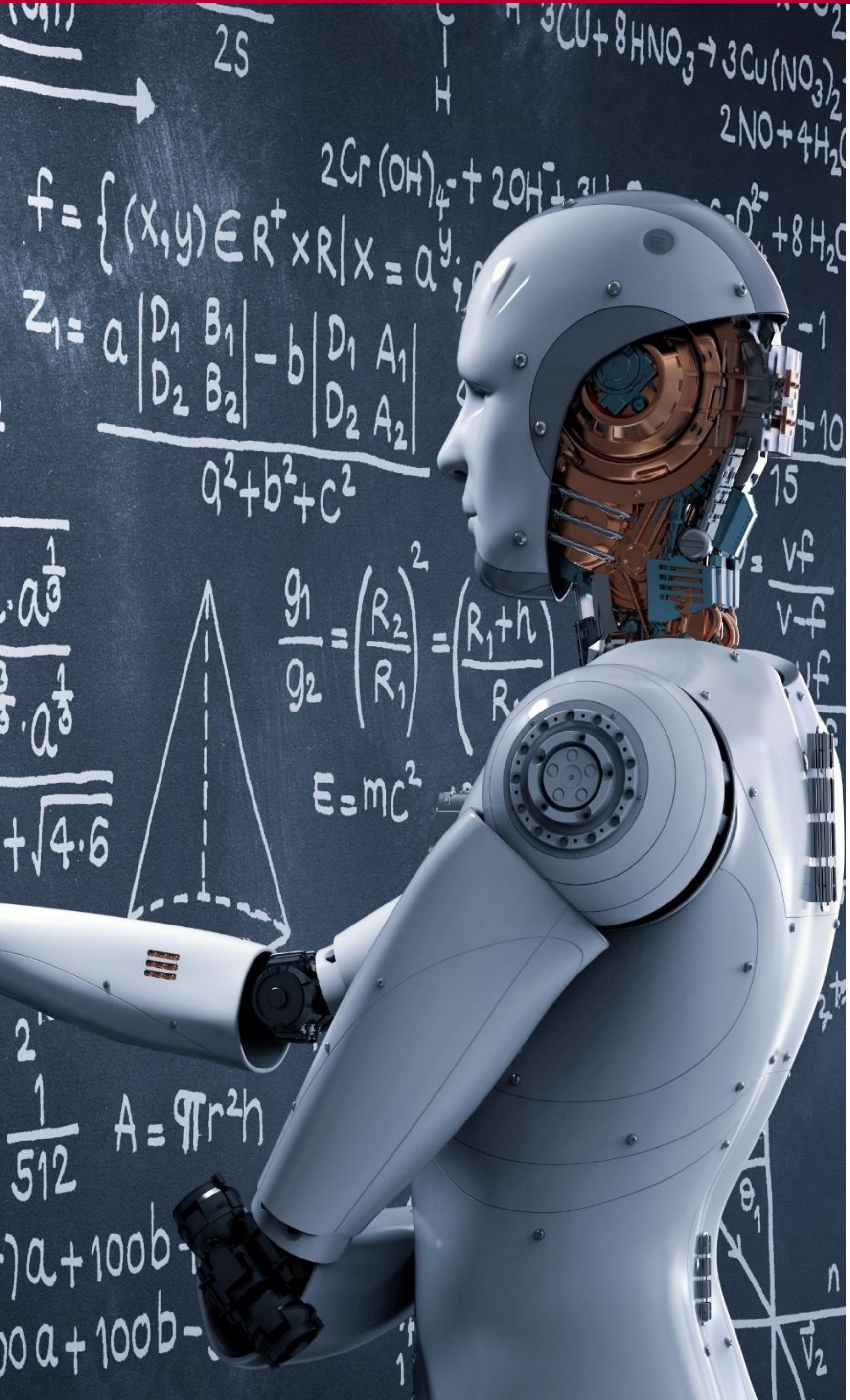

Research Center for
Information Management

Fraunhofer
FIT

Smart Sustainability Simulation Game

Case 2: Predictive Maintenance - Unit 1
24.05.2024

FIM Research Center for Information Management
Fraunhofer Institute for Applied Information Technology FIT,
Branch Business & Information Systems Engineering

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Prof. Dr. Martin Weibelzahl

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www.wirtschaftsinformatik.fraunhofer.de/bise

Augsburg Bayreuth Frankfurt Luxembourg Munich Stuttgart

01 Organizational information

No Lecture on Tuesday, 21.05.2024

Pfingsten

- Next lecture: Tuesday, 28.05.2024, 2 pm

DIGITAL SCHMIEDE BAYERN

GESTALTE DIE VERWALTUNG VON MORGEN

Bewerbungsschluss: 06.06.2024
Programmzeitraum: 05.08.2024 – 29.10.2024
Standort: München

Was wir bieten...

DIGITALISIERUNG MIT IMPACT

Arbeite an echten Herausforderungen der bayerischen Verwaltung und schaffe nachhaltigen Mehrwert für die Bürgerinnen und Bürger.

FACHLICHE & METHODISCHE WEITERBILDUNG

Lerne agiles Arbeiten und neuste digitale Innovationsmethoden kennen und wende diese direkt im Projektkontext an.

NETZWERKAUFBAU

Vernetze Dich mit anderen Fellows und treffe spannende Experten und Mentoren aus der öffentlichen Verwaltung und darüber hinaus.

ZUSÄTZLICHE BENEFITS

Neben einem finanziell vergüteten Stipendium während des Programms bekommst Du ein Zeugnis, das Deine Leistungen und Fähigkeiten hervorhebt.

Wen wir suchen...

- ✓ **Junge Digitaltalente** ab dem 4. Semester mit **betriebswirtschaftlichen, gestalterischen,** oder **technischen** Fähigkeiten und Interesse
- ✓ Begeisterung und Affinität für die menschzentrierte Entwicklung digitaler Innovationen
- ✓ Leidenschaft und Motivation unsere öffentliche Verwaltung zu verbessern
- ✓ Deutschkenntnisse (min. B1) und Bereitschaft vor Ort zu arbeiten

www.digitalschmiede.bayern

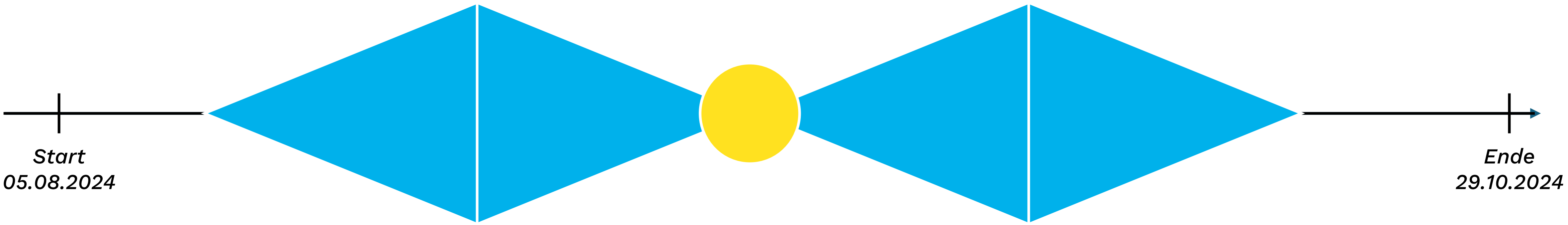
Ein Programm der: byte Bayerische Agentur für Digitales

in Kooperation mit: Bayerisches Staatsministerium für Digitales

organisiert von: mantro, Fraunhofer FIT, fim Forschungsinstitut für Informationsmanagement

DIGITAL SCHMIEDE BAYERN

Programmphasen im Überblick



On-boarding	Verstehen	Verknüpfen	Gestalten	Umsetzen	Off-boarding
1 Woche	4 Wochen	2 Wochen	3 Wochen	3 Wochen	1 Woche
Teambuildung & Einführung	*Entwicklung eines Problemverständnis*	*Definition einer Problemstellung*	*Exploration von Lösungsräumen*	*Verproben eines Lösungsansatzes*	*Feedback & Übergabe*

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DIGITAL SCHMIEDE BAYERN

Bewerbungsschluss: **06.06.2024**

Infoveranstaltungen:

- 14.05.2024, 18 Uhr (virtuell), Teilnahme über Zoom
- 27.05.2024, 18 Uhr (virtuell), Teilnahme über Zoom
- 03.06.2024, 18 Uhr (virtuell), Teilnahme über Zoom

Wöchentliche Drop-in-Termine für Deine Fragen:

- Jeden Dienstag vom 07.05. bis zum 04.06.2024 von 17:00 bis 17:30 Uhr (virtuell), Teilnahme über Zoom

JETZT BEWERBEN!

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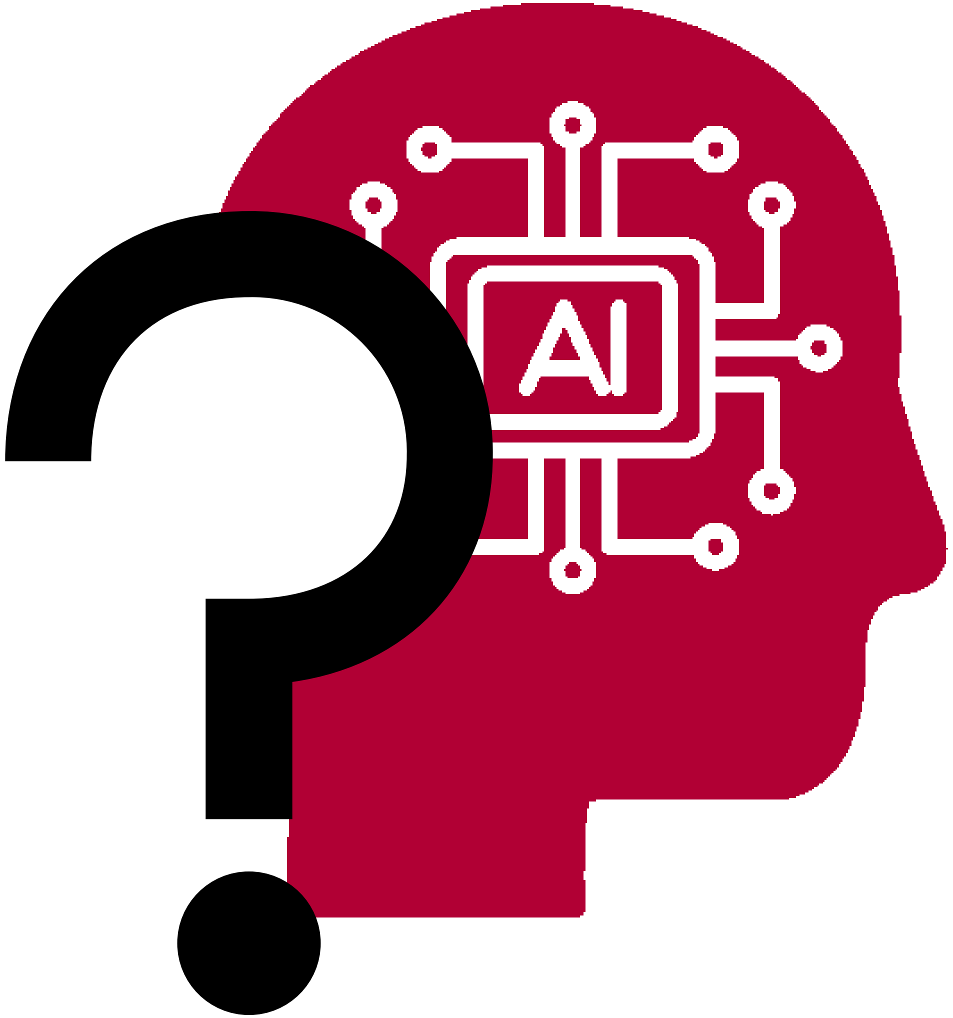
Ein Programm der: byte BAYERISCHE AGENTUR FÜR DIGITALES

in Kooperation mit: Bayerisches Staatsministerium für Digitales

organisiert von: mantro, Fraunhofer FIT, fim Forschungsinstitut für Informationsmanagement

Time for Feedback



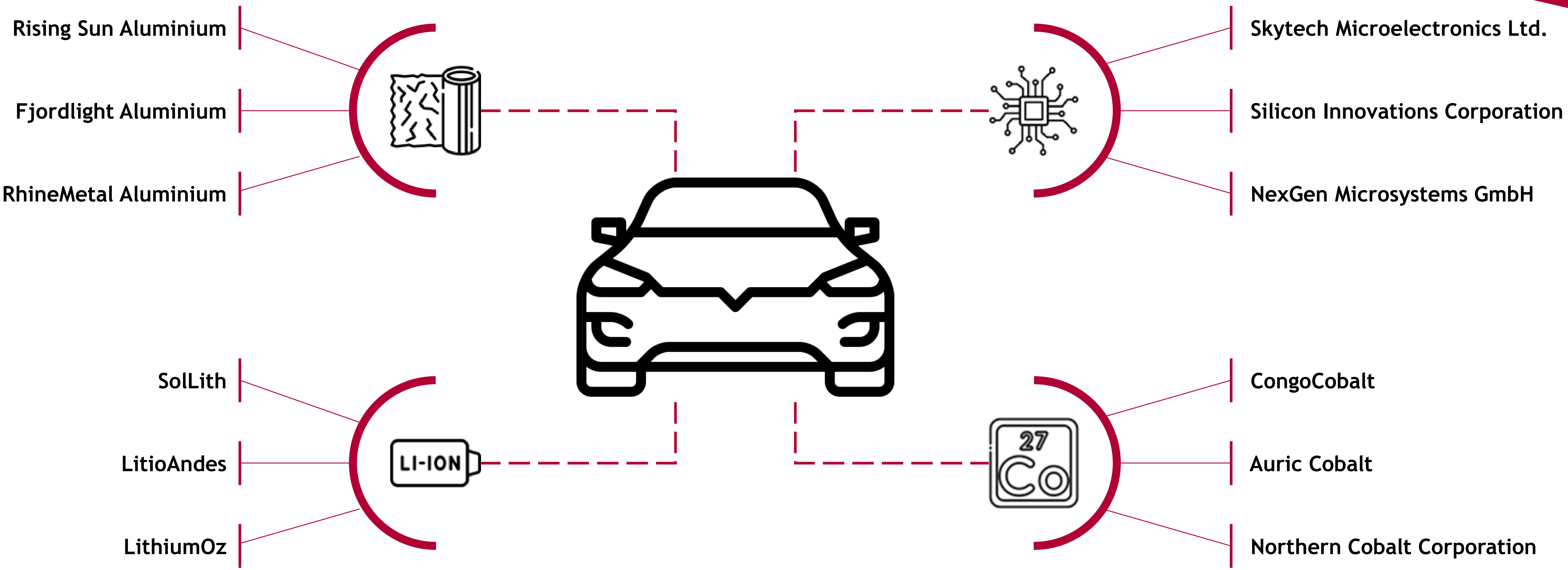
How was the second week?

Any questions?

02 Case 1 – Your results

Case 1: Missing materials

Recap



Task

Calculate the daily prices for aluminum, microchips, lithium, and cobalt for the next 5 years by performing a time series analysis. Decide which supplier you would like to select and how much material you would like to buy by the deadline in five years.

Case 1: Final portfolio

Recap

Budget

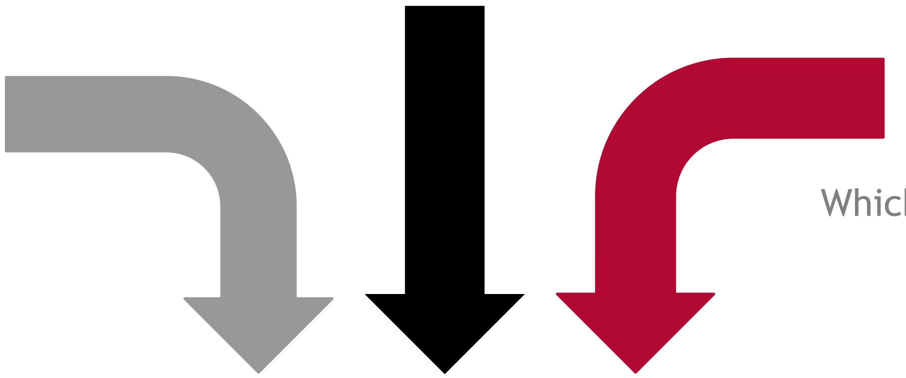
How is the existing budget allocated?

Estimated prices

How will prices develop?

Supplier selection

Which supplier is the most attractive?



Final portfolio

From which supplier do you order how many materials?

(Only one supplier per material)

Case 1: Time schedule

Recap

Establishment of a generic development environment for data and analysis

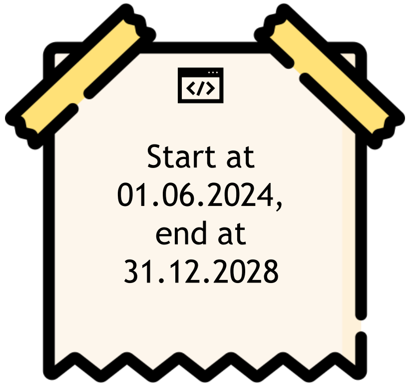
Time series analysis and price estimation for the first material

Submission of results and presentation of selected approaches

Analysis of the additional data and creation of a procurement plan

Submission of the final results

Case 1: Keep in mind



Your results

Team Penguin

Lithium & Cobalt

Team Goat

#Cars: 472,073

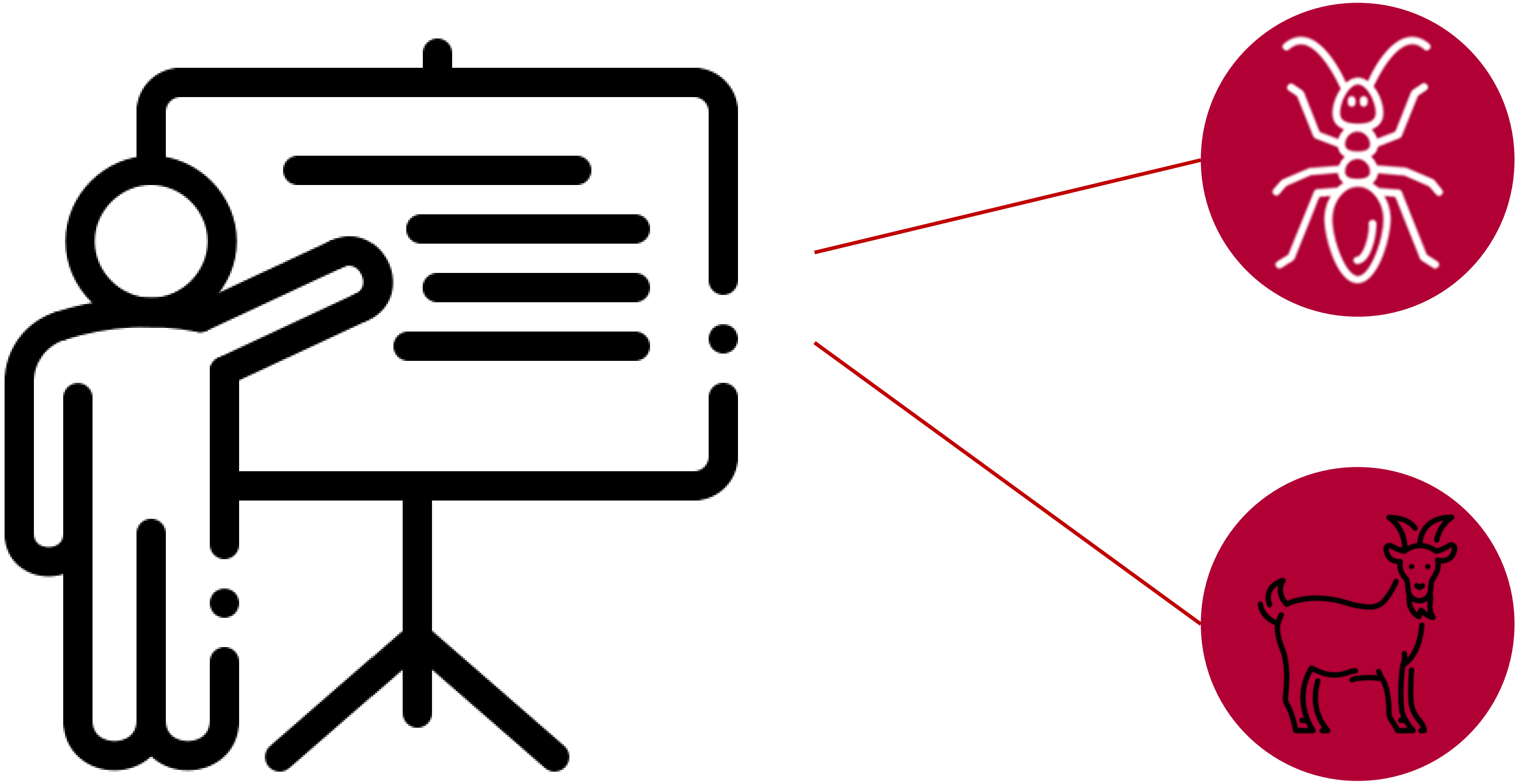
Team Ant

CO_2: 36.7 t / Car

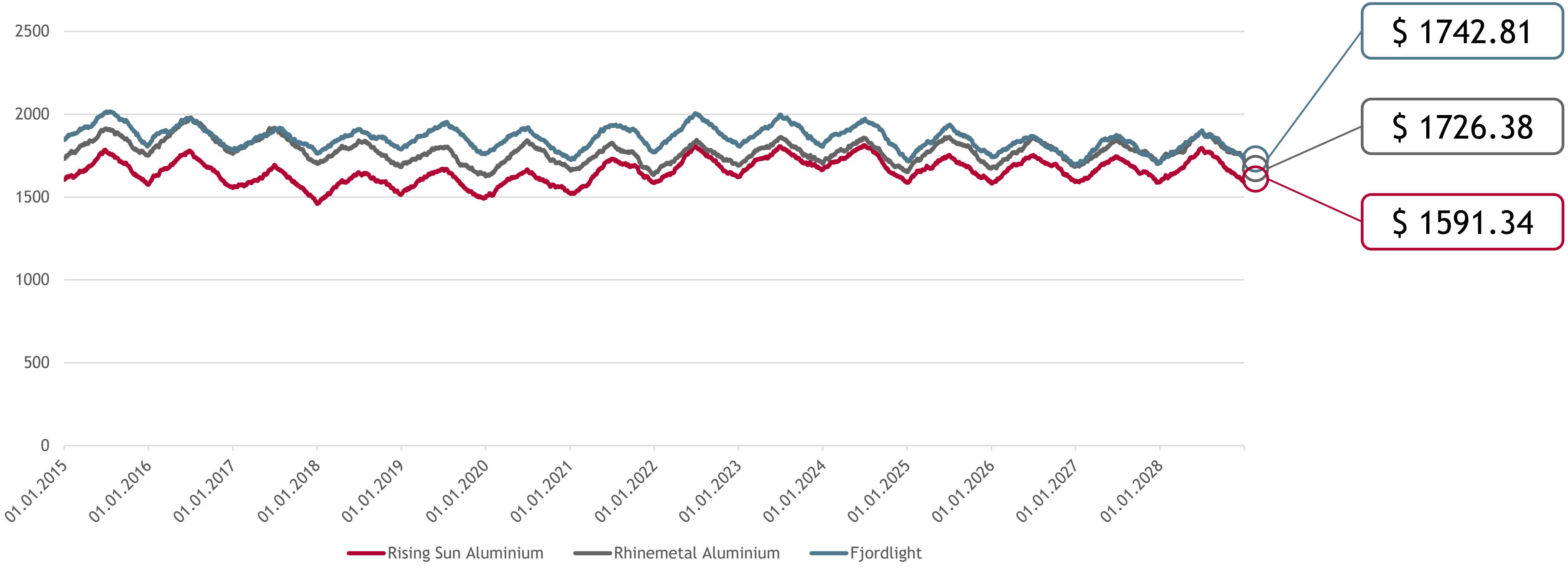
Team Goat

Impact: Best Conditions

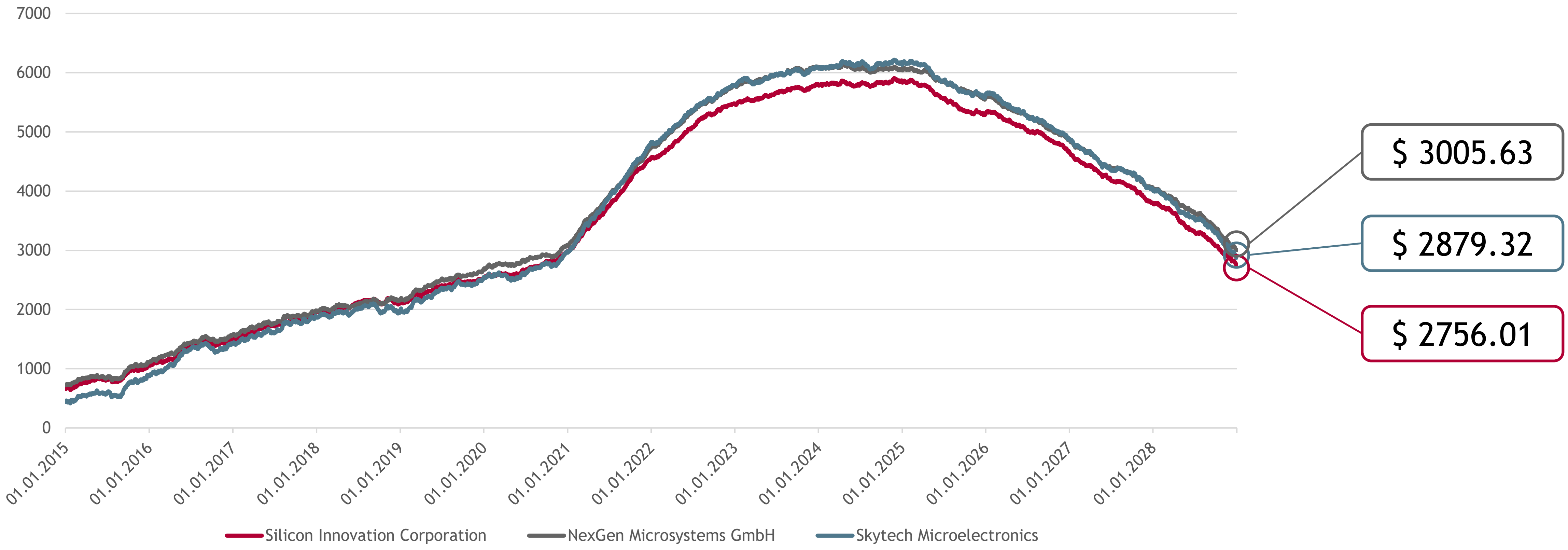
Case 1: Presentation of results



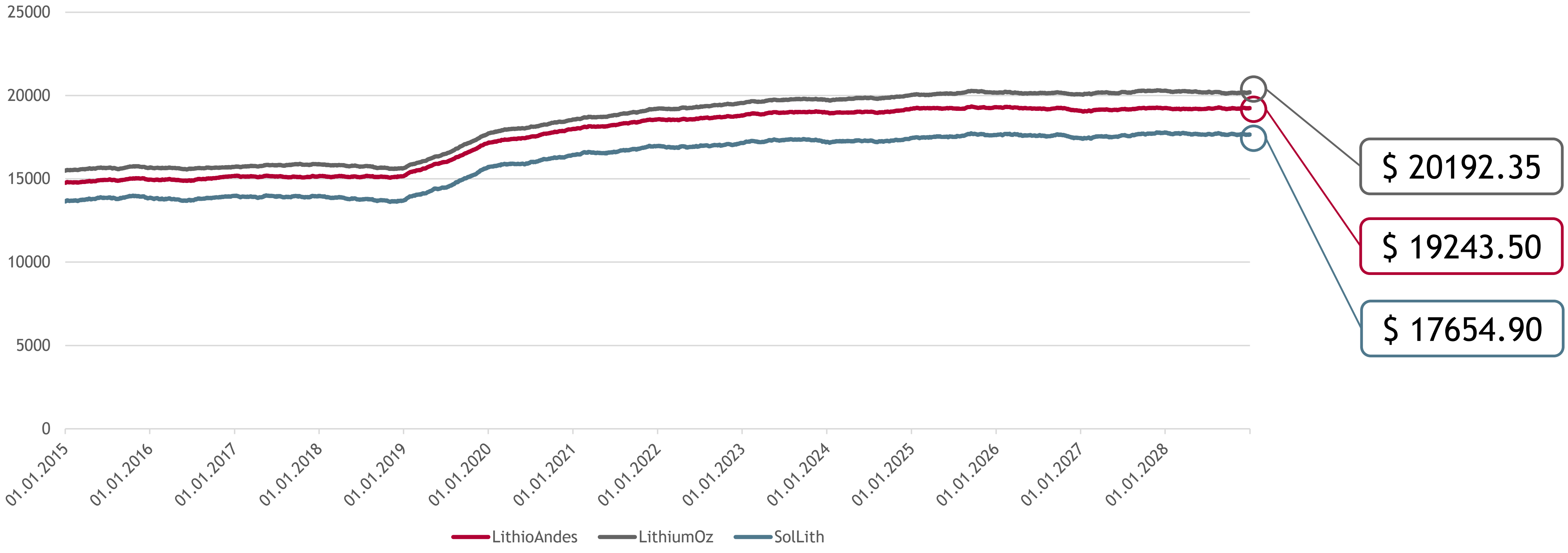
Case 1: Final aluminum prices



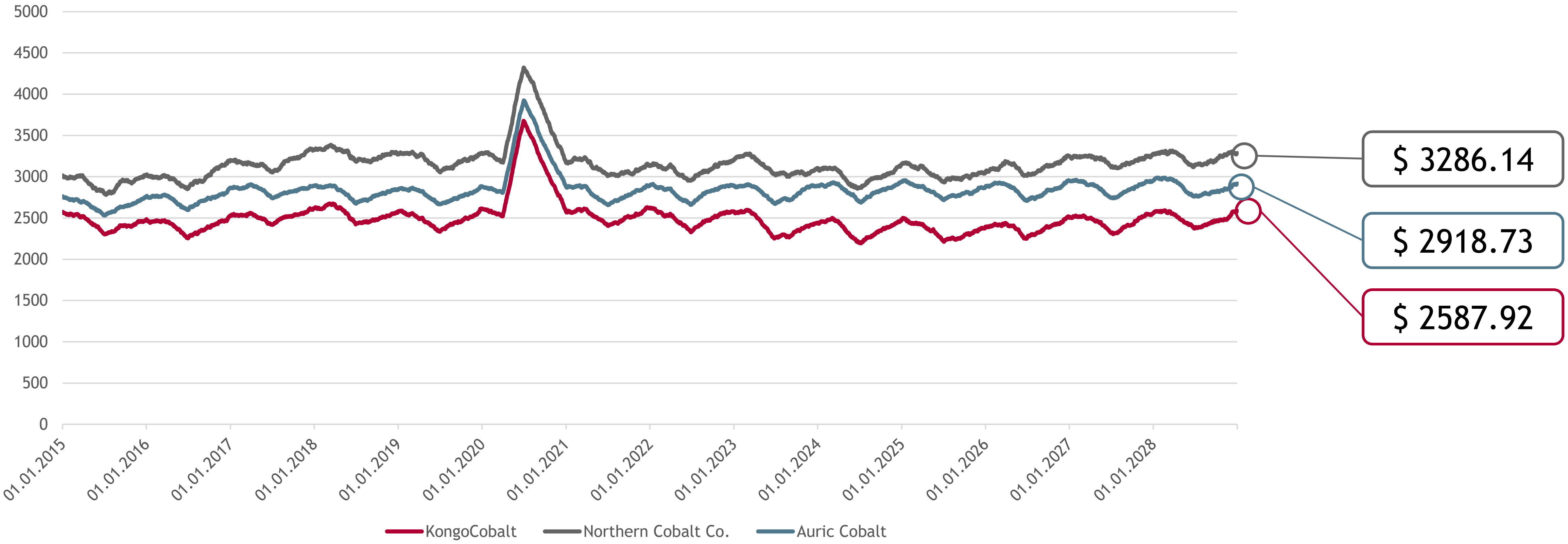
Case 1: Final microchip prices



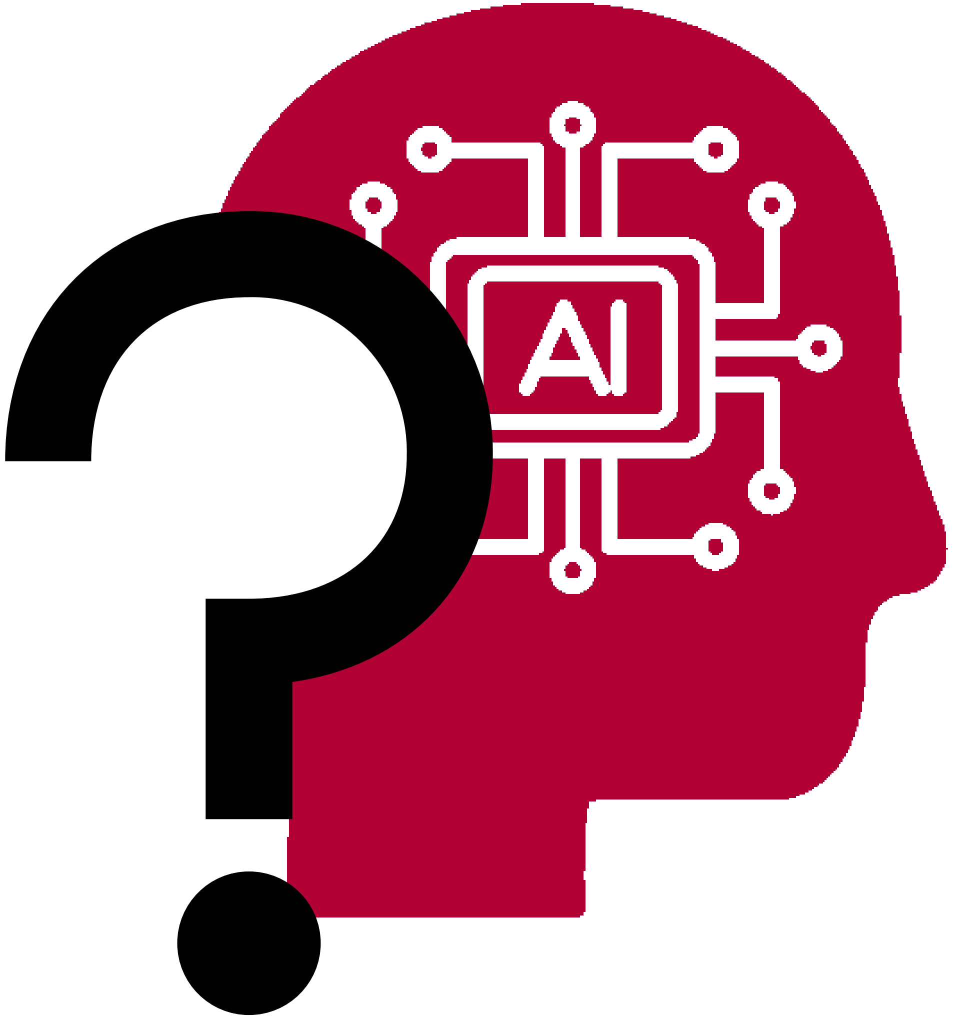
Case 1: Final lithium prices



Case 1: Final cobalt prices



Time for Feedback



Any questions?

03 Case 2: Production - Unit 1

Overview of the cases

Case 1: Material procurement

- What materials should I buy and when?
- Value chain level: Procurement

→ Time Series Analysis

Case 2: Predictive Maintenance

- How often and when should I maintain my machine?
- Value chain level: Operations/production

→ Predictive Analytics

Case 4: Recycling

- How much effort do I put into recycling?
- Value chain level: After-sales-services

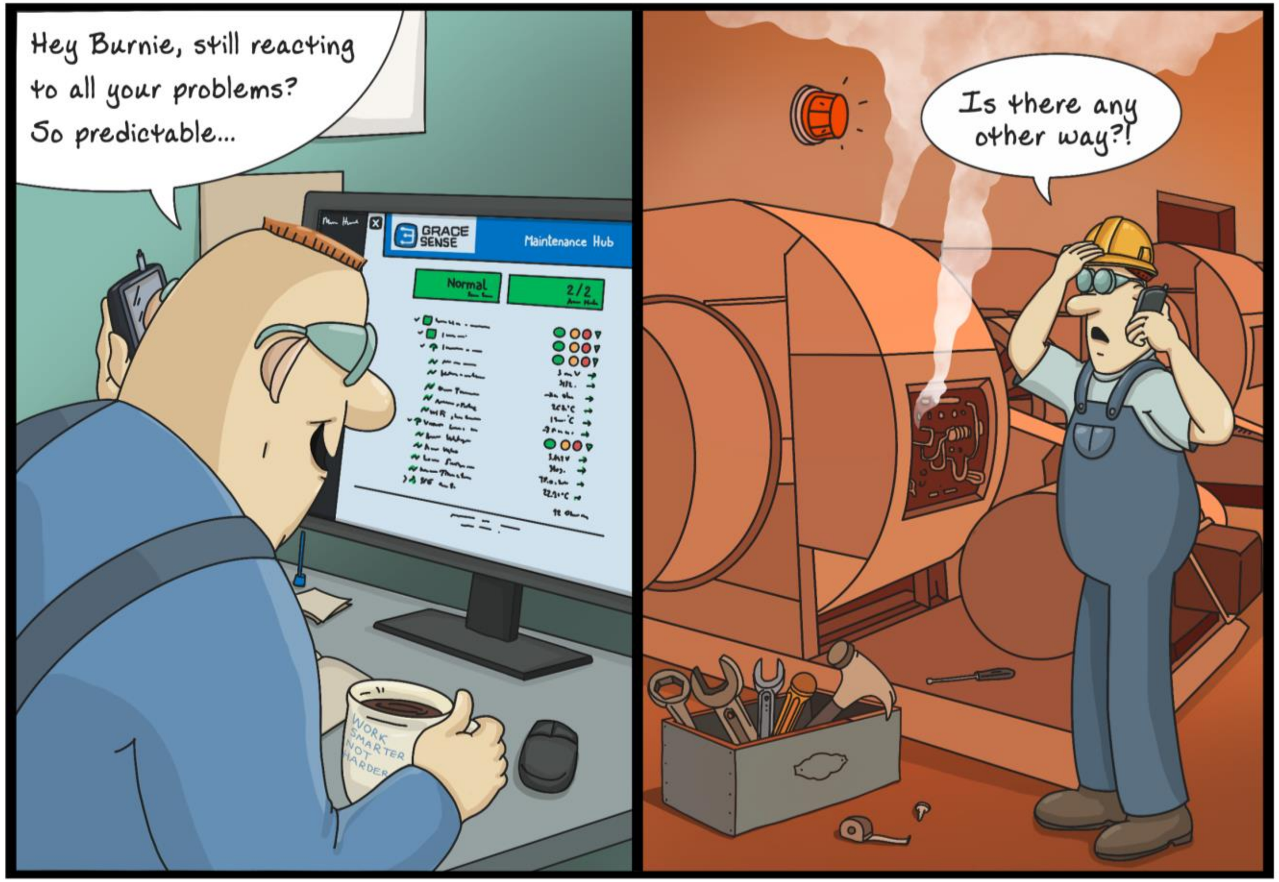
→ Process Mining

Case 3: Quality Management

- How to ensure good quality?
- Value chain level: Operations/production

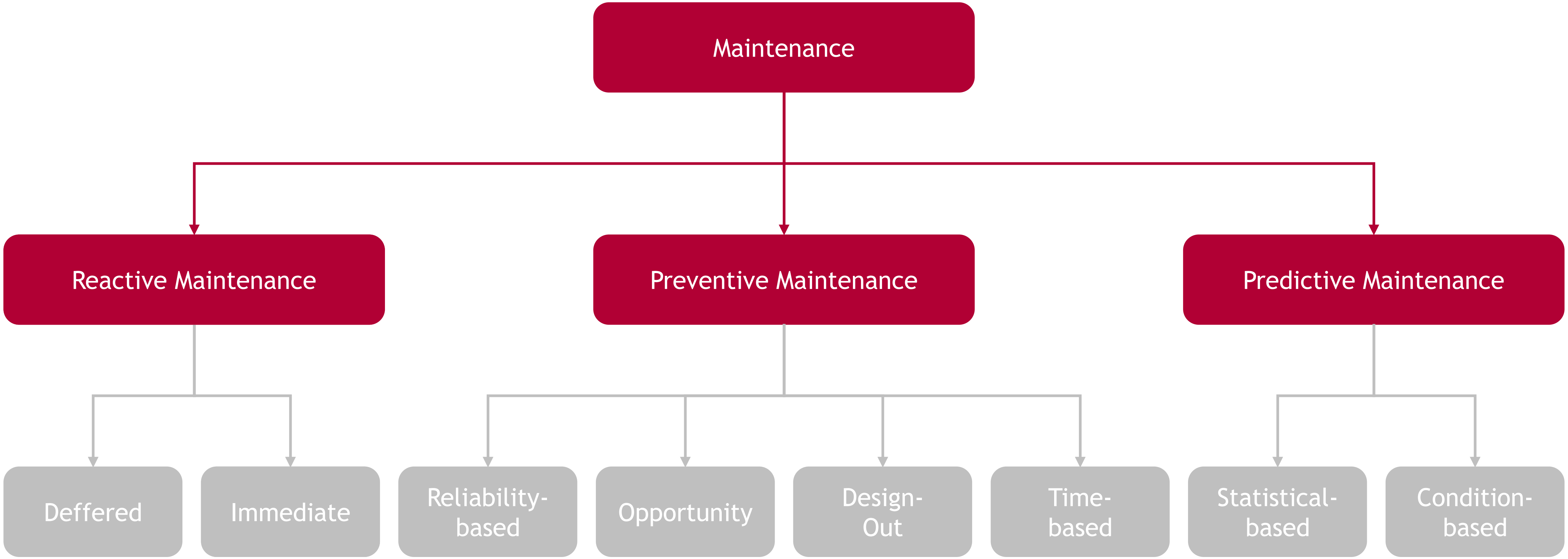
→ Computer Vision

Maintenance is all about working smarter, not harder



PREDICTIVE MAINTENANCE VS. REACTIVE MAINTENANCE

Maintenance can be categorized into different types



Predictive maintenance as a facilitator for performance

"A comprehensive **predictive maintenance management program** uses the most **cost-effective techniques** (e.g., vibration monitoring, thermography, tribology) to **obtain the actual operating condition of a system of systems** and based on this actual data **schedules all maintenance activities** on an as-needed basis." (Mobley, 2002)

- Identification of critical faults and the corresponding sensor data
- Fault prediction based on sensor values and current machine states
- Calculation of fault occurrence probabilities enables intelligent maintenance planning

Predictive maintenance provides multiple benefits

Reduction of spare parts inventories, as maintenance operations are planned proactively

Minimize unplanned outages and reduce downtime and repair time

Optimization of instance maintenance costs through optimized and dynamic instance maintenance plans

Identification of possible mis adjustments and improvement potentials on the machine

Predictive maintenance comprises several activities

Data Evaluation

Recording & analysis of the data stock and matching of service reports and existing device data

Failure Predicition

Selection and implementation of fault prediction algorithms

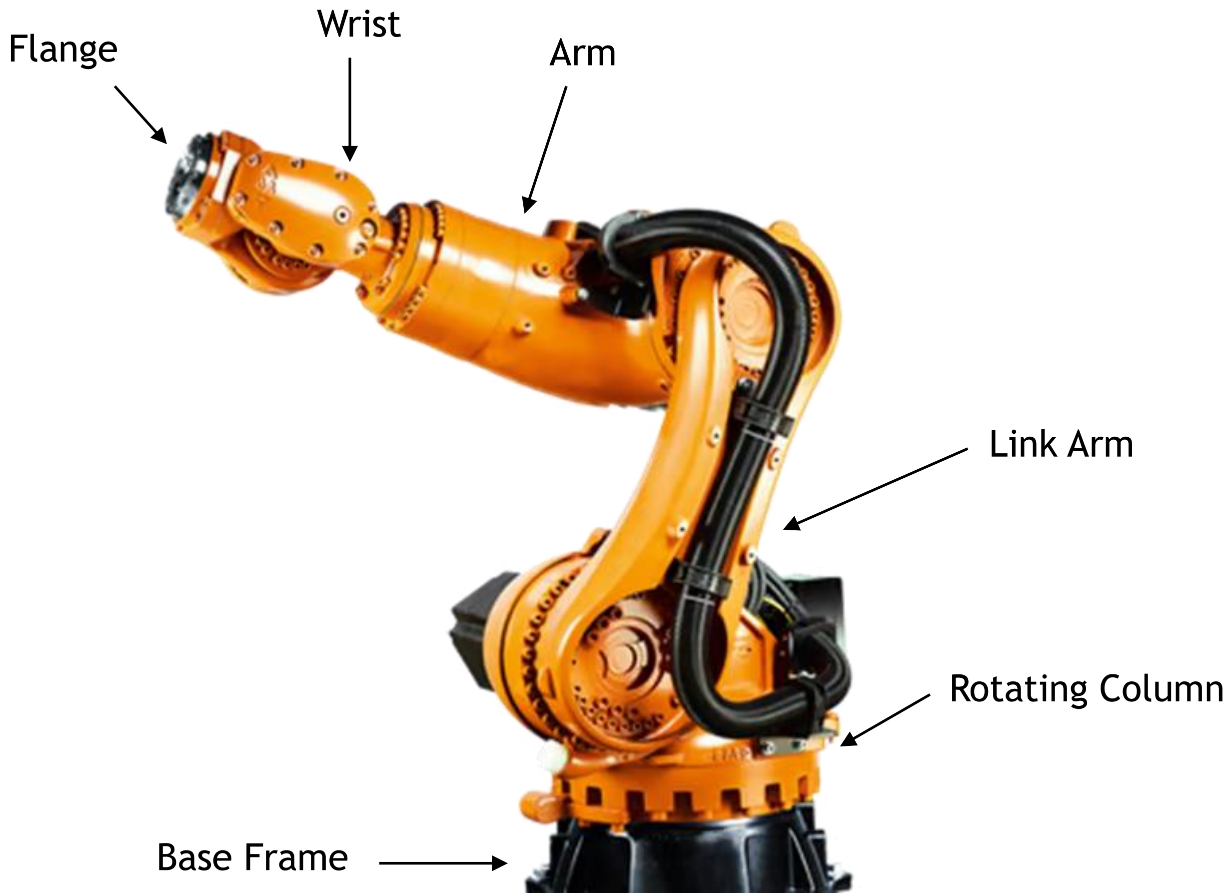
Decision Support

Determination of optimal maintenance times under certain target parameters (e.g., maintenance costs, damage costs)

Predictive maintenance in practice: industrial robots

Example: KR QUANTEC nano – Kuka

- **Exemplary application fields in practice:**
  - Laser welding
  - Handling
  - Cutting & separation
  - ....
- **Technical details:**
  - Load capacity [kg]: 120 - 180
  - Reach [mm] (arm length): 1573 – 2100
- **Further information:**
  - https://www.kuka.com/de-de/branchen/automobilindustrie



Industrial robots can be equipped with different effectors

Industrial robots can be equipped with different types of end effectors such as for gripping, lasering or welding. In this way, the one industrial robot can be used for different tasks.

Edison Cars AG has several welding robots in their production line.

Predictive maintenance comprises several activities

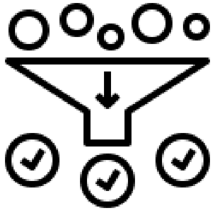
1. Data Availability

- It is important to have a look at the data
- “Our model will be as good as our data “

2. Data Labeling

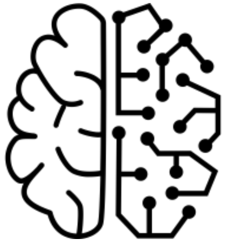
- Data has to be labelled the right way

3. Data Preprocessing



- Preprocessing has to become to overcome common challenges in analyzing data (see next slide)

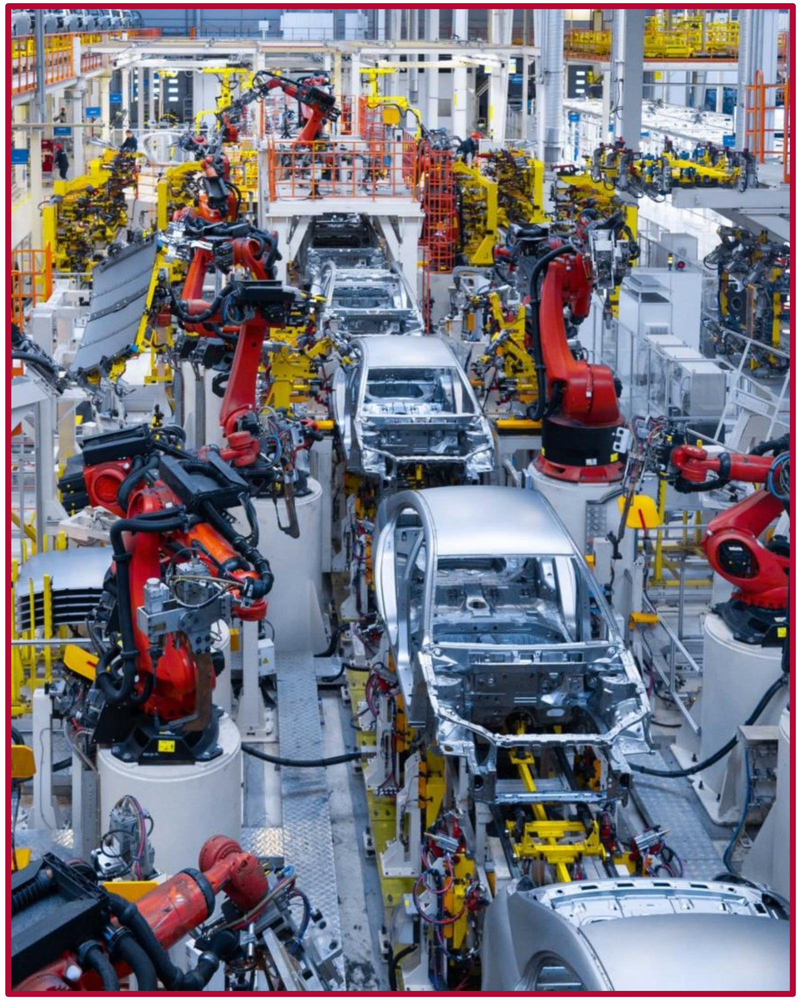
4. Machine Learning



- It is important to choose the right model
- e.g. SVM, neural network, LSTM-RNN

Case 2: Maintenance department of Edison Cars AG

Case 2: Maintenance department of Edison Cars AG



Distributed production facilities

- Manufacturing of e-mobility vehicle batteries at four sites worldwide (Germany, China, South Africa, USA)
- Strong demand for e-mobility vehicle batteries requires permanent and saturated production

Central maintenance department

- Unscheduled machine breakdowns repeatedly lead to production stops and require cost- and time-intensive maintenance work
- Coordination of all activities to ensure permanent availability from the headquarters in Germany

Rethinking maintenance strategy

- The company has already made great efforts in the past to improve maintenance intervals to ensure permanent availability
- Board of Edison Cars AG made the strategic decision to move from reactive maintenance towards predictive maintenance

Case 2: Maintenance department of Edison Cars AG

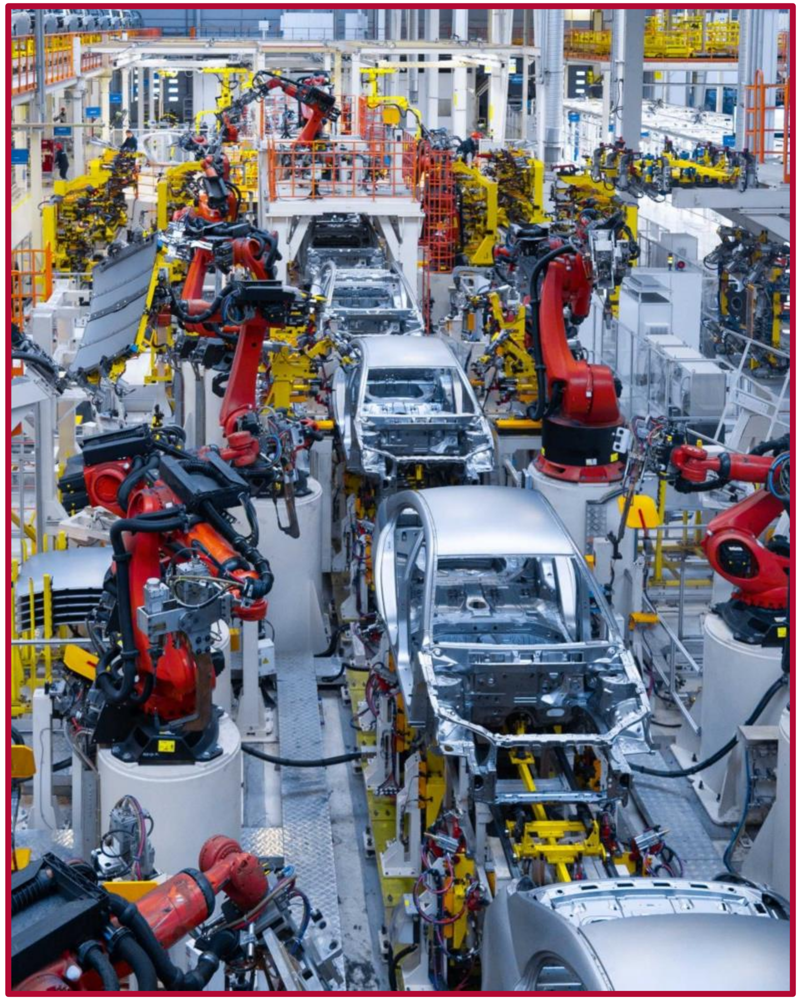
The production lines depend highly on a **functioning maintenance strategy**, as the failure of a single machine may shut down the entire process, resulting in **immense follow-up costs**

The head of maintenance demands an **efficient use of human resources** and aims at a **sustainable use of hardware** (e.g., sensor technology, spare parts)

The CEO aims for **high machine availability** and does not accept downtimes that cause production losses

The Edison Cars AG is committed to revise the existing maintenance concept

Case 2: Maintenance department of Edison Cars AG



To produce electric cars efficiently, Edison Cars AG uses **several industrial robots** in its production lines. Each robot has sensors for self-control.

- Temperature Sensors
- Vibration Sensors
- Pressure Sensors
- ....

Case 2: Maintenance department of Edison Cars AG

Simplified example

The Edison Cars AG collected data from **20 industrial robots** in its production lines in a test scenario. Here, the industrial robots **worked until they crashed**.

Key results of the experiment:

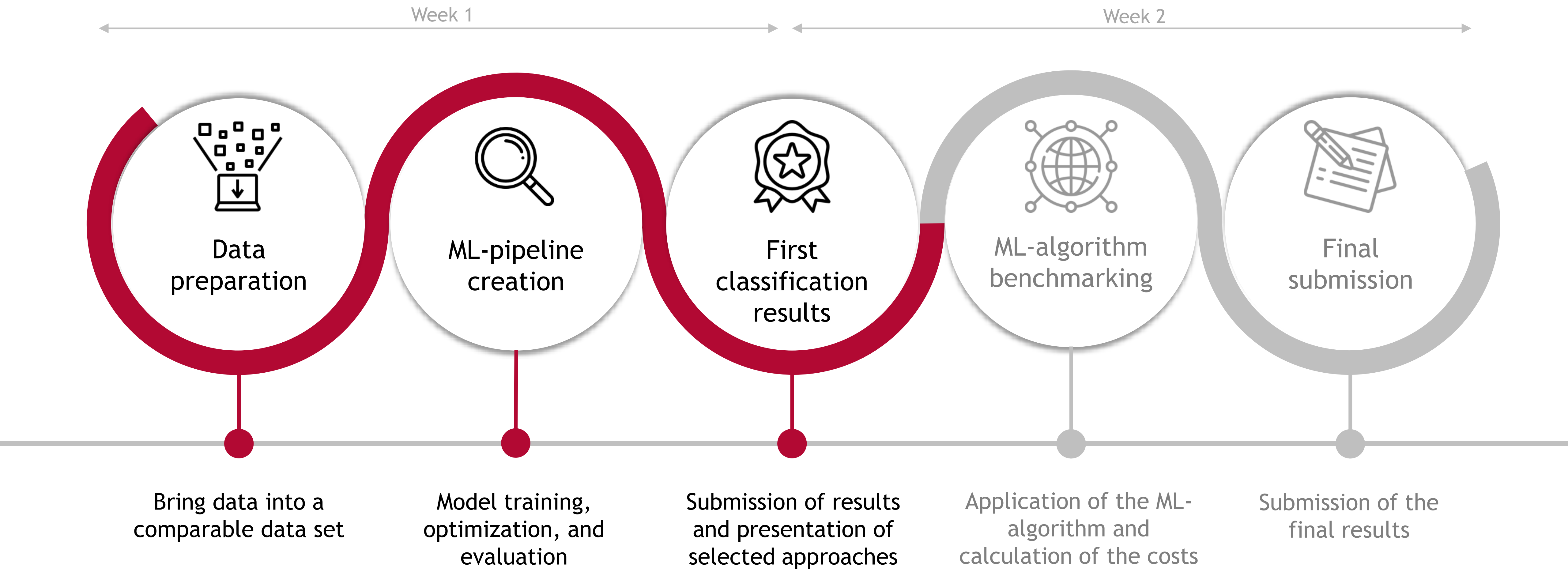
- The most common reason for a defective industrial robot is a faulty welder and loose screws
- The signs of a defect are overheating and strong vibrations
- The defect can be traced back to results from 4 temperature and 4 vibration sensors
- Data from 8 sensors per industrial robot are provided
- For each industrial robot, about 6000 unlabelled data points for each sensor were collected

Case 2: Maintenance department of Edison Cars AG

Determine from the given sensor values of 20 robots with the **help of an algorithm** whether a robot currently **works well, requires maintenance, or is at risk of breaking down**. Also, describe your **labeling strategy** for the test data and mention the aspects that influenced your choice (e.g., late maintenance may cause costs for production).

The management of Edison Cars AG would like you to implement the new predictive maintenance system.

Case 2: Time schedule



Case 2: Input

Worksheet
Contains description of the task and the exact submission details

Task completion

Data
Represents the sensor values of 20 robots

Code Template (if necessary)
Provides framework for the development and provides basic functionality

Case 2: Submission

The following documents must be emailed to **s3g@fim-rc.de** as one zip folder by **02:00 PM** on **27.05.2024**:

Machine Learning Model
Exported trained model and confusion matrix of the training results

Code
Code file(s) for reproducing your results, with installation instructions if necessary

Submission

Presentation
A PowerPoint presentation explaining your approach

Case 2: Excursus confusion matrix

True Positive:
The algorithm correctly predicts an error.

Consequence:
The result is a predictable service and less plant downtime.

False Positive:
The algorithm predicts a fault even though there is no fault.

Consequence:
Carry out a check of the plant. There is no repair carried out.

TP	*Actual error (Σ89465)*	*Actual error free (Σ601974)*	FP
Forecast error	72951	1959	*Precision: 97.38%*
Forecast error free	16514	600015	*Neg. Pred. Value: 97.32%*
FN	*Sensitivity: 81.54%*	*Specificity: 99.67%*	TN

False Negative:
The algorithm does not predict predicts an error, although an error is present.

Consequence:
The result is a service that cannot be planned and a higher plant downtime.

True Negative:
The algorithm does not predict an error and there is no error is present.

Consequence:
No service occurs.

Case 2: Excursus 3x3 Confusion Matrix

		Predicted classification		
Actual classification	Classes	A	B	C
	A 100	True 90	False 2	False 8
	B 200	False 7	True 180	False 13
	C 150	False 3	False 6	True 141

Value	Result
n	= 100 + 200 + 150 = 450
True	= 90 + 180 + 141 = 411
False	= 2 + 8 + 7 + 13 + 3 + 6 = 39

Case 2: Evaluation criteria

Evaluation criteria

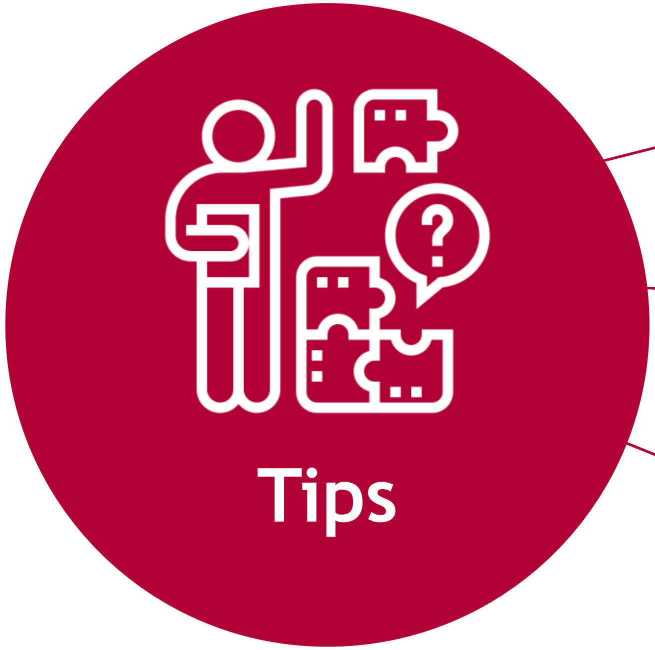
Code Quality
Is the code executable, readable and contains comments?

Prediction Quality
How good does the model work on the hidden test set?

Explanation
Is the selection of the approach presented in a comprehensible way?

Bonus
The best prediction receives a bonus

Case 2: Tips for the implementation

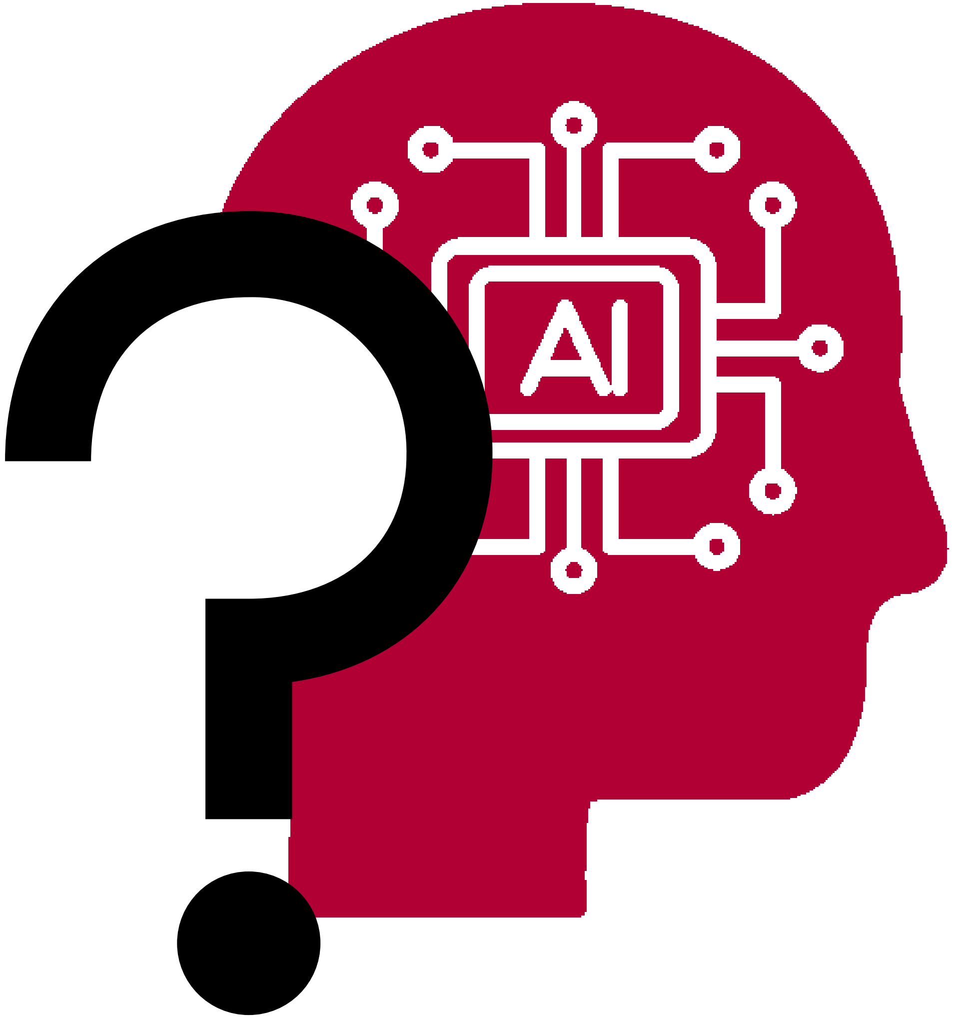


Remember the tasks and activities you successfully applied in case 1.

First analyze the given data sets before starting with programming.

Preprocess your data first.

Case 2: Any Questions?



Any Questions?