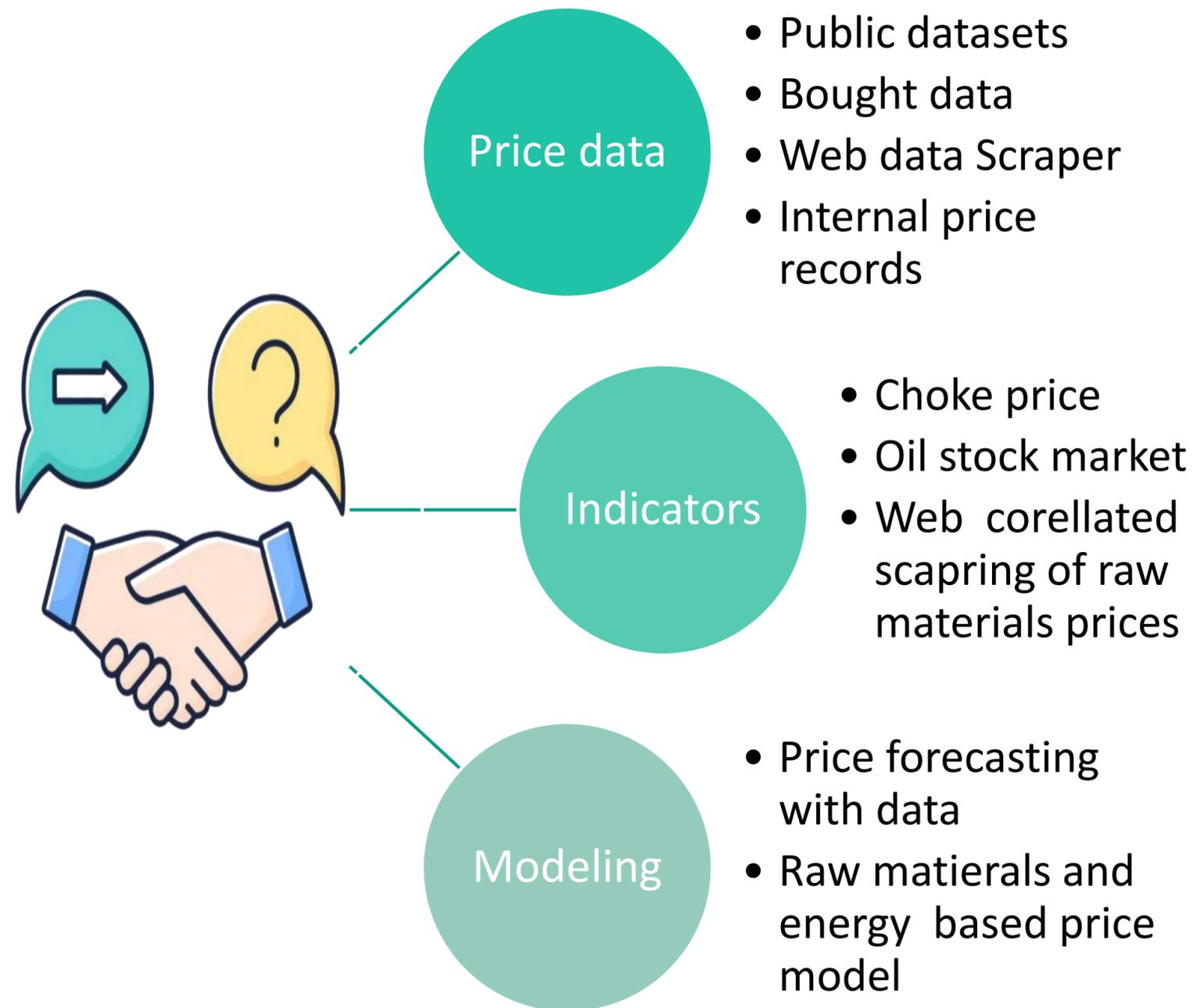


Co-funded by the
European Union

DI-TRODE



Scarcity Prediction



Prediction

- **Baselines:** cost-plus (Σ BOM_share \times index + energy + freight + FX + overhead), moving-avg, SARIMA.
- **Models:** SARIMAX/Prophet (exog = composite index, energy, FX), LightGBM/XGBoost (lags Δ 1M Δ 3M, rolling vol, FX \times commodity, utilization, month).
- **Probabilistic:** quantile GBM or NGBoost \rightarrow P10 / P50 / P90.
- **Hierarchy:** train family \rightarrow adjust SKU via residual deltas.

Testing

- **Walk-forward** (monthly); metrics = MAPE MAE bias pinball-loss.
- Deploy if \geq 10–15 % MAPE gain + good quantile coverage.
- Stress on \pm 20 % commodity / \pm 10 % FX shocks.
- Contract-aware check after model (floors, tiers, FX).

Deployment

- **Pipeline:** ingest \rightarrow features \rightarrow model \rightarrow contract logic \rightarrow DB/Dashboard.
- **Outputs:** per SKU P10/P50/P90 (1–6 M) + SHAP drivers.
- **Ops:** weekly refresh, version with MLflow/DVC, monitor MAPE & drift, auto-retrain on 3 bad cycles.
- **Interface:** dashboard (fan chart, scenario sliders), CSV to ERP, manual adjust with log.