Design Considerations for AI/ML, IoT & SaaS based Industrial Decarbonization

The Fifth Elephant (Aug 2023)

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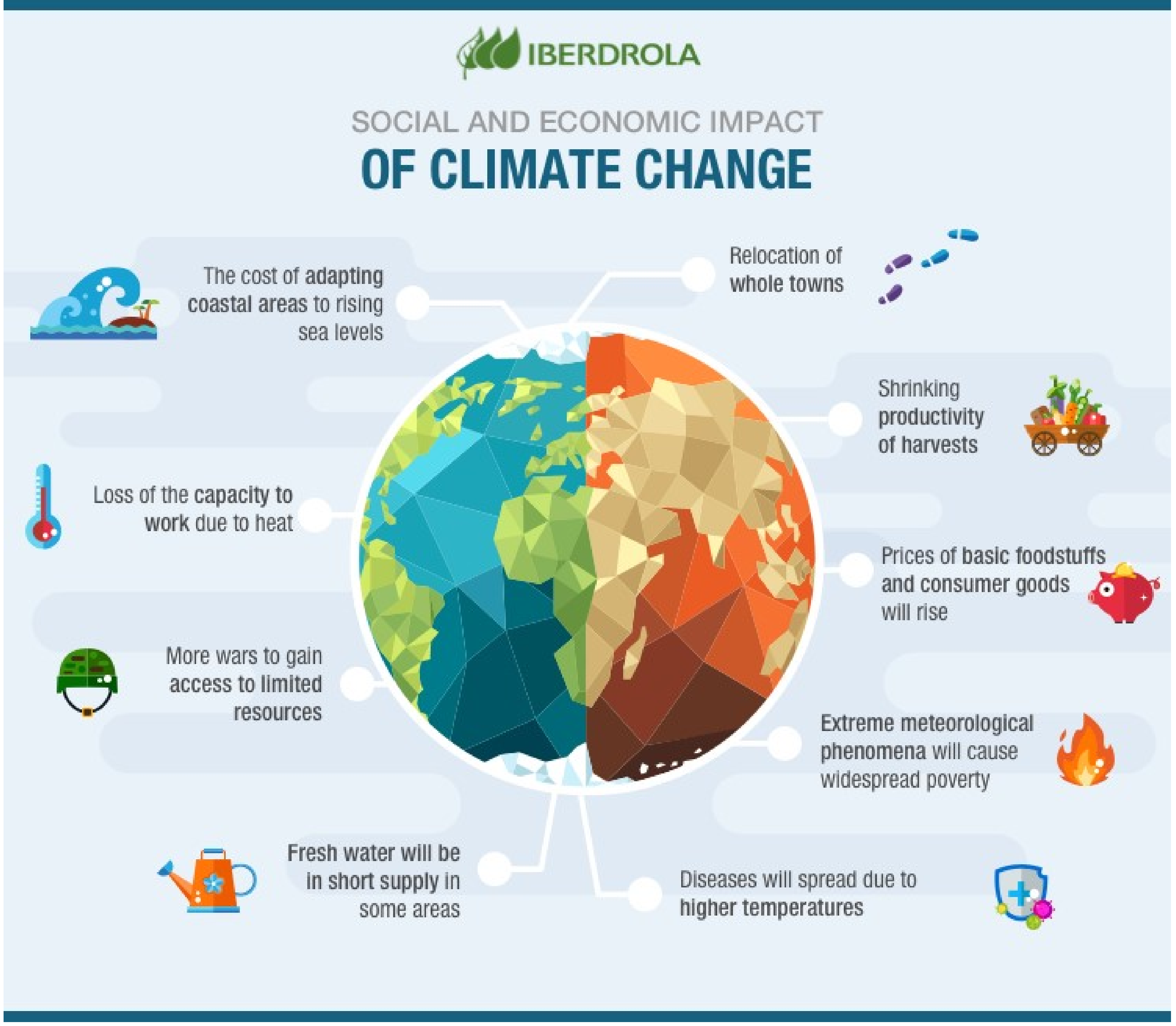
Climate Change & Global Warming

Consequences of Inaction →



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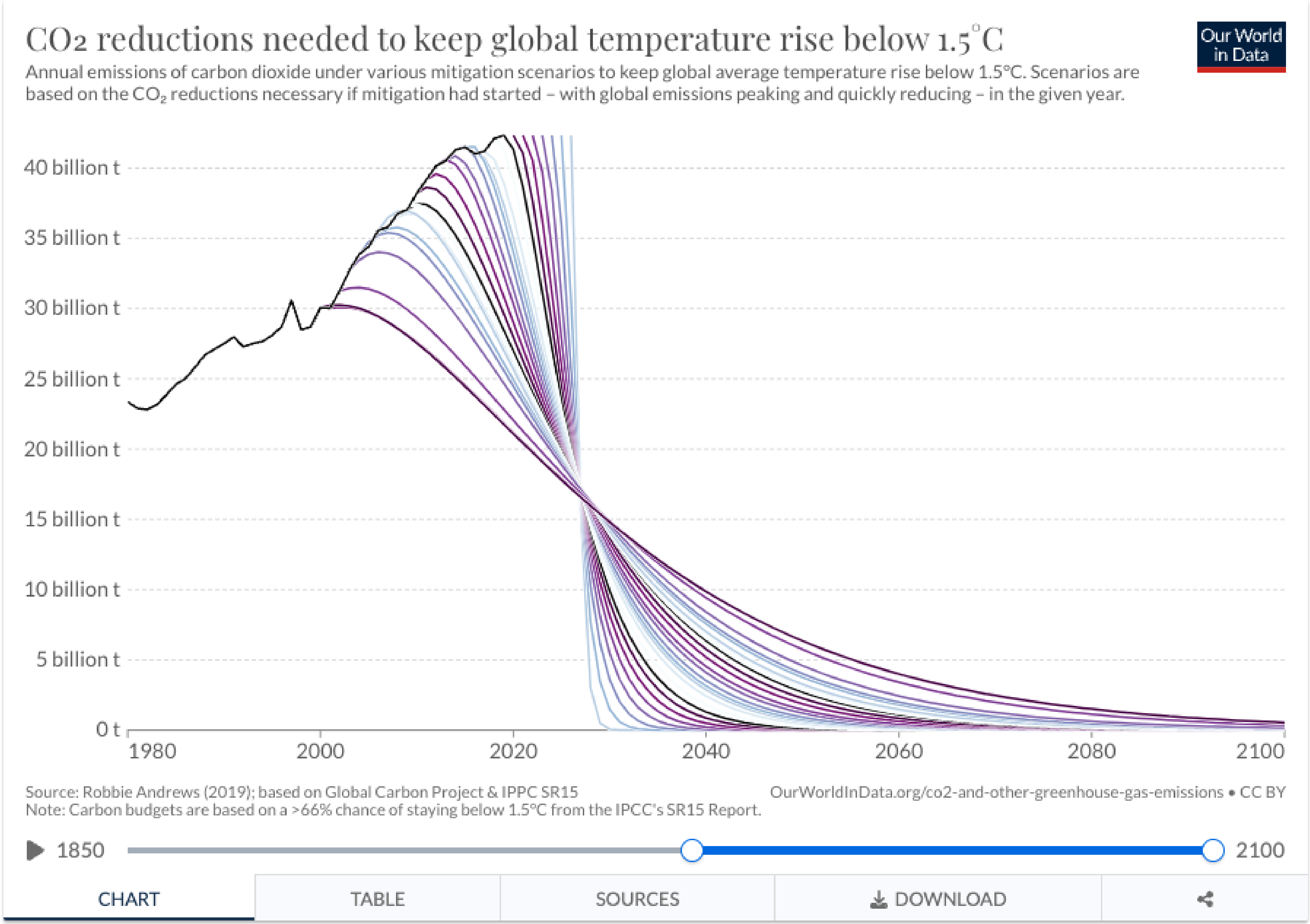
GHGs causing Global Warming: CO2, CH4, …

4X-8X Emission Cuts Needed to stave off an Apocalyse →



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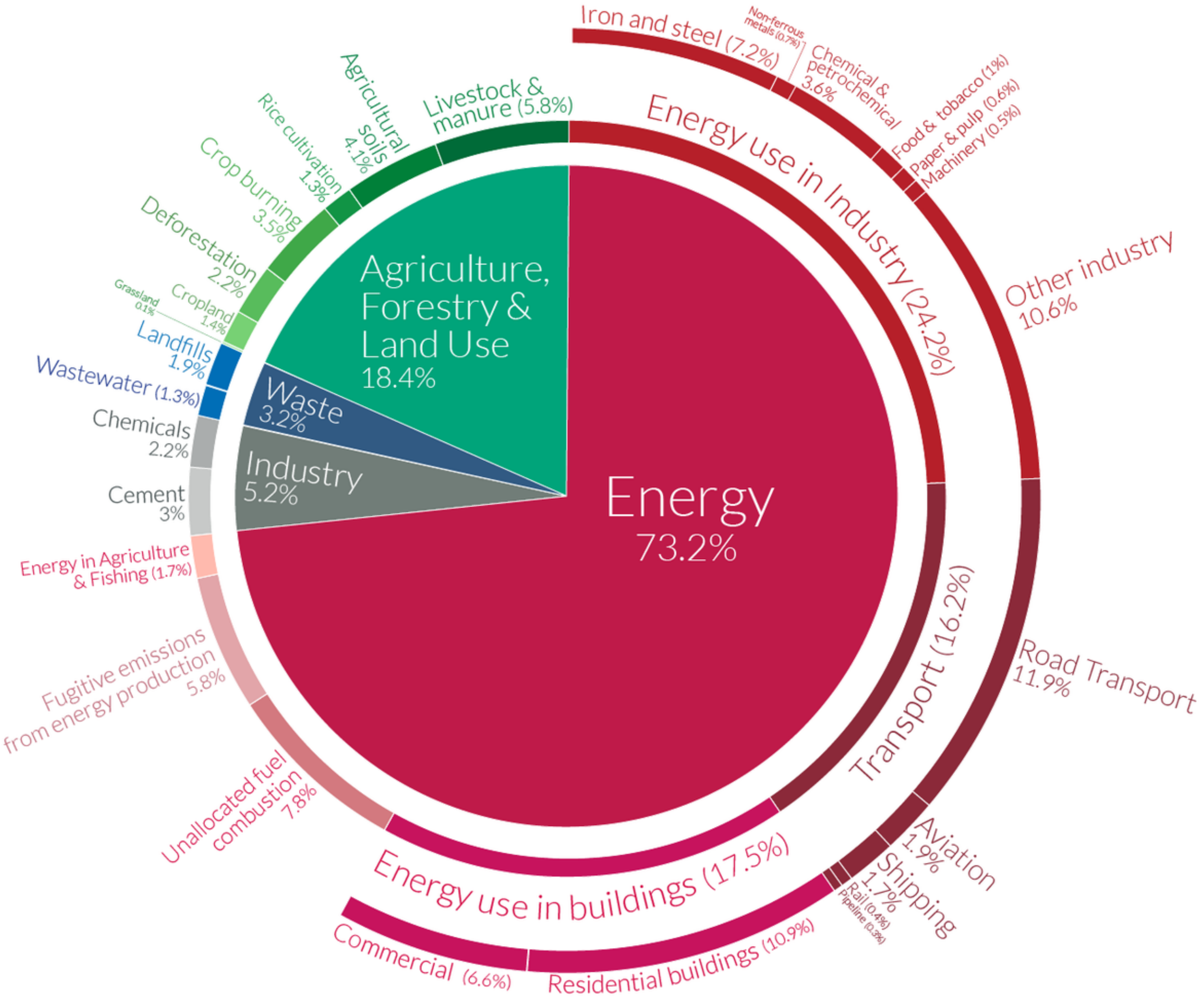
GHG Sources:

Steel, Cement, Oil, Chemicals, Mining add up to 40+% →

Global greenhouse gas emissions by sector

This is shown for the year 2016 – global greenhouse gas emissions were 49.4 billion tonnes CO_2eq.

Our World in Data



OurWorldinData.org – Research and data to make progress against the world's largest problems.

Source: Climate Watch, the World Resources Institute (2020).

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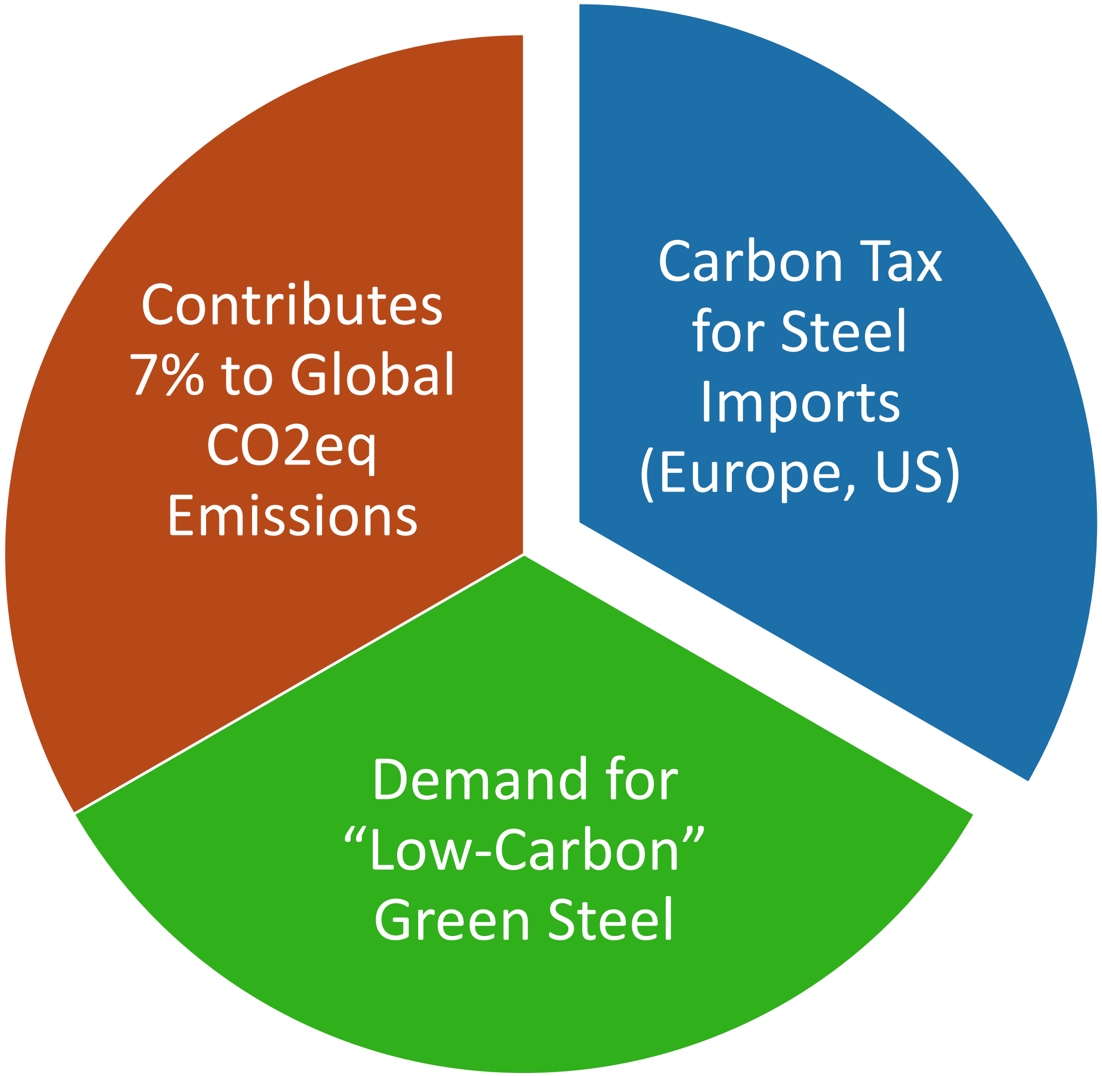
Opportunity: Reduce Emissions in Steel Production



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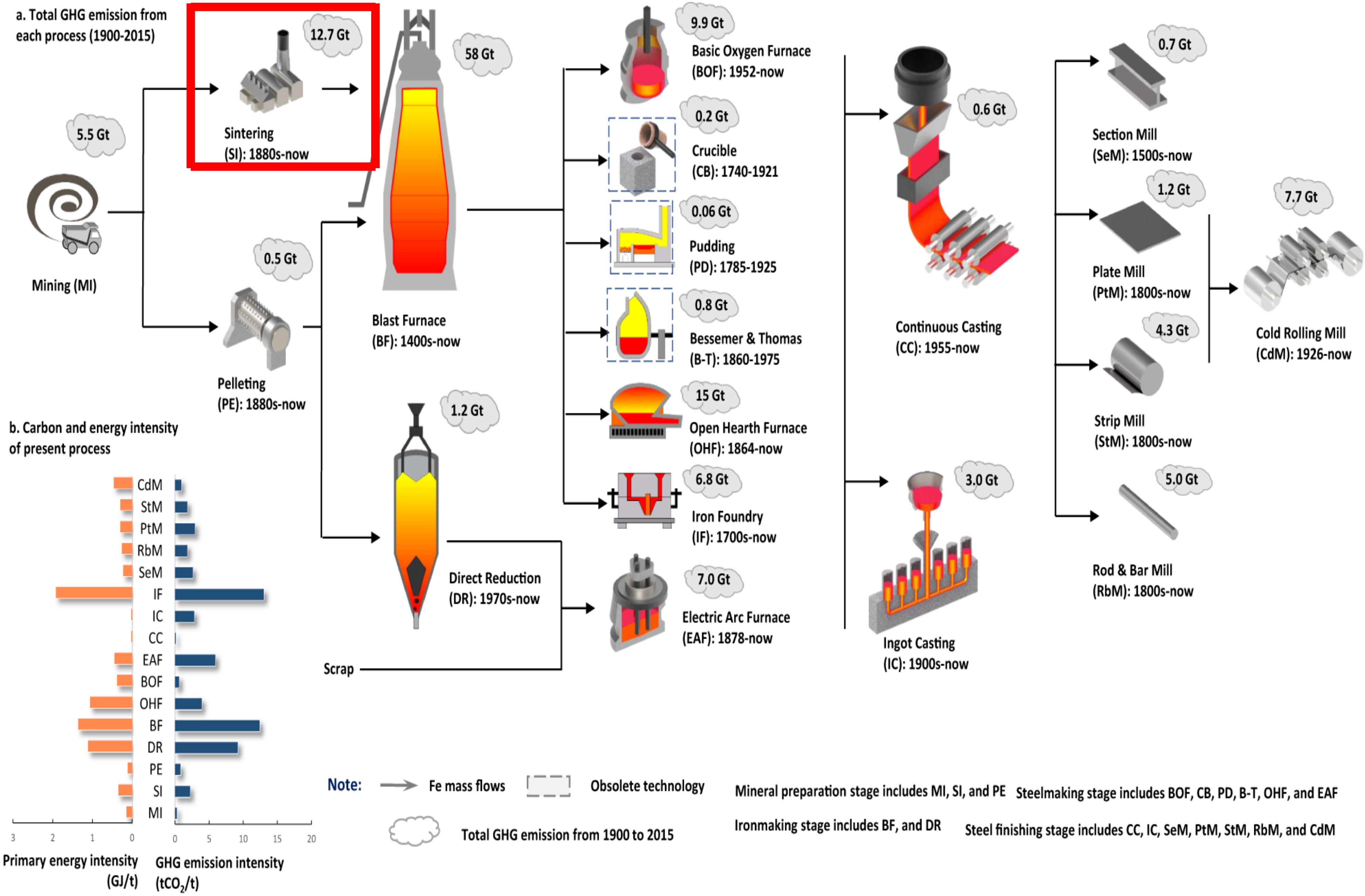
Sintering process contributes 17% of GHGs in Steel Production →



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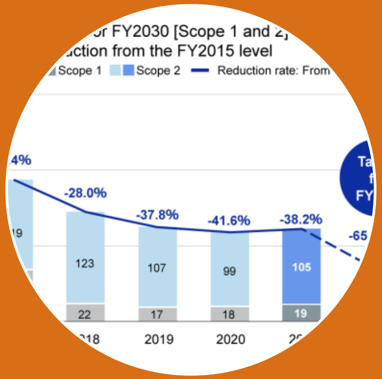
Objectives in Steel (Sinter) Production

Throughput

Maintain or Increase: impacts Revenue



Emissions

Maintain or Reduce: impacts Carbon Offset Costs

Equipment Availability & Efficiency

Zero Down-Time: Spares Cost, Profitability

Scale across new Sinter Processes, Technologies

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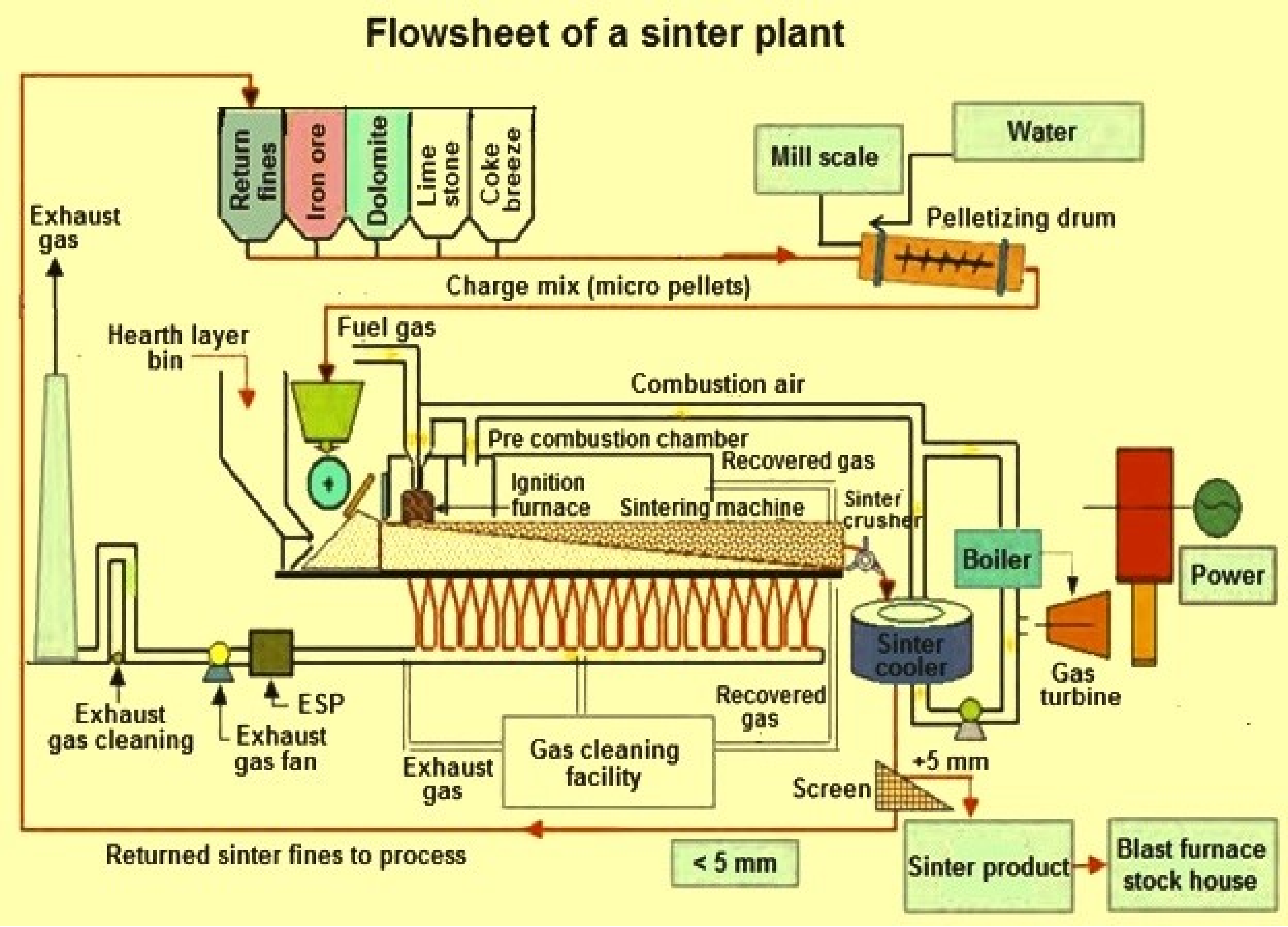
Model the relationship between

Input Resources, Throughput and GHG emissions →

Goal: Closed Loop Recommendation Engine



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Top-of-Mind Questions for Models/Data to Answer

Estimation

Next Batch: Steel Throughput

Next Batch: Return Materials

Forecasting with Recommendations

Future Batches: Steel Throughput & Emissions

Future Batches: Input Change Recommendations for Target Output

What-If Analysis

Cost-Benefit Tradeoffs: Simulations of Input vs Forecast

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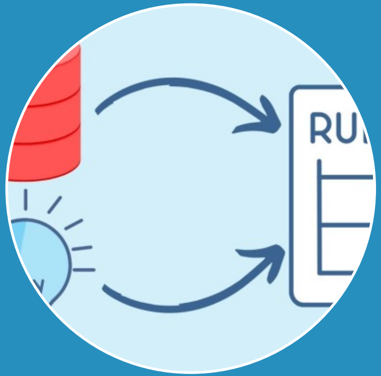
Evolution of Models in Steel (Sinter) Production

Heuristics (Tribal Knowledge)



Rules Based (Experiential)

AI/ML (Sensors, deep insights)

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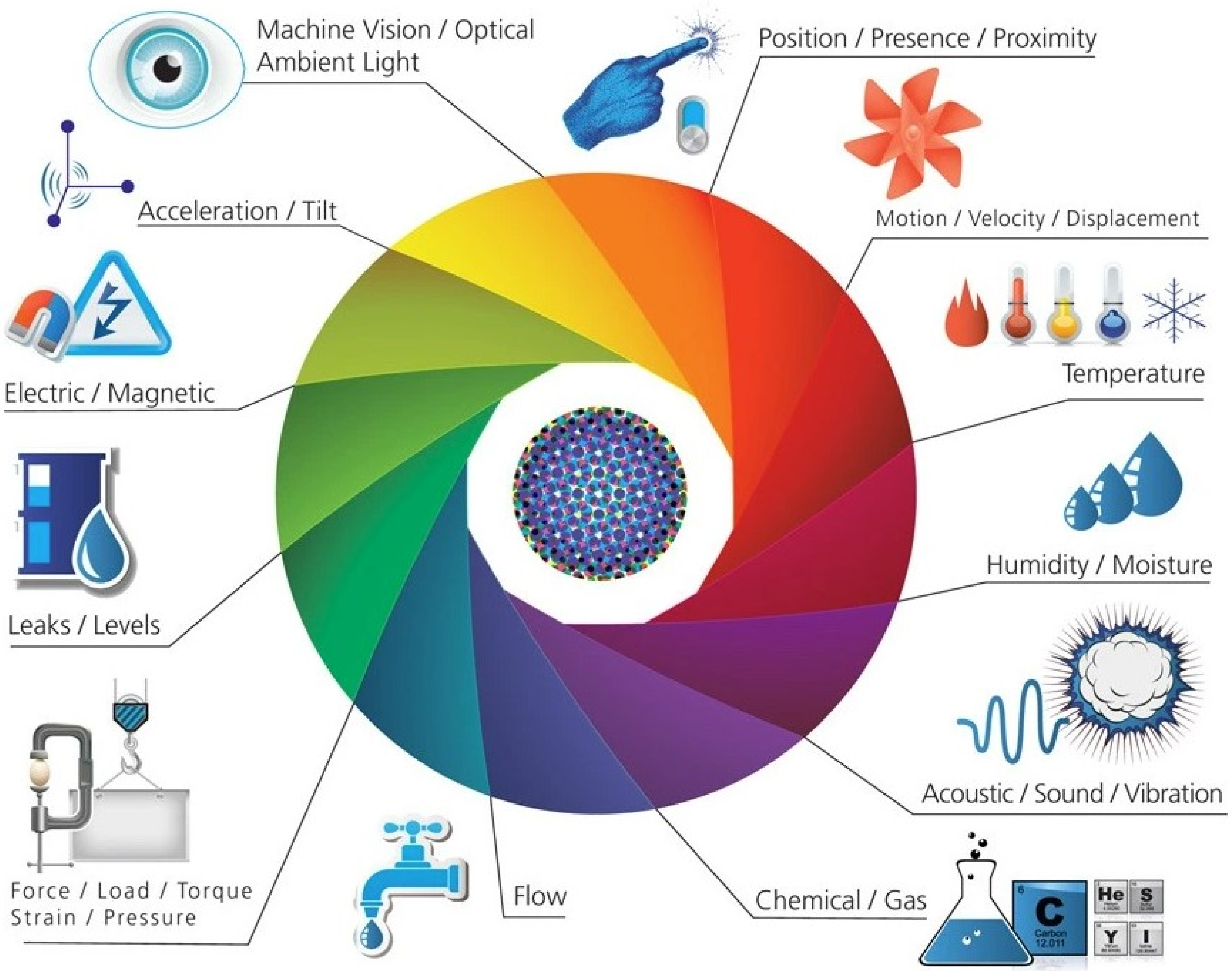
Sinter AI/ML Models : Sensors (p.s. learn how they work!)



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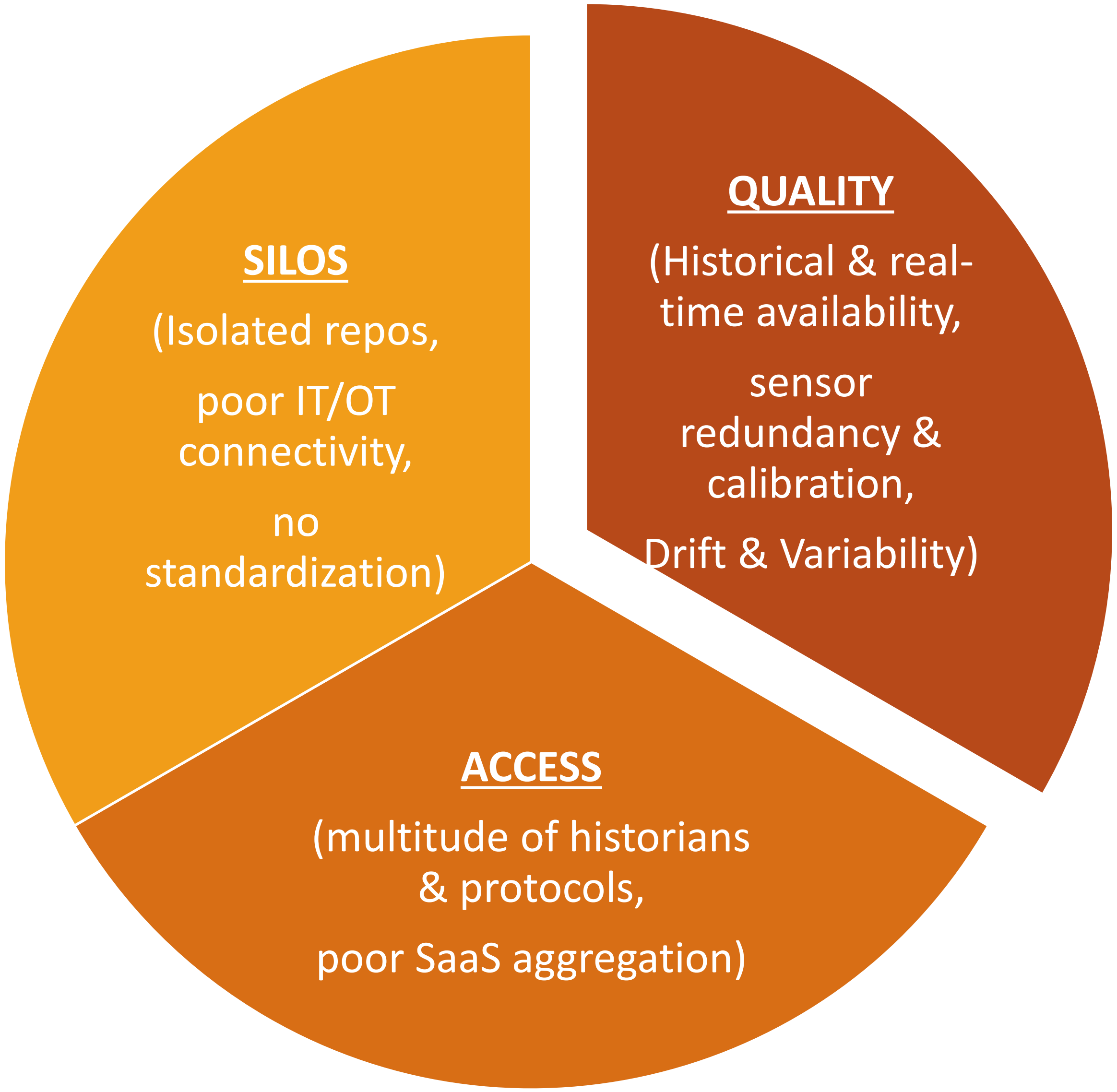
AI/ML Models: Data Challenges



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Mitigating Data Challenges

Connectivity

Standarize IT/OT connectivity, data frequency, formats

Quality

Redundancy design,
Calibration error detection,
Data error design,
Data drift detection,
Environmental monitoring

Access

Security design,
SaaS connectivity,
Edge design

Scale across different Sinter plants and Process Variations

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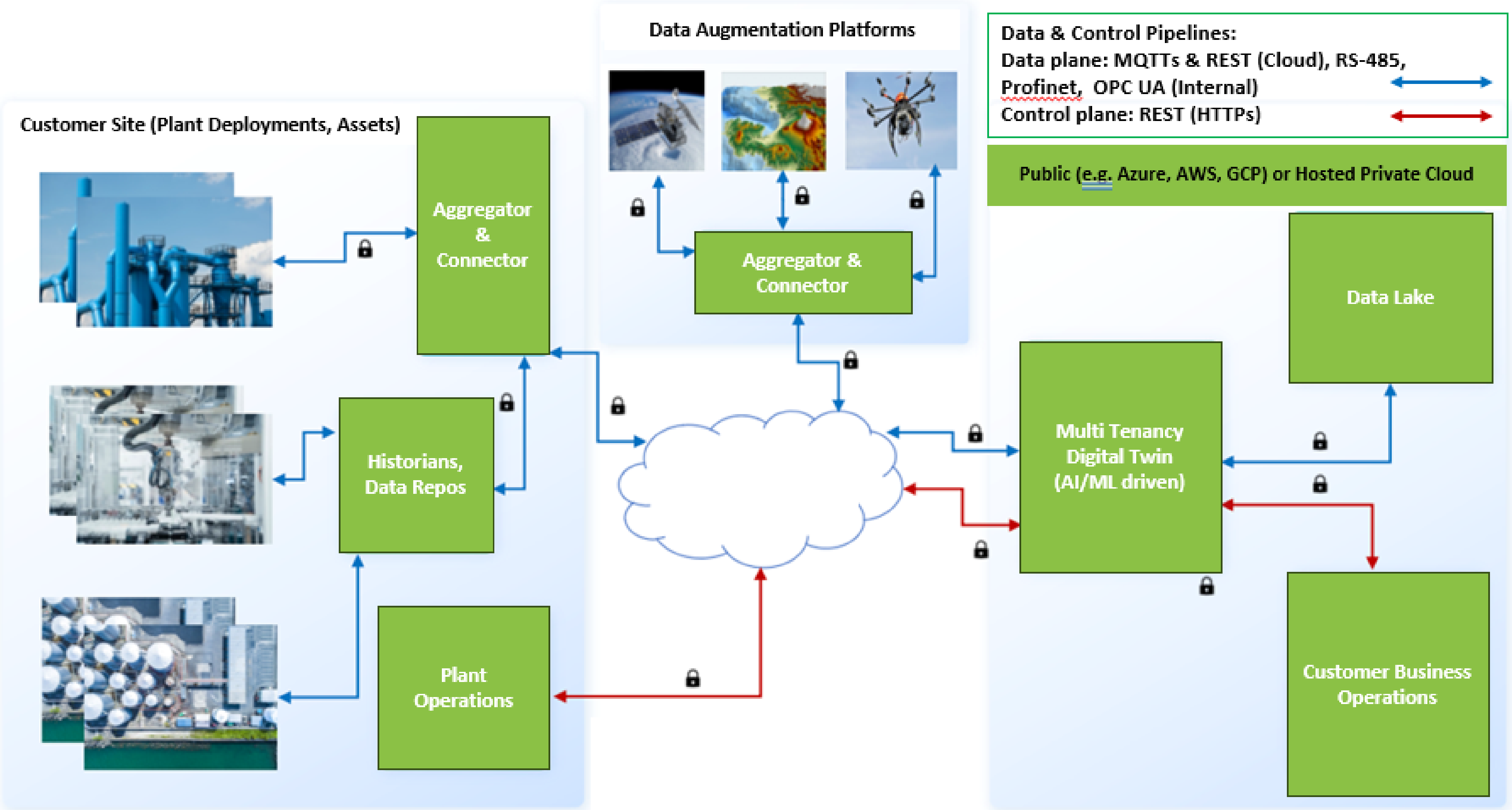
Software Deployment Architecture



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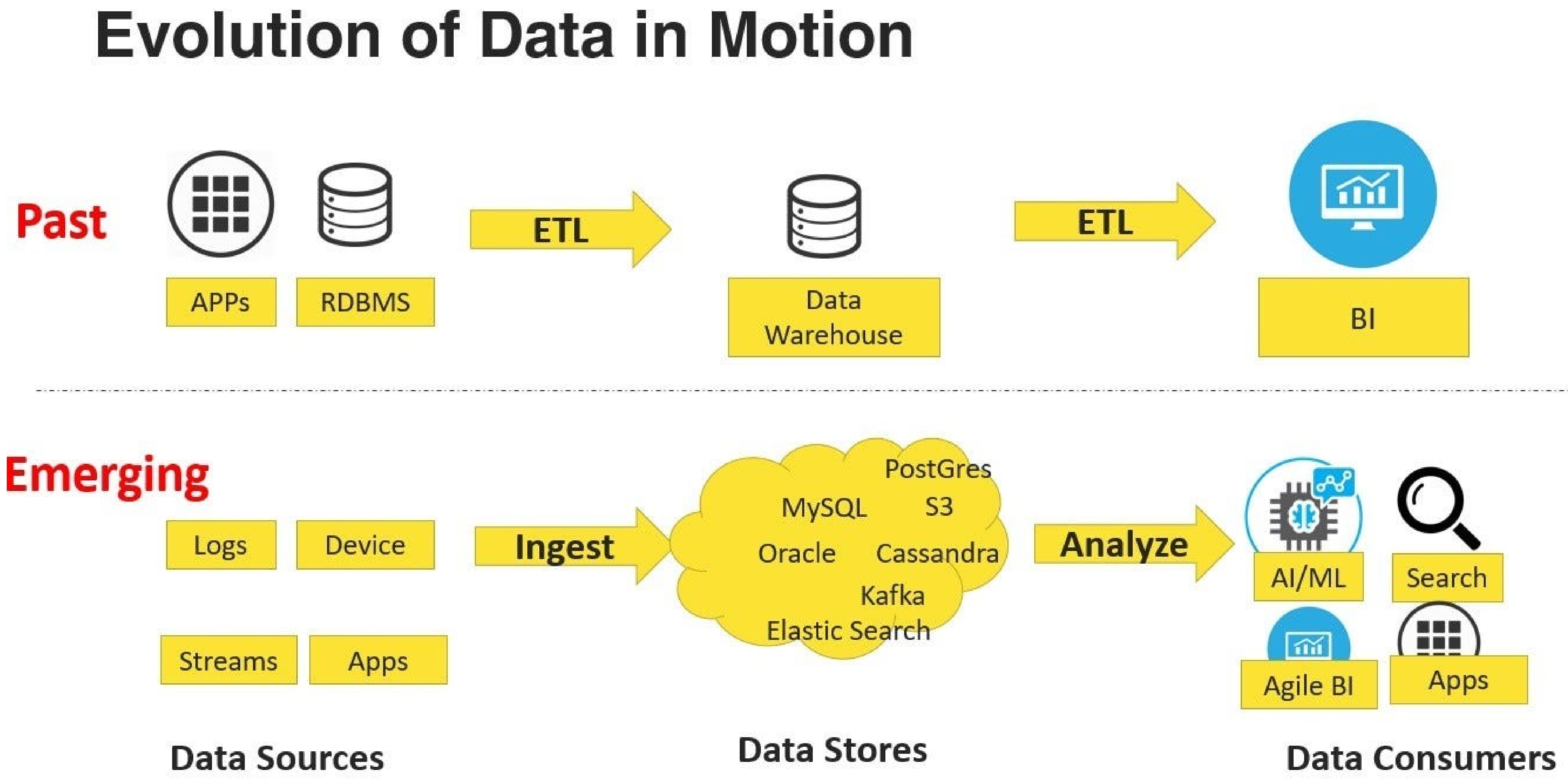
Data Pipelines (p.s. this too is important!)



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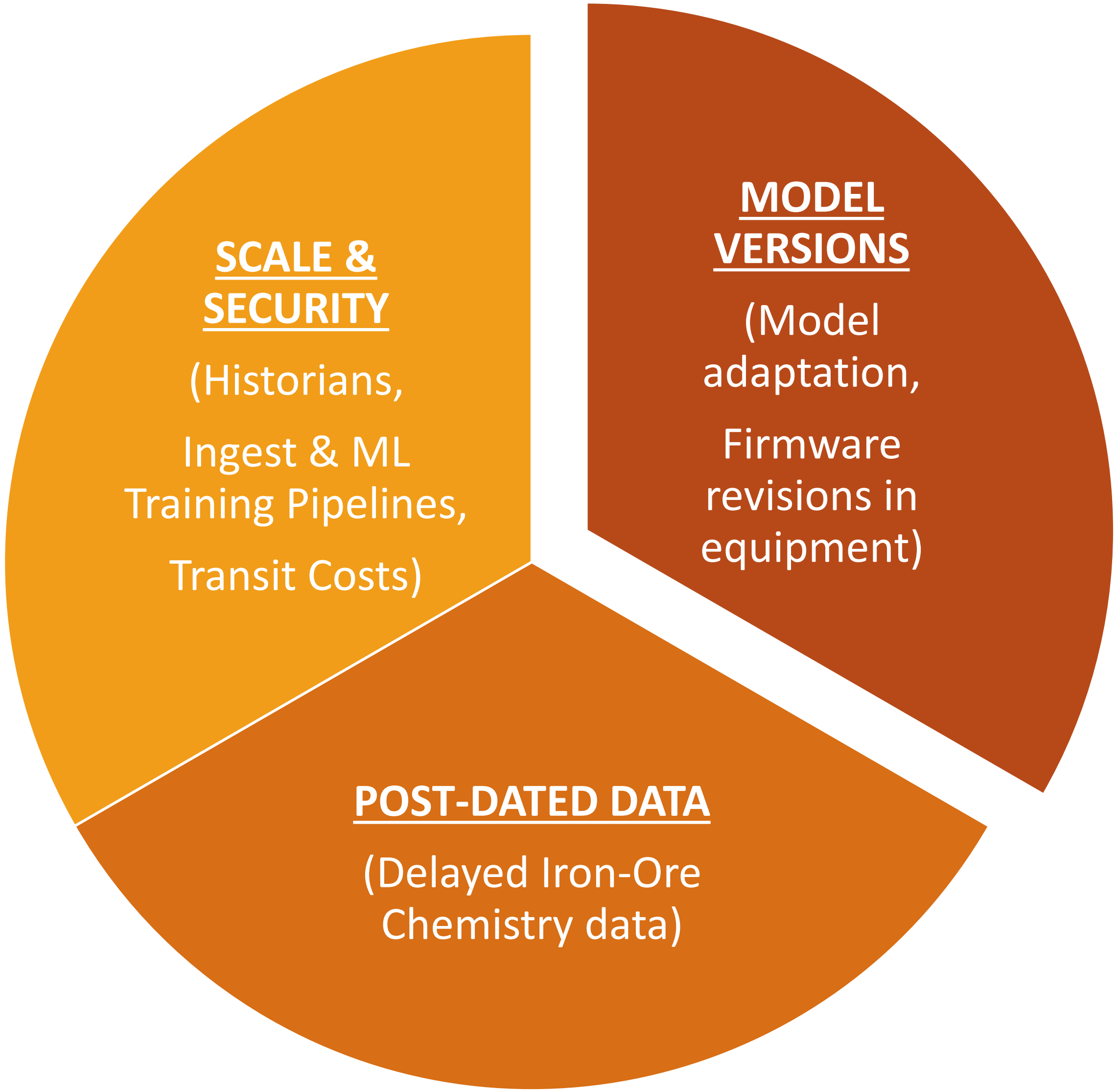
Data Pipelines : Challenges



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Mitigating Data Pipeline Challenges

Scale & Security

Multi Tenancy Design,

SOC2, RBAC & Credentials Design,

Common Data Clouds,

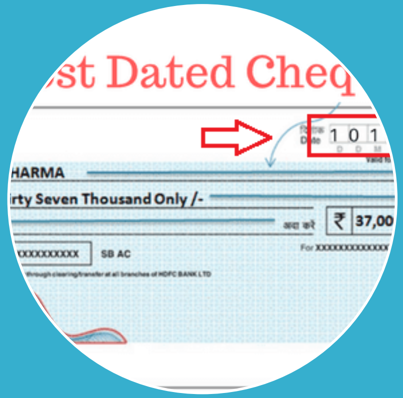
Priority channels

Model Versions

Standardized and Versioned (Internal) Data Models,

firmware and equipment versioning,

Data abstraction



Post-Dated Data

Impute post-dated data based off domain expertise e.g. previous batch chemistry

Scale across different Cloud Deployments, Different Plants

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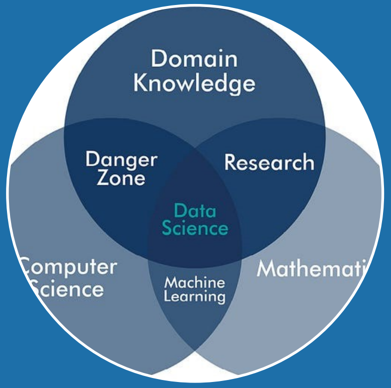
Sinter Plant ML Models : Can It/Will It Work ?



Domain Knowledge

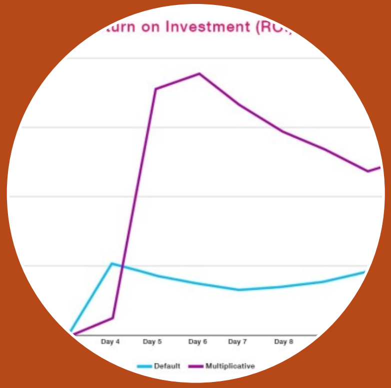
Process expertise ?

Data semantics expertise ?

Explainability

Can AI/ML surpass 30-40 years of process experience ?

How do I explain results, demonstrate repeatability ?



Returns

Quantify the returns?

What will happen when process technology matures?

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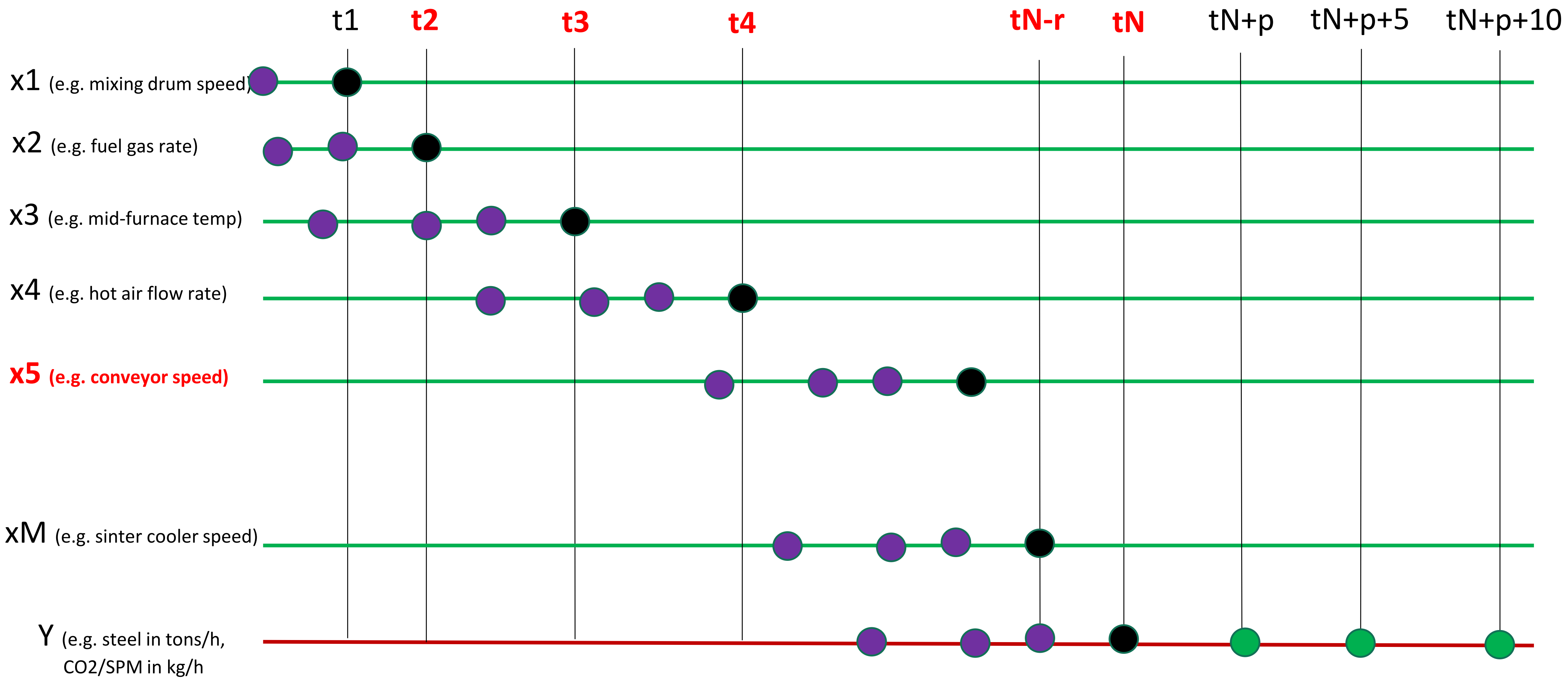
Sinter Plant ML Models: Time Series Nuances



Y(tN) = f(X(t1, tN-r)) : estimator for Throughtput & Emissions

Y(tN+p, tN+p+10) = g(X(t1-Z, tN-r)) : forecaster for Throughput & Emissions based of Z samples of X

ty = h(x5) for 1< y <= N : h is a perturbation for each t2 … tN

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Sinter Plant ML Models : Approach

Account for variable tY's ?

Analyse X(t) vs Y(t) to determine best {tY}

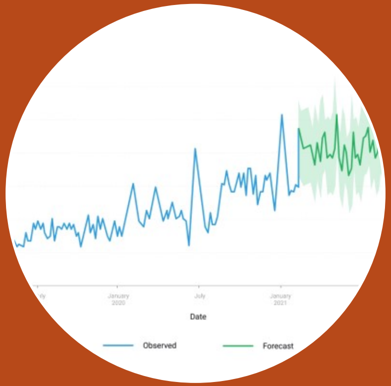
Analyse x5(t) with Sinter SOP design to determine best x5 and hence best {tY}

Estimator f(x)

Dataframe realignment: i.e. {xI} with {tY}

SVM, DNN, …

Temporal models: humidity, temperature, ore H20-content



Forecaster g(X)

T future timeslots from "Z" X(t) collections

LSTM, B-LSTM, …

No single all-in-one model for f(X) or g(X)

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Sinter Plant ML Models : Approach (cont'd)

Recommendations ?

Recalibrate g(X) to a specific tN+F future timeslot

Leverage PSO optimizer for optimal X values for given Y objectives

X variables cannot be adjusted in one step. Need to follow Sinter SOP for step-increments

"F" and SOP introduce brittleness owing to per plant/process variations and management objectives

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AI/ML for Steel (Sinter) Plants : Lessons & Questions

- Domain knowledge: Data Semantics, Physical Process Layout and Sinter SOPs is a Must
- Enterprise grade focus on Errors, Support/Troubleshooting, Diagnostics, HA, Recovery and Security.
- Robustness of AI-based algorithms to be validated via FMEA design
- Need many models (temporal & geo-based) even for the same process and customer
- Is “Transfer Learning” possible across sinter plants – jury is still out?
- Approach is reusable across different processes – how do I reduce domain and training time?
- Closed-loop control: Insufficient Data Sets to reliably deploy for critical operations

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THANK YOU !

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