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voestalpine Stahl, Linz, Austria

Methodologies and tools for designing a decision support system for energy management

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29 October 2024

ESTEP 2024 Annual Event

ESTEP European Steel Technology Platform

20 years together

H2 FOR GREEN STEEL 3rd INTERNATIONAL CONFERENCE *meets* A CIRCULAR ECONOMY DRIVEN BY THE EUROPEAN STEEL

voestalpine ONE STEP AHEAD.

PRIMETALS TECHNOLOGIES

Project co-funded by the Research Fund for Coal and Steel (RFCS) G.A. 101034060

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Contents

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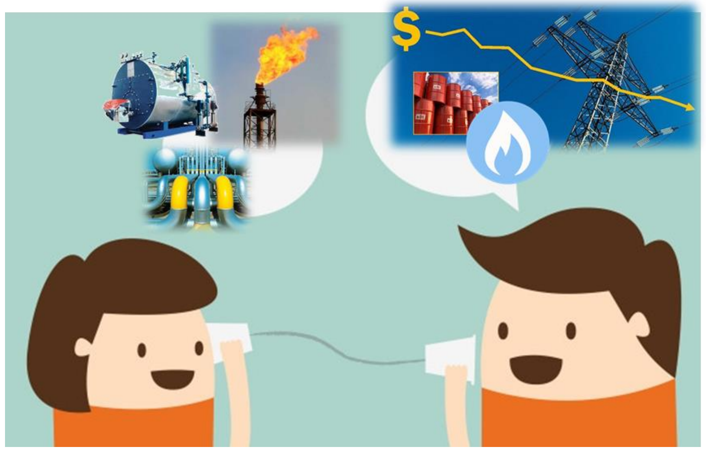
Introduction

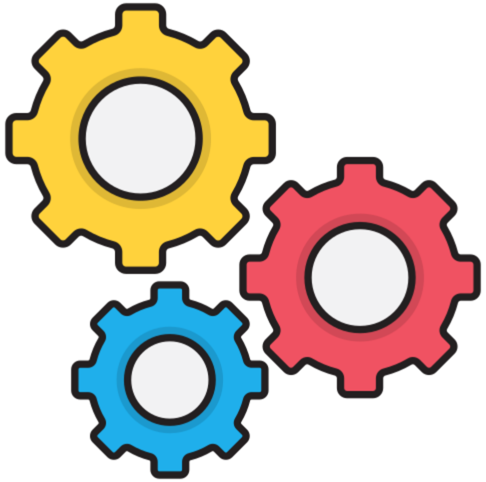
Strategic management of energy in a company to optimize energy efficiency, reduce costs, and minimize environmental impact.

Main goals: Reduce energy consumption, improve the efficiency of production processes, reduce CO_2 emissions, and comply with environmental regulations.

A **DSS** is needed for:

- **Energy consumption monitoring**
  - Detection and continuous monitoring of consumption in real time or periodically.
  - Data analysis to identify consumption trends and peak usage.
- **Energy cost optimization**
  - Identifying solutions to reduce costs
  - Scenario simulation and comparison of strategies to save energy and reduce CO_2 emissions.
- **Energy demand forecasting.**
  - Use of forecasting algorithms based on historical, weather and production data.
  - Real-time adaptation to respond to changes in demand.
- **Integration of renewable and/or byproduct sources**
  - Evaluation of the potential for integration of renewable energy
  - Resource planning based on variability of energy sources.
- **Predictive maintenance management, etc…**





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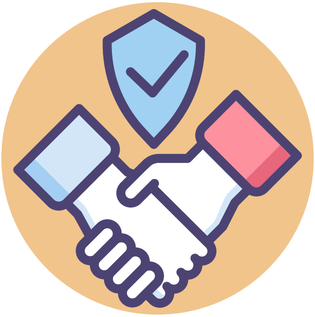
Introduction

Issues:

- **Complexity of integrating byproduct energy sources.**
  - Variations in energy production and problematic forecasting of source availability.
  - Need for solutions for energy balancing and peak generation management.
- **Cost and complexity of technology**
  - Lack of commercial software in the field
  - Implementation of advanced monitoring systems and sensors is expensive (through commercial libraries)
  - Stability and reliability of open-source libraries
  - Interoperability issues between legacy systems and new technologies.
- **Data quality and availability.**
  - Inconsistent, incomplete data or data collected in different formats can compromise analyses.
  - Difficulty in accessing data in real time and at a granular level for some consumption areas.
- **Data security and privacy**
  - Need to ensure security of collected data, especially in industrial settings.
  - Protection of sensitive information for compliance with privacy regulations.
- **System scalability and adaptability**
  - Adapting DSS to changes in business or industrial structures can be complex.
  - Scalability issues when integrating new components or energy sources.



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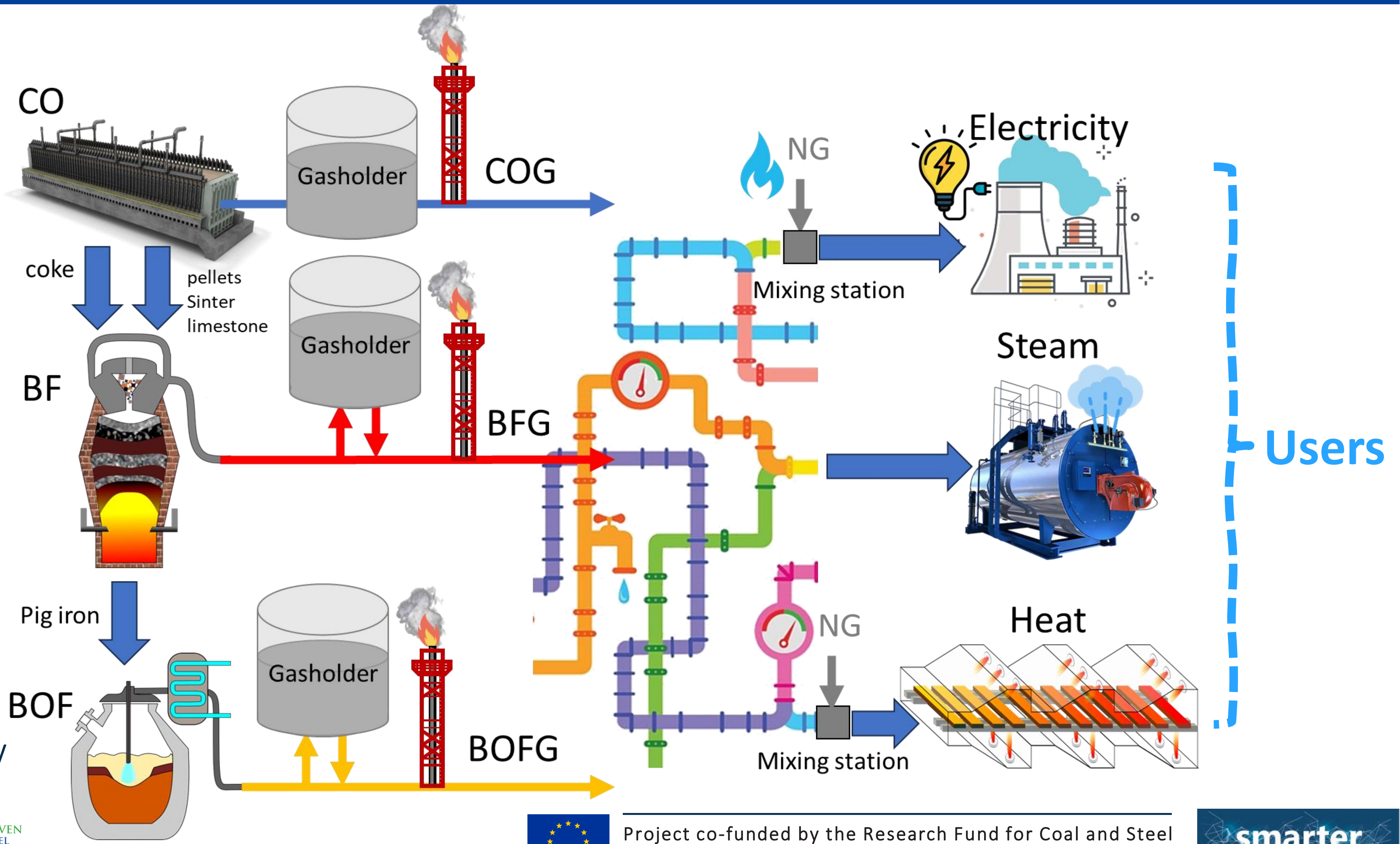
A case study: Optimization of process offgas distribution

Coke Oven Gas (COG)
- Variable volume flow production and Net Calorific Value (NCV)
- The highest Net Calorific Value (NCV), ~ 50% of Natural Gas (NG)

Blast Furnace Gas (BFG)
- Slowly variable volume flow production and NCV
- The lowest NCV (~9% of NG NCV)

Basic Oxygen Furnace Gas (BOFG)
- Good NCV (~25% NG NCV)
- Discontinuous volume flow production and variable NCV



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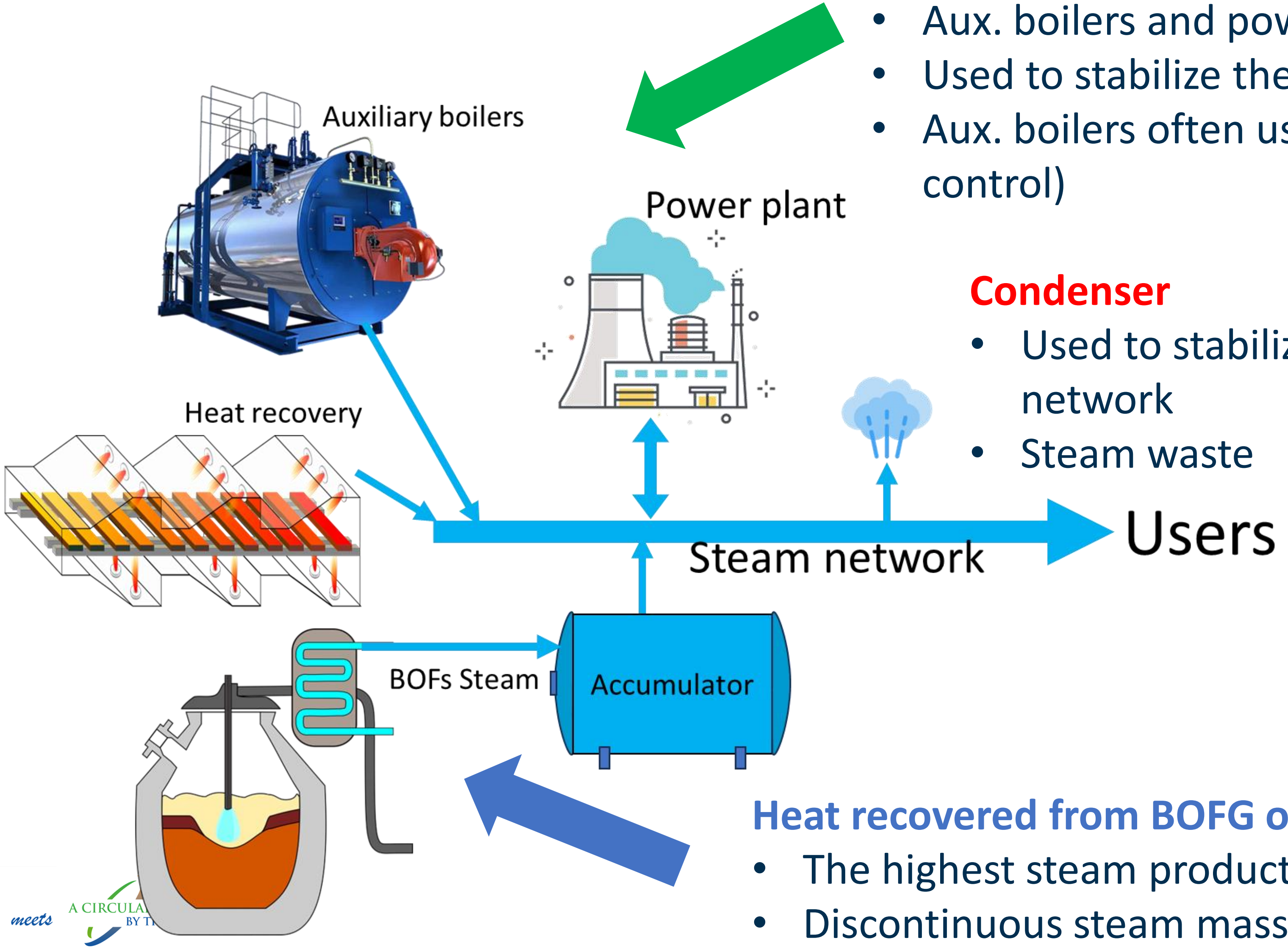
A case study: Optimization of process offgas distribution



Controllable steam production

- Aux. boilers and power plant
- Used to stabilize the pressure in the network
- Aux. boilers often used in switching mode (pressure control)

Condenser

- Used to stabilize the pressure in the network
- Steam waste

Heat recovered from BOFG or from furnaces

- The highest steam production
- Discontinuous steam mass flow

A case study: Optimization of process offgas distribution

Research Fund for Coal & Steel

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GASNET

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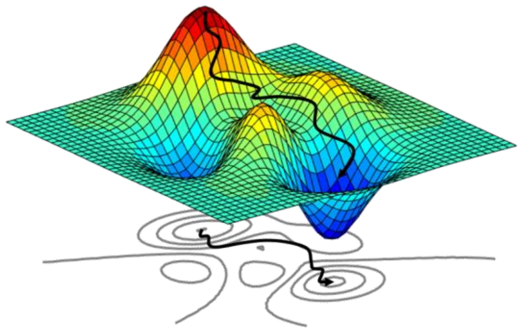
Management optimization of the off-gas networks within integrated steelworks

Methodologies for control systems, optimization and modelling, and DSS for process operators



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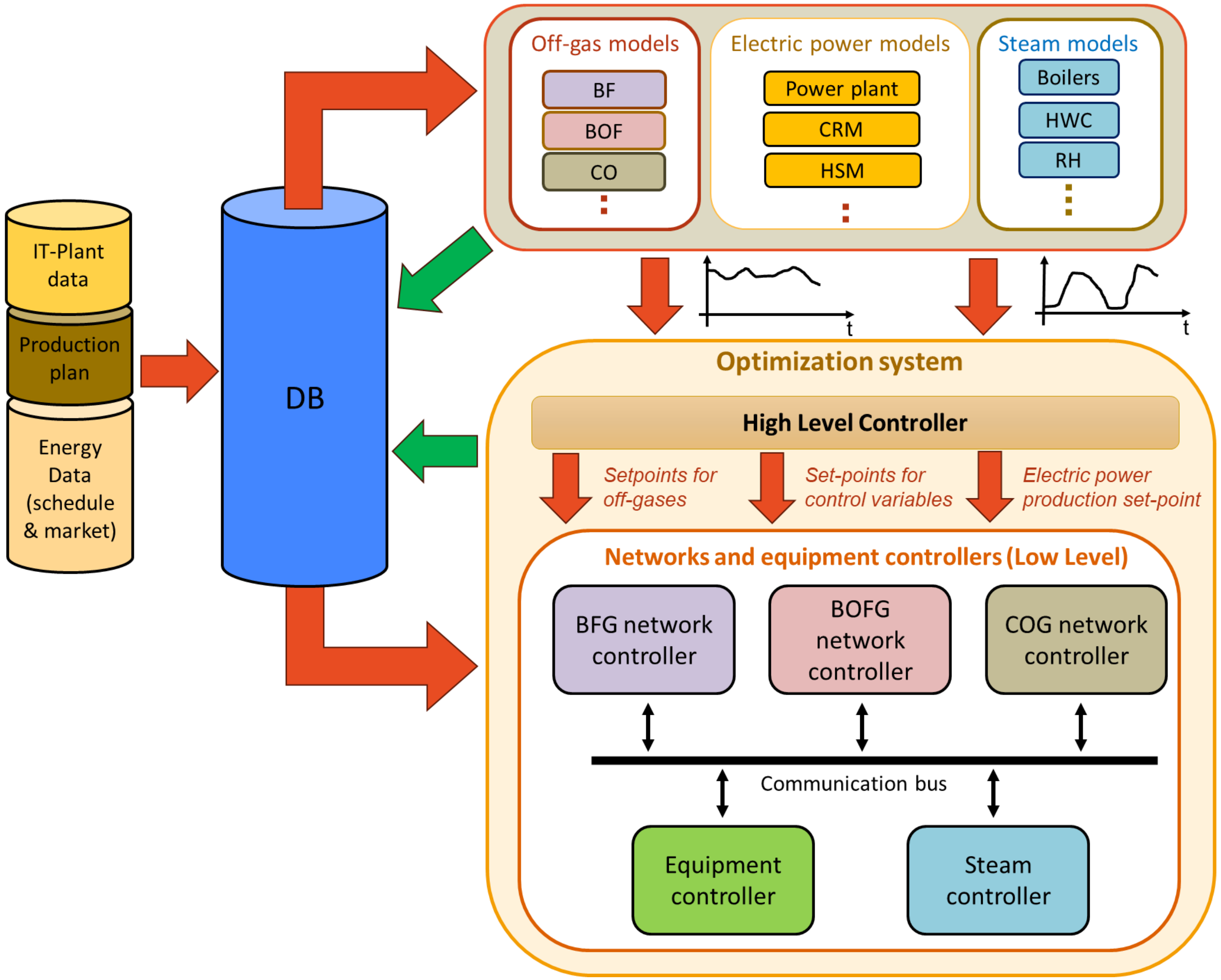
Architecture

A **database** for collecting data from different sources

- Scheduling of the production
- Current and past measures

And a **communication system** based on webservices



A Digital Twin

- Describes the current and future behavior of the integrated steelworks:
  - POGs
  - Electricity
  - Steam
  - Heating
- Modelled and validated through field data + **continual learning**

The optimization system

- Optimizes in real-time the control strategy
- Shows KPIs and control strategies to process operators through HMI

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Methodologies

A digital twin is a virtual representation of a physical object, process, or system, updated with real-time data to simulate, predict, and optimize performance.

Key Components:

- Physical Entity: The actual object or system being modeled.
- Digital Model: The virtual counterpart that mirrors the physical entity.
- Data Connection: Real-time data flow between the physical and digital versions.

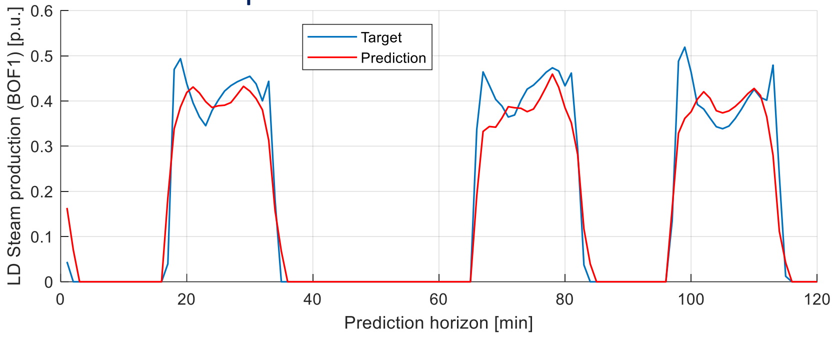
Modelling and forecasting objectives:

- POGs production and consumption
- Electricity consumption and production
- Steam production and consumption
- Equipment: power plant, gasholders, boilers, etc.

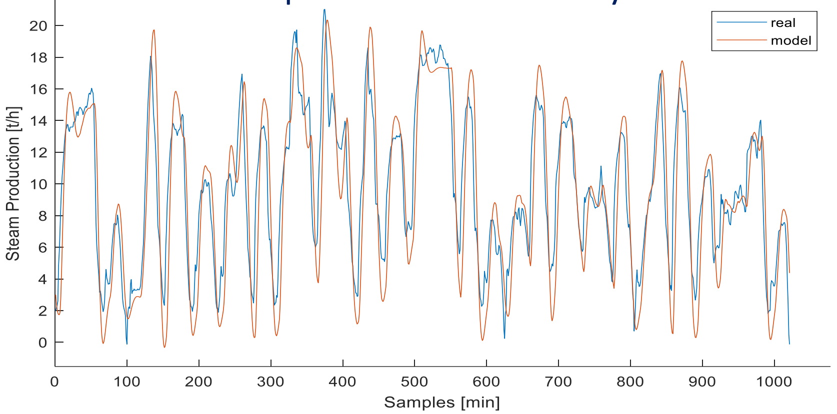
Methodologies:

- Energy forecasting
  - Deep Echo State Networks and Feed forward neural networks
  - Nonlinear ARMAX models
  - Gaussian regression models
  - Moving average models (for slowly changing energy streams)
- Networks and equipment models:
  - Linear correlations and state space models

Steam production in the LD boilers



Steam production in auxiliary boilers



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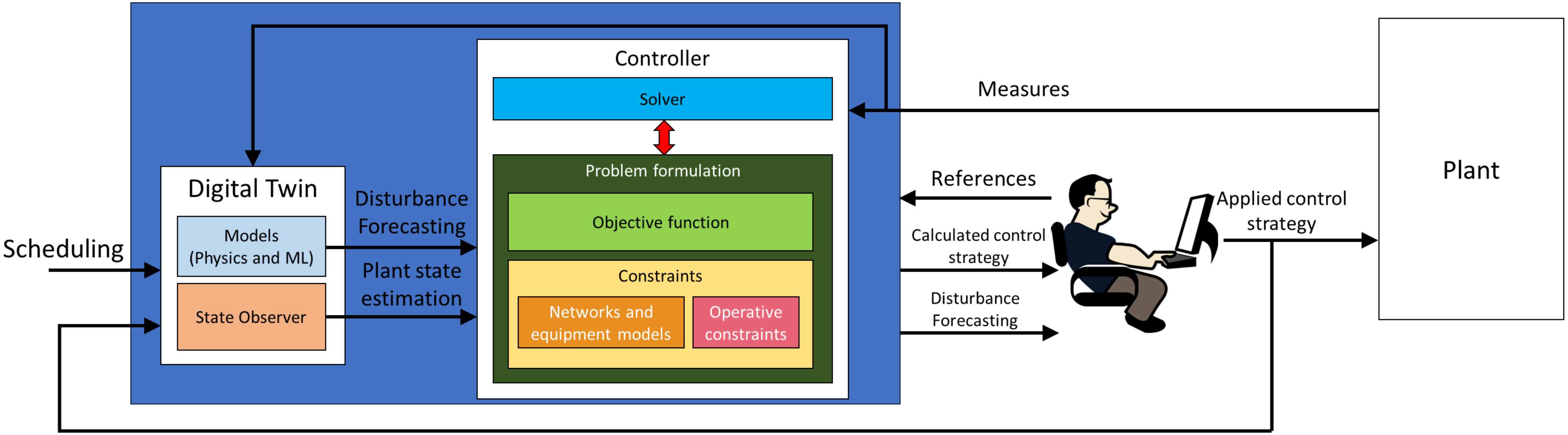
Control and automated Decision-Making process:



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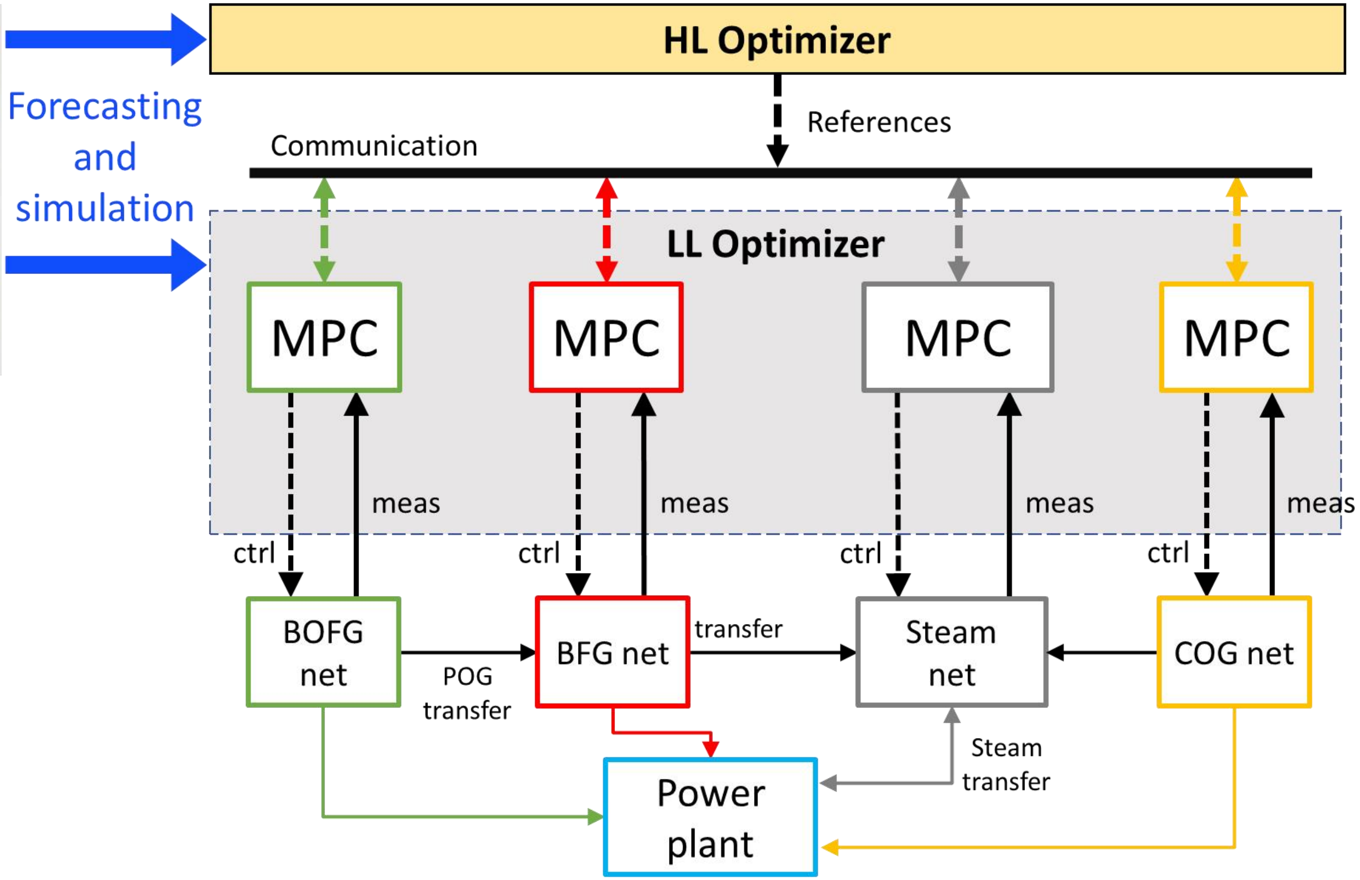
Methodologies

Control and automated Decision-Making process:

Digital Twin



The HL Optimizer solves a Linear Programming (LP)

- **Costs**: minimization of overall Economic balance and energy wastes
- **Constraints**: main constraints on equipment and power plant

The LL Optimizer solves a Mixed Integer Linear Programming (MILP)

- **Costs**: economic costs and environmental impact of each energy network
- **Constraints**: detailed list of constraints (networks, equipment, etc.)

Main decision variables:

- Electricity production scheduling + Gas mix
- Gas mix to furnaces and their modalities
- Gas mix to Steam Boilers and modalities
- POG transfer between different networks

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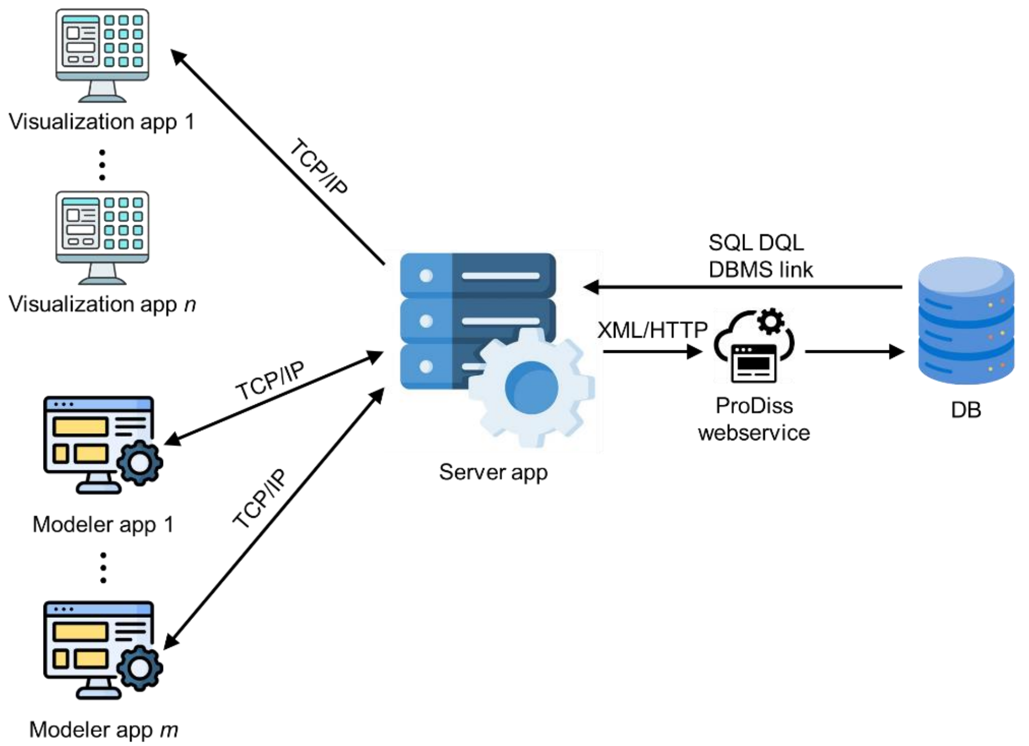
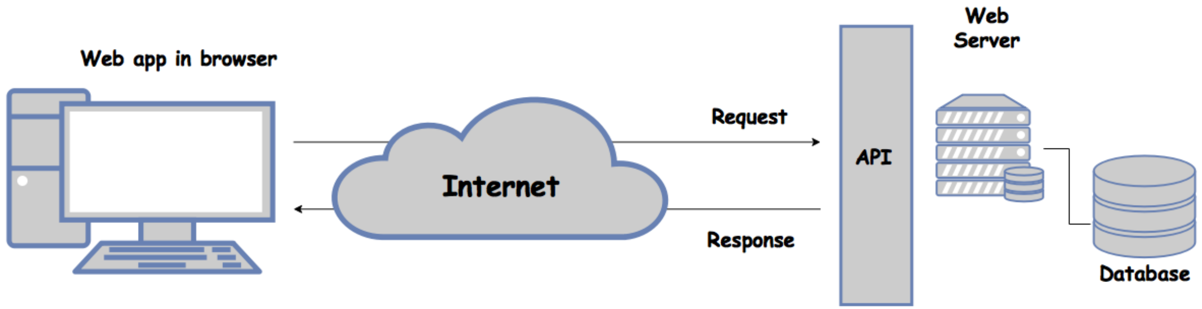
Technologies

Two versions of the software:

- A «standalone» based client-server paradigm for prototyping the concept: Tre principali applicazioni:
  - A server application
  - A viewer application
  - A digital twin application

- A production software based on RESTful webservices that run on a server and can be called through a web API





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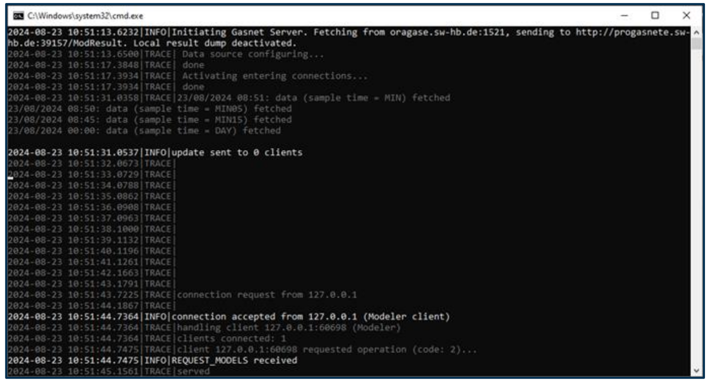
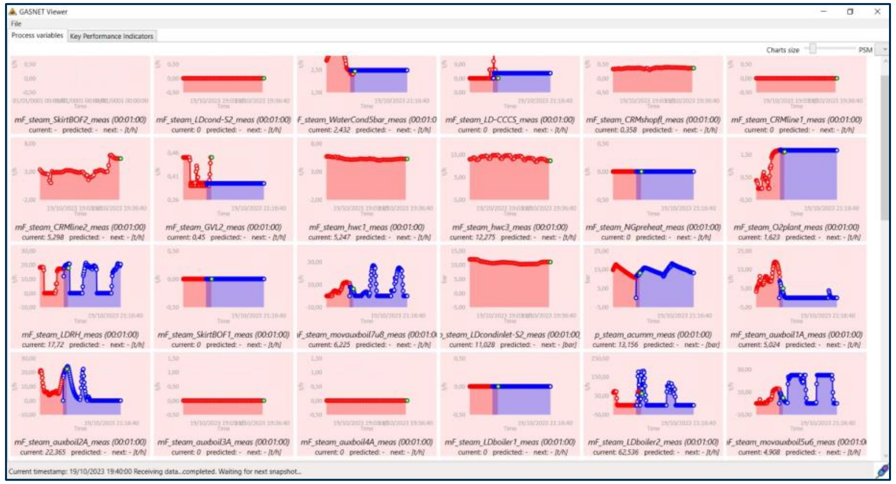
Technologies

Server app



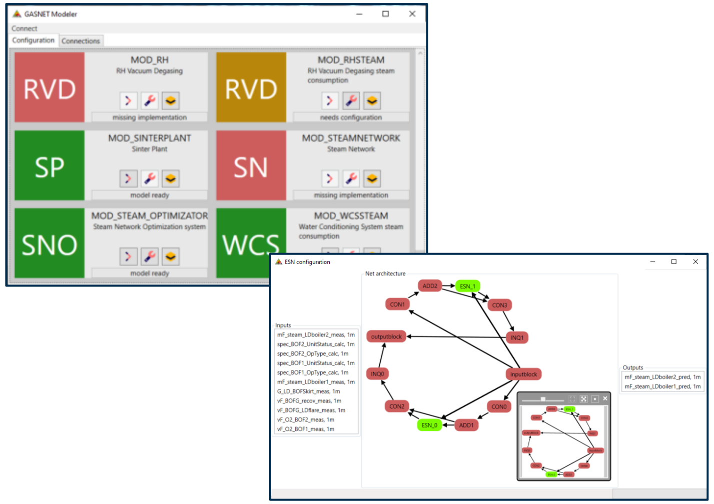
- Fetches data from the DB and distributes it to clients
- Sends digital twin calculations to the DB and process operators' HMIs

Viewers app



- GUI for visualizing measures, KPIs, and forecasting of the digital twin
- Organizes the data visualization in function of the plant/system/energy media

Modeler app (gemello digitale)



- For configuring, training and simulating models withing the digital twin
- Several methodologies for system modelling

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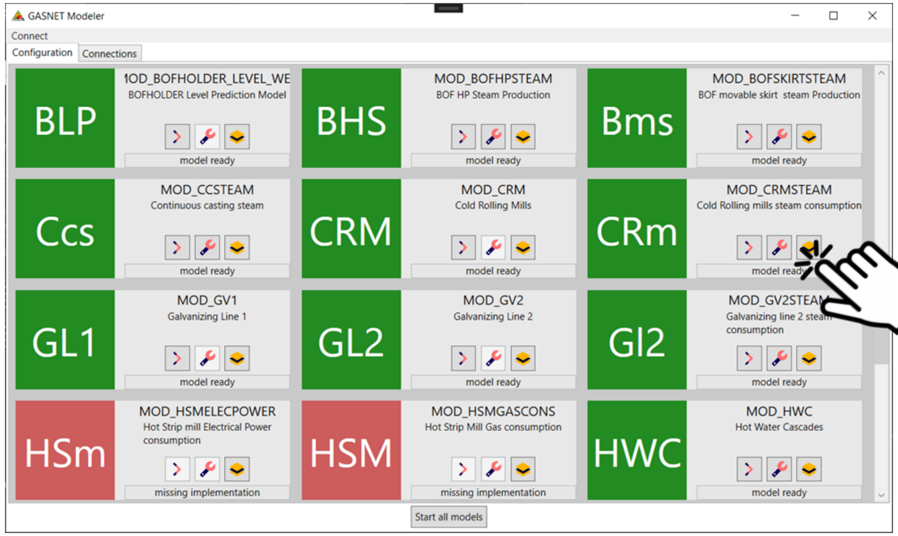
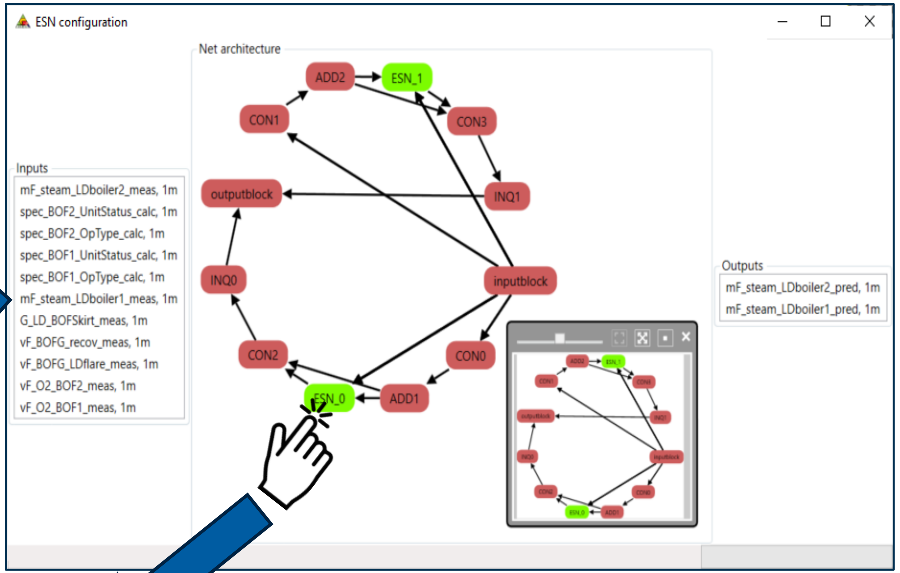
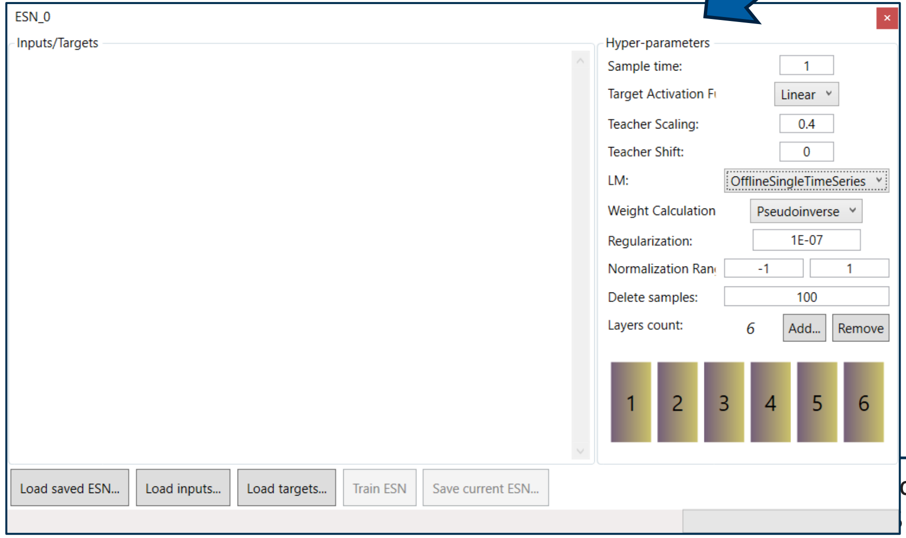
Technologies

20 years together





Model configuration (Simulink like)



Configure model' parameters

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Technologies

	Digital Twin	Optimization system
Prototype	MATLAB, python	MATLAB, YALMIP, GUROBI OPTIMIZATION
Production	C#, Microsoft .NET, ASP.NET, python, Keras, Flask	C#, Microsoft .NET, Google OR-Tools

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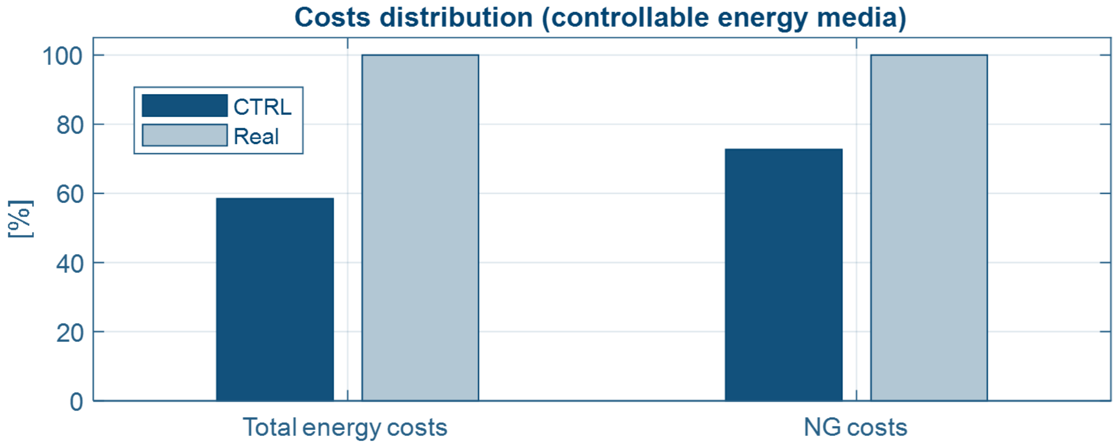
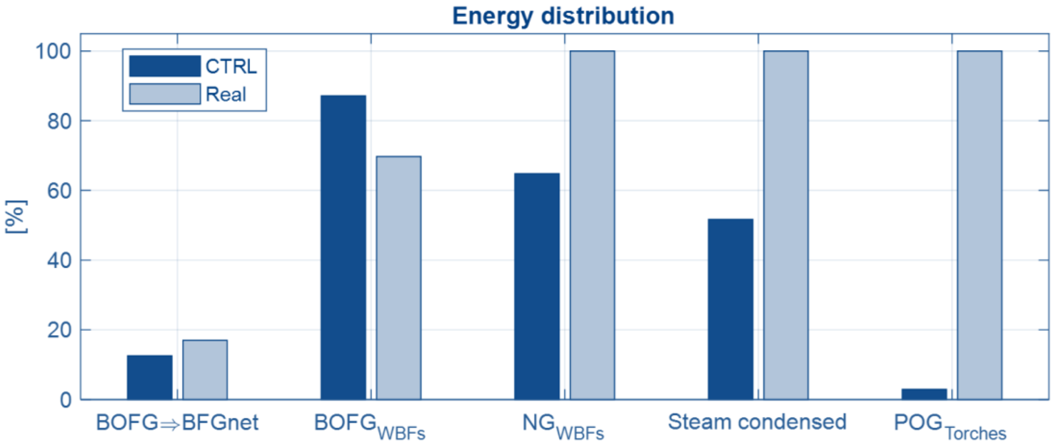
Off-line tests

- Simulation campaign for offline testing the digital twin and control strategy.
  - Several scenarios have been simulated for different periods of steel production and unexpected disturbances and faults (including maintenance periods)
- Tests are ongoing for steam network controller @ ArcelorMittal Bremen





$KPI_{torches\%}$ [%]	$KPI_{€\%}$ [%]	$KPI_{NG\%}$ [%]
-96.9	-41.56	-27.49

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Discussion and summary

PROS

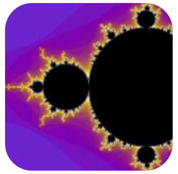
ML is effective for forecasting energy flows

Easy prototyping (Matlab / Python)

Realtime plantwide control

Solutions accepted by process operators

CONS



Long and complex industrialization through open-source libraries (Google Or-tools, Tensor flow, etc.)

Non-Open-source optimization libraries are expensive (CPLEX, Gurobi, etc.)

Custom DSS requires a long engineering phase

DSS + operators vs **Automatic control**: control action must be applied ASAP

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Questions

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