Supplying the data for data-driven metallurgical industry

Digital Twins and AI, interoperability, and standards

ALCHIMIA

THTH Association

Autumn webinar 2025

12th November 2025

BFI Excellence in Applied Research

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@Alchimia_EU

Alchimia Project

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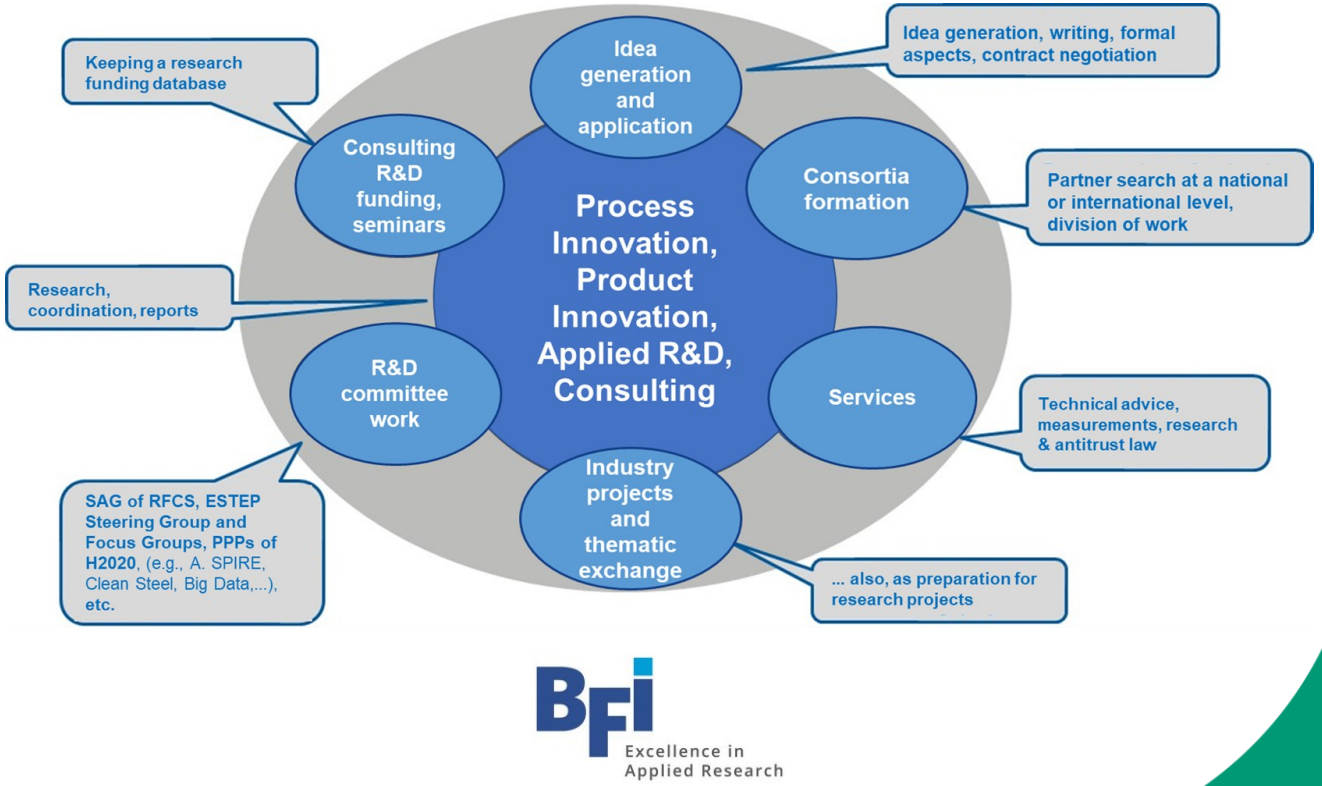
BFI (VDEh-Betriebsforschungsinstitut)

- Non-profit research center
- Applied research in process industry, especially steel production
- Located in Düsseldorf, Germany
- Employees: ~100
- https://www.bfi.de/



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ALCHIMIA project

- “Data and decentralized Artificial intelligence for a competitive and green European metallurgy industry”

- Duration: 9/2022-11/2025 (39M)
- Horizon Europe grant 101070046
- https://alchimia-project.eu/

EVIDEN an atos business

celsa

MANDAT INTERNATIONAL

BFI

FONDERIA DI TORBOLE EF GROUP

CARDIFF UNIVERSITY
PRIFYSGOL CAERDYDD

EXUS

Sant’Anna Scuola Universitaria Superiore Pisa

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ALCHIMIA project themes (at least)

- (Steel/cast iron production) process optimization with decision support

- Tools:
  - AI models
  - »Non-AI» models
  - Federated Learning, Continual Learning

- Human factors
  - Human-centric Design (HCD)

- Life Cycle Assessment (LCA)

- Standardization

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ALCHIMIA use cases

Focus of this presentation

Celsa

Fonderia di Torbole

- Environmental concerns
- Efficiency
- Economic(al) feasibility
- Human-centric design (HCD)

- Solution: data-driven tools

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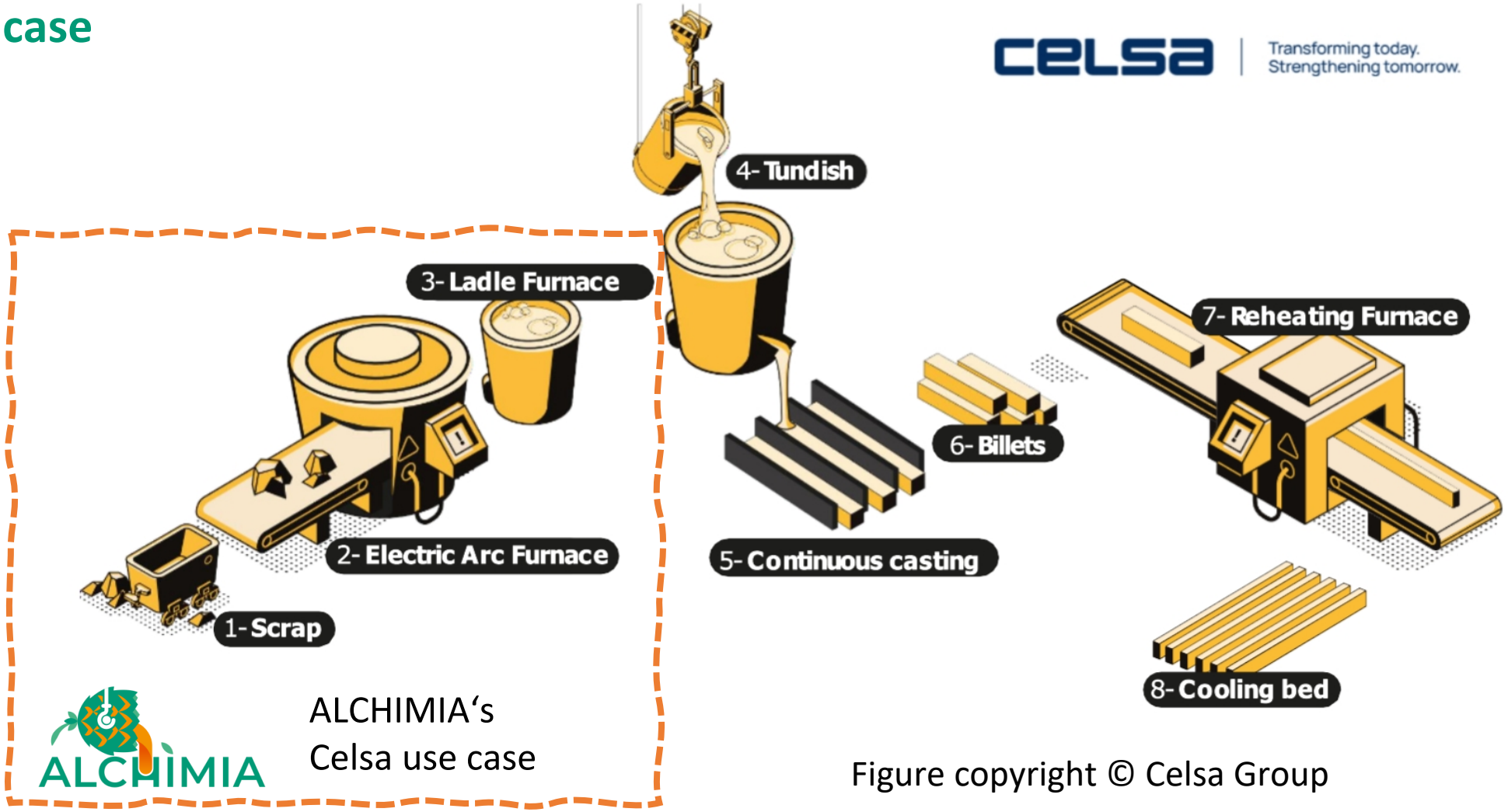
Celsa use case



ALCHIMIA's Celsa use case

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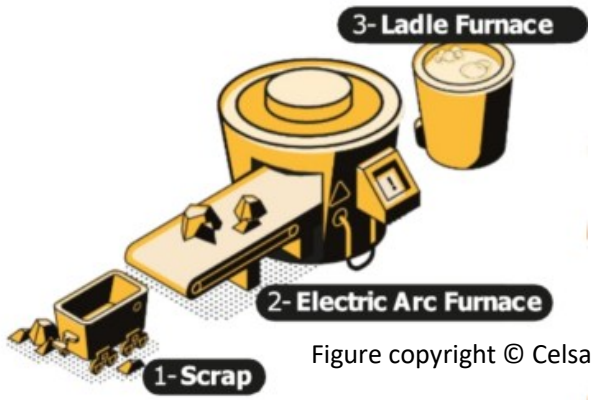
Modeling technologies: AI vs. non-AI

AI technologies applied:

- Multi-linear regression
  - Scrap characterization
- Neural networks
  - Ladle Furnace
  - Scrap processing
  - Scrap inventory
- Federated Learning
- Continual Learning

Other technologies applied:

- Linear optimization
  - Scrap mix optimization
- Physical/analytical modeling
  - Electric Arc Furnace



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Federated Learning and Continual Learning

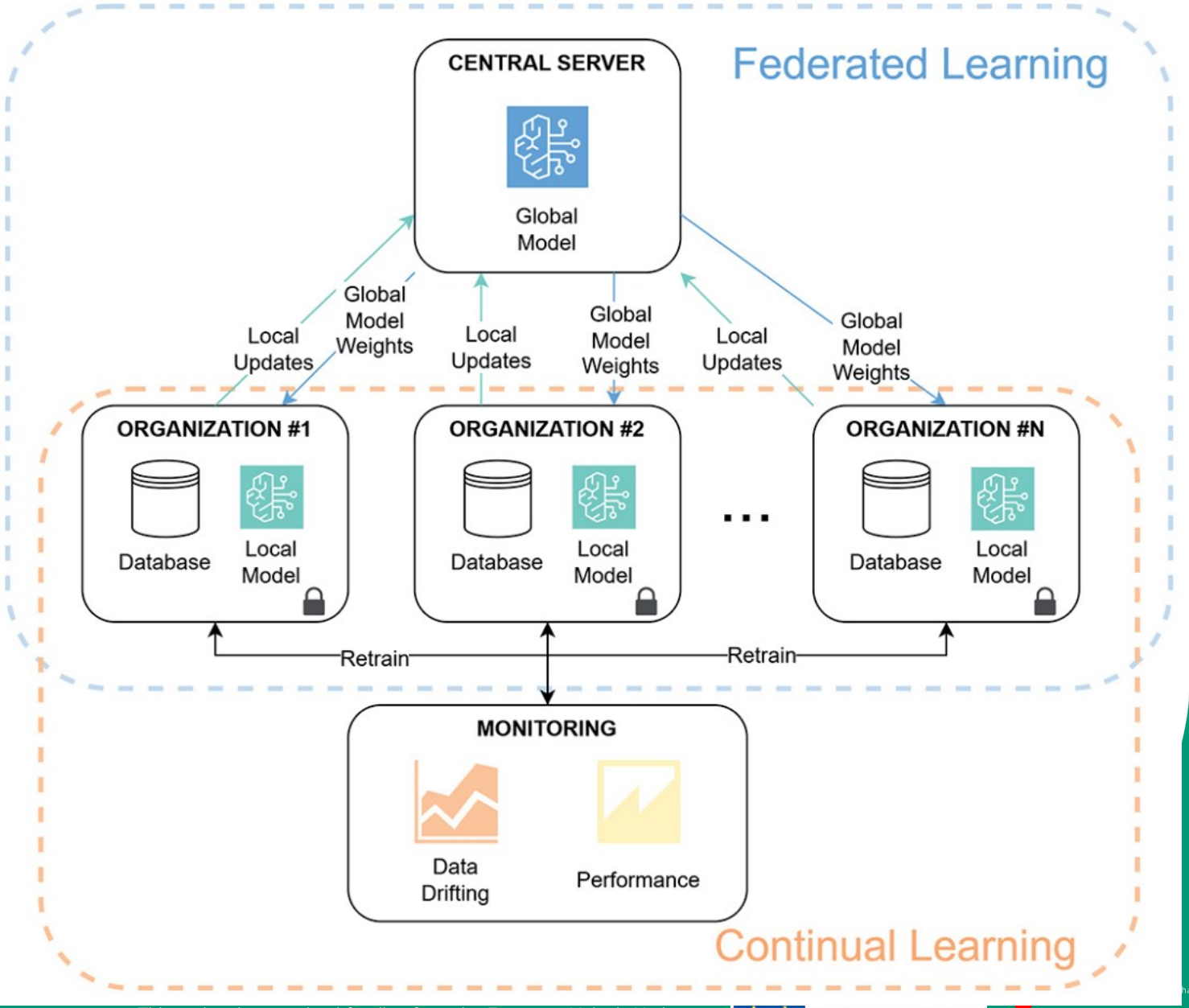

Image from:
doi:10.5281/zenodo.14741719

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Digital Twin example: Electric Arc Furnace

- Operator receives online recommendations based on:
  - Simulated process state
  - Adjustable setpoints
- Recommendations:
  - Timing of:
    - Basket charging
    - End of burner operation
  - Remaining amount of:
    - Electrical energy
    - Oxygen

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Federated Learning (FL) in practice

- Applications in ALCHIMIA:
  - Ladle Furnace model; neural network
  - Electric Arc Furnace model; parametrization of dynamic/analytical model
    - Non-conventional FL application
- Datasets should be balanced and of good quality
- FL results below from Ladle Furnace:
  - Plant 1 and 3: clear improvement
  - Plant 2: no advantage due to coverage/quality in others

R2 score: regression performance
MSE: Mean Squared Error

Model	Features	Plant 1		Plant 2		Plant 3	
		R2 Score	MSE	R2 Score	MSE	R2 Score	MSE
Local	FinalTemperature	0,278	137,33	0,580	36,65	0,158	59,10
Federated	FinalTemperature	0,446	98,88	0,579	45,56	0,299	32,77

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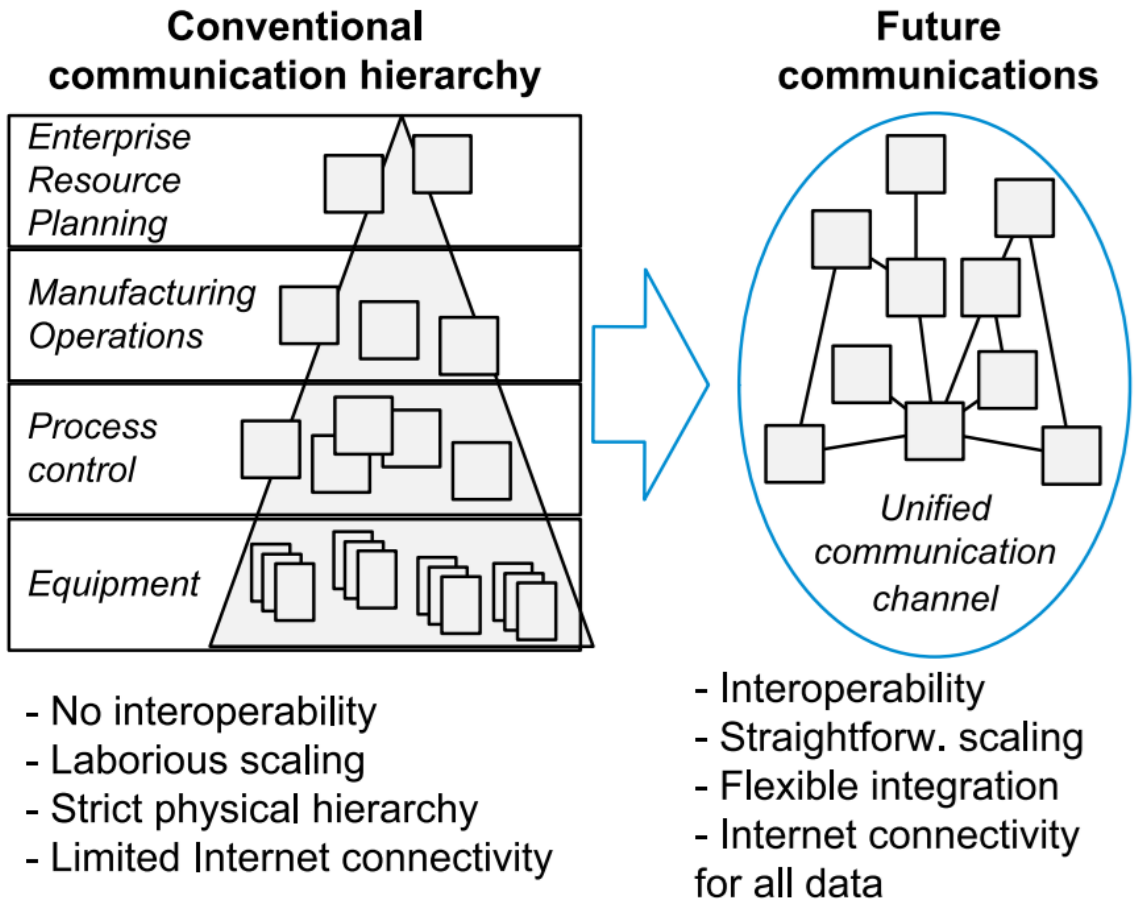
Towards networked systems and microservices



- Data integration happens increasingly with microservices
- ALCHIMIA is an example of this trend

Picture: Kannisto et al.; https://doi.org/10.1016/j.jii.2021.100253
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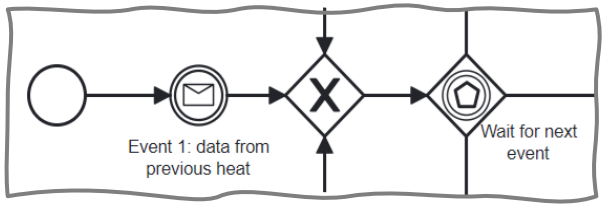
Interoperability: the most difficult aspects

- Legal interoperability
  - What can we do with the data?
  - Related: International Data Spaces / Gaia-X

- Functional interoperability
  - Workflows and sequences
  - What should happen and when?



- Semantic interoperability
  - What is the structure and meaning of the data?

```
{
  "id": "...",
  "type": "...",
  "dateObserved": "...",
  "chemicalAnalysis": { ... }
}
```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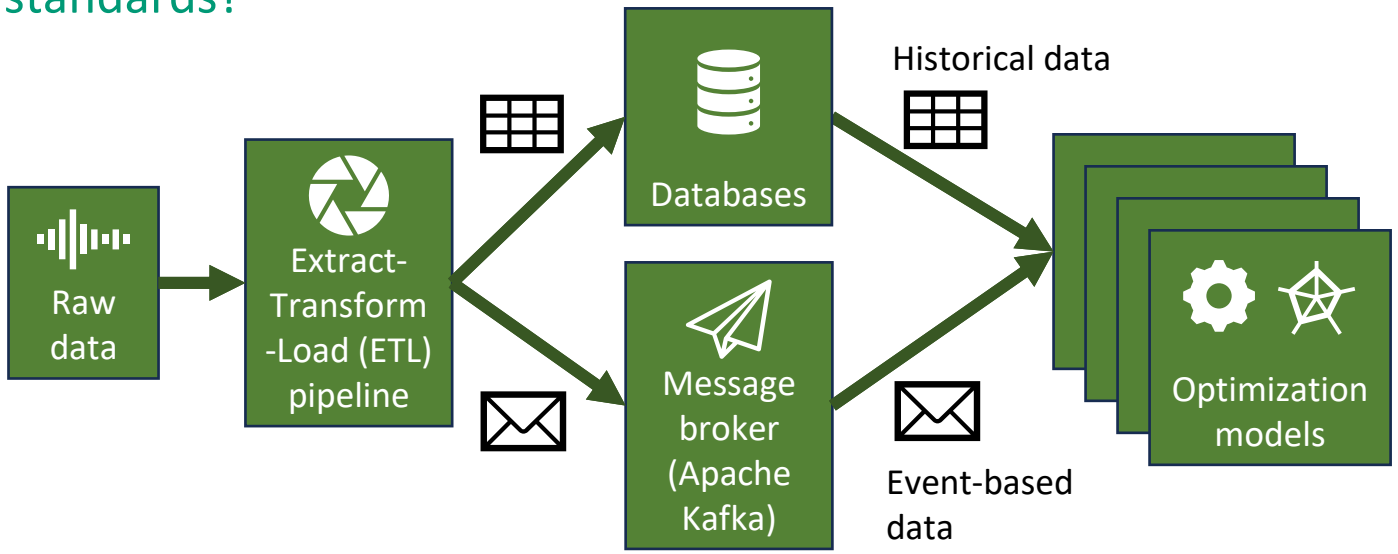
ALCHIMIA data integration mechanisms

- Historical data: databases
  - E.g., heat-related measurements
  - Could use systems with JSON API
    - Use data model standards?

- Event-based data: JSON via message broker
  - E.g., „scrap basket added“



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To standard or to not standard – a research project viewpoint

Standards help us all. However…

Opportunities

- Re-use knowledge across actors, projects, countries, …
- Do not „re-invent the wheel“
- Include own results/needs to standards during development?

Challenges

- Lifecycle: research project vs. standardization project
  - Deep expertise needed (vs. short-term research projects)
- Funding: research project vs. std group membership
- Cost to access standards

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Open standards

- Lighter alternative to conventional standards
  - Available to everyone
  - Often easier to contribute to
- Example: Smart Data Models (SDM)
  - Related to FIWARE
  - JSON data model; linked data too
  - Various domain represented

- ALCHIMIA contribution to SDM: subject „ProcessIndustry“ with message structures:
  - MaterialAddition
  - ProcessChemicalAnalysis
  - ProcessEvent

```
{ "id": "urn:ngsi-ld:ProcessChemicalAnalysis:PlantHelsinki:Furnace2:32781",
  "type": "ProcessChemicalAnalysis",
  "dateObserved": "2025-07-17T14:07:00Z",
  "processName": "furnace2",
  "heatNumber": 10071,
  "chemicalAnalysis": {
    "sampleNumber": 2,
    "chemicalConcentration" : [
      { "substance": "Fe", "percentage": 0.9873 },
      { "substance": "Cu", "percentage": 0.005 }
    ]
}}
```


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Conclusions

- ALCHIMIA demonstrates metallurgy-related optimization with Digital Twins
  - Both AI and „non-AI“ used
- Federated Learning can improve model performance
- Data (quality) and interoperability are paramount
- Standards and open standards enable knowledge re-use; not always easy though

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THANK YOU!

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