PRIMETALS TECHNOLOGIES

Advanced process modelling for optimising integrated steel plant operation

Advanced Process Modelling Forum 2017

The use of advanced process modelling in optimizing integrated steel plant operation

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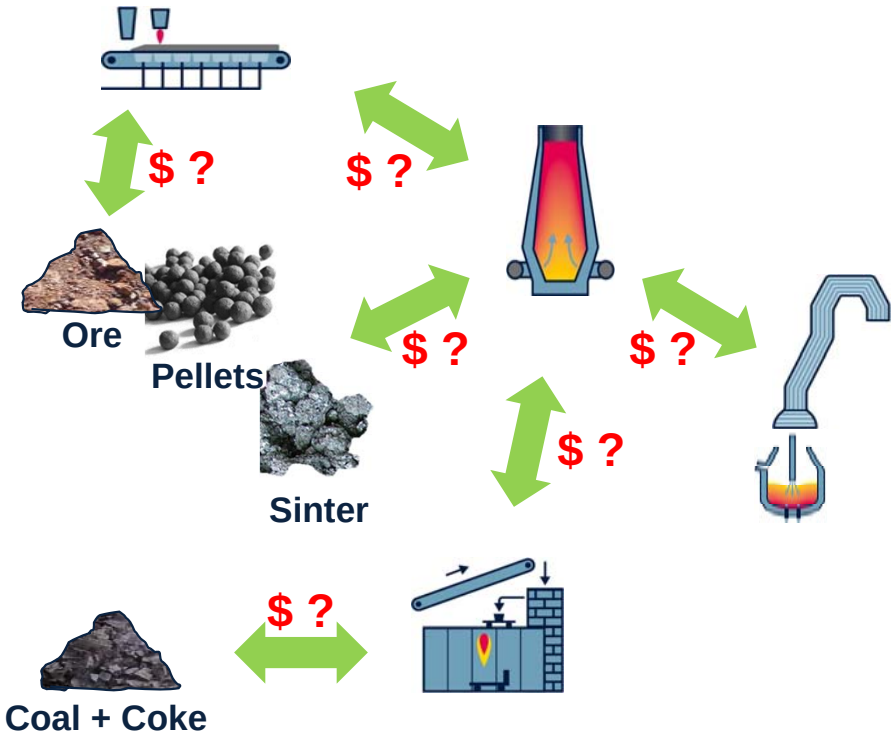
Bernd Weiss

Content

Motivation



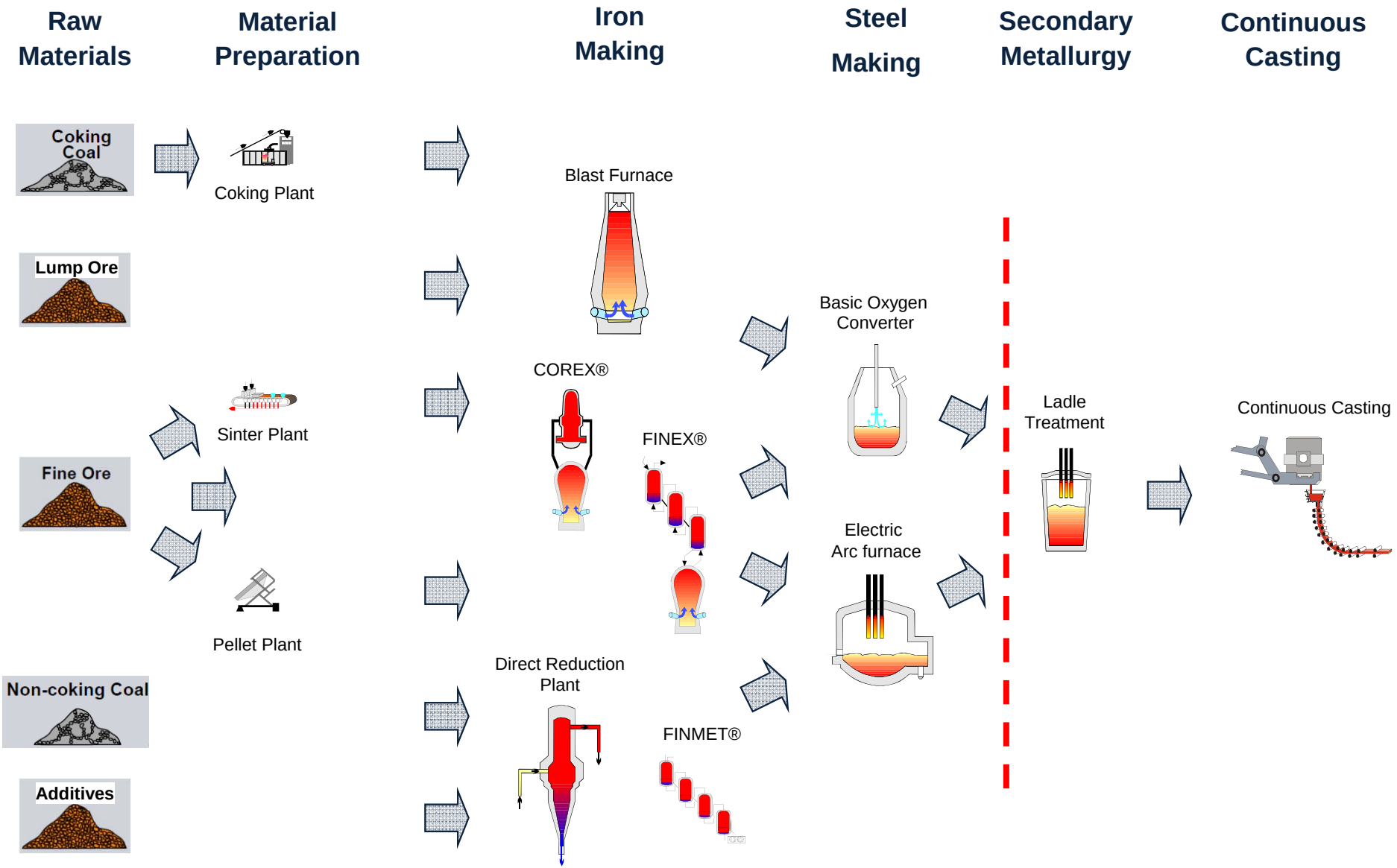
Zn, S, P ?

$$min \sum Costs = ?$$

$$max \sum Profit = ?$$

- Main problem – there is no calculation platform available for comprehensive connected integrated steel plant balancing
- Single plants are performing stand-alone analysis of material flows, resulting in inconsistency on interfaces and take over points
- Internal consumption figures calculation imprecise
- Integrated operation planning, raw material purchase and optimization difficult

Models



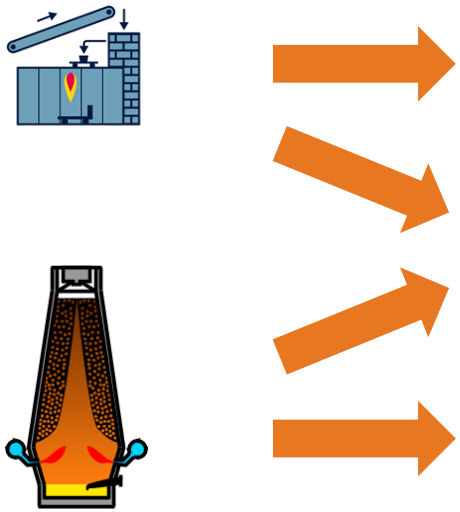
Models

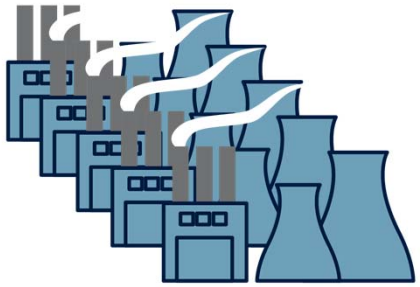
Raw material preparation	Iron + steel making route	Heat + waste heat integration	CO_2 – sequestration + ECO solutions
Beneficiation	Corex®	Directly + indirectly fired heaters	Pressure swing adsorption
Pelletizing plant	Finex®	Off gas waste heat recovery systems	Reformer
Sinter plant	Hot blast stoves	Combined steam cycles	Electrostatic precipitator
Coking plant	Blast furnace		Cyclones
	Midrex®		Bag house filters
	Basic oxygen furnace		Top gas recovery turbine
	Electric arc furnace		

Over 250 models available for metallurgical process modelling

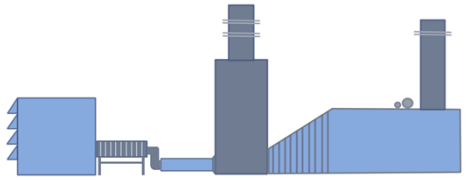
Models

- Power plant applications development
  - Usage of by-product gases for steam and electricity provision (~ 200 MW(el) and 100 t/h steam)
    - Coke oven gas
    - Blast furnace gas
    - Addition of natural gas





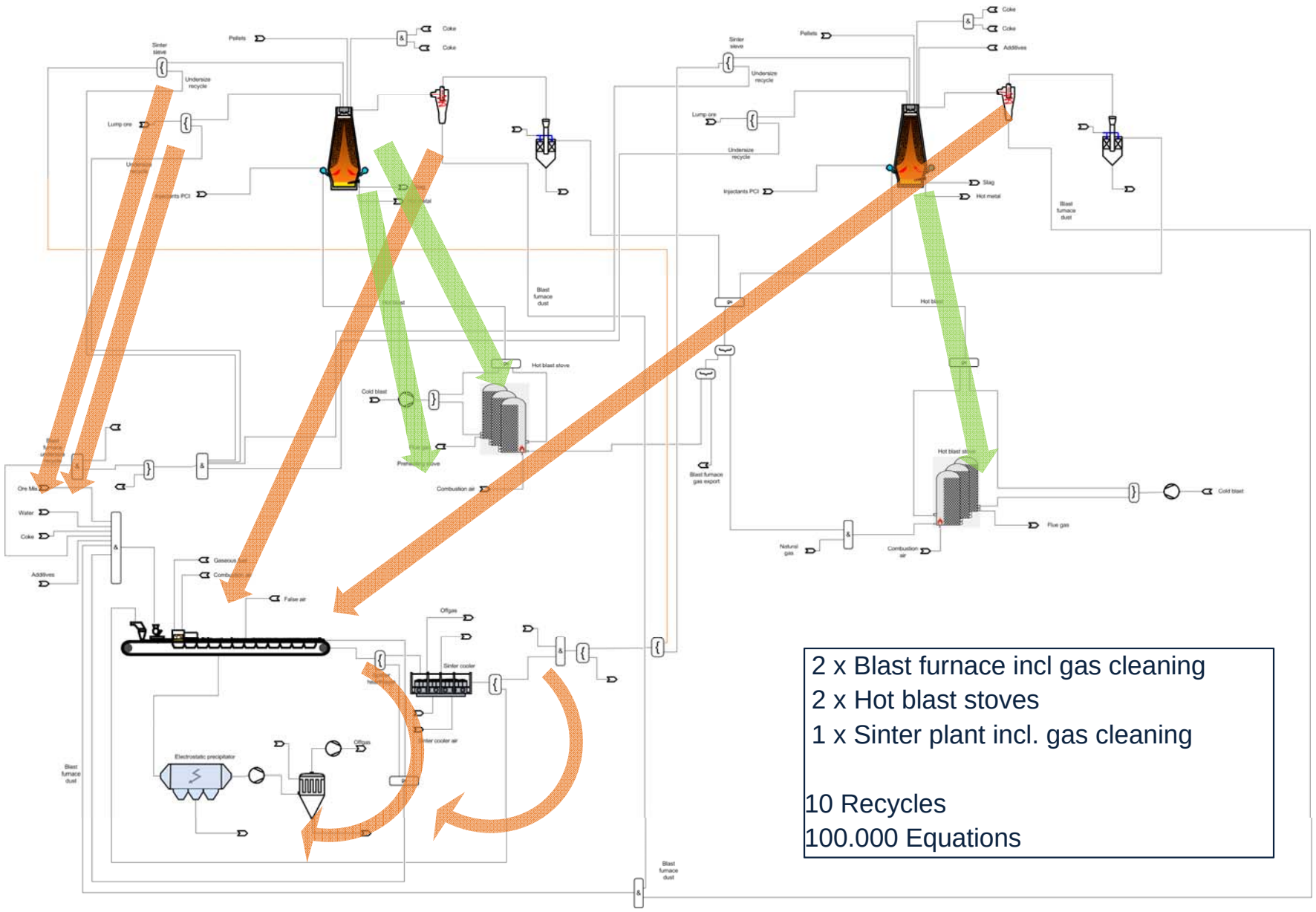
- 5 Blocks – gas fired steam generators



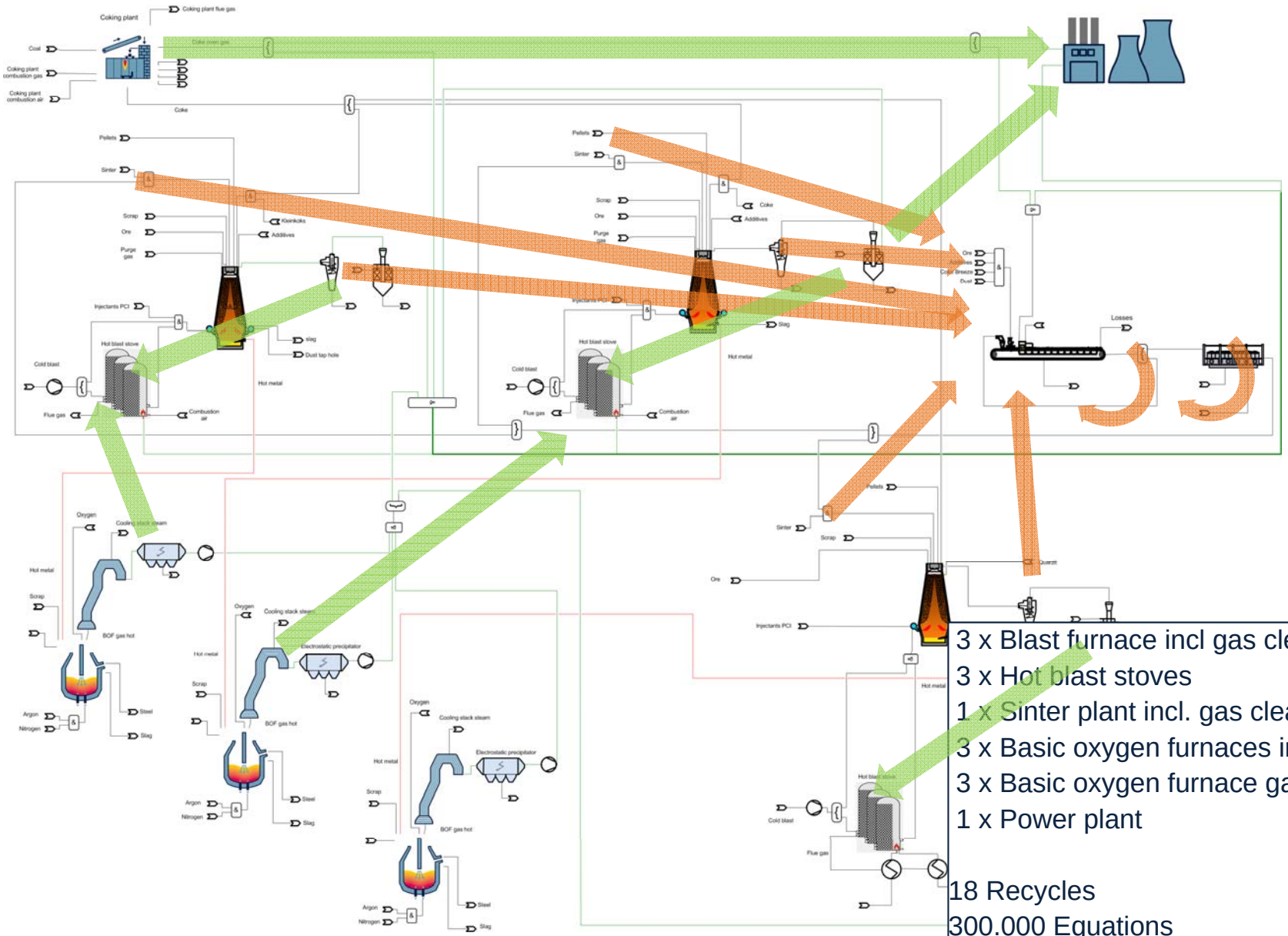
- 1 Block – gas turbine with gas fired steam generator

- Steam generators setup
  - Multiple stage heat exchangers
  - Multiple stage steam turbines with extraction steam
  - Feed water preheating with deaeration

Flow Sheets



Flow Sheets



3 x Blast furnace incl gas cleaning
3 x Hot blast stoves
1 x Sinter plant incl. gas cleaning
3 x Basic oxygen furnaces incl. gas cleaning
3 x Basic oxygen furnace gas cooling
1 x Power plant

18 Recycles
300.000 Equations

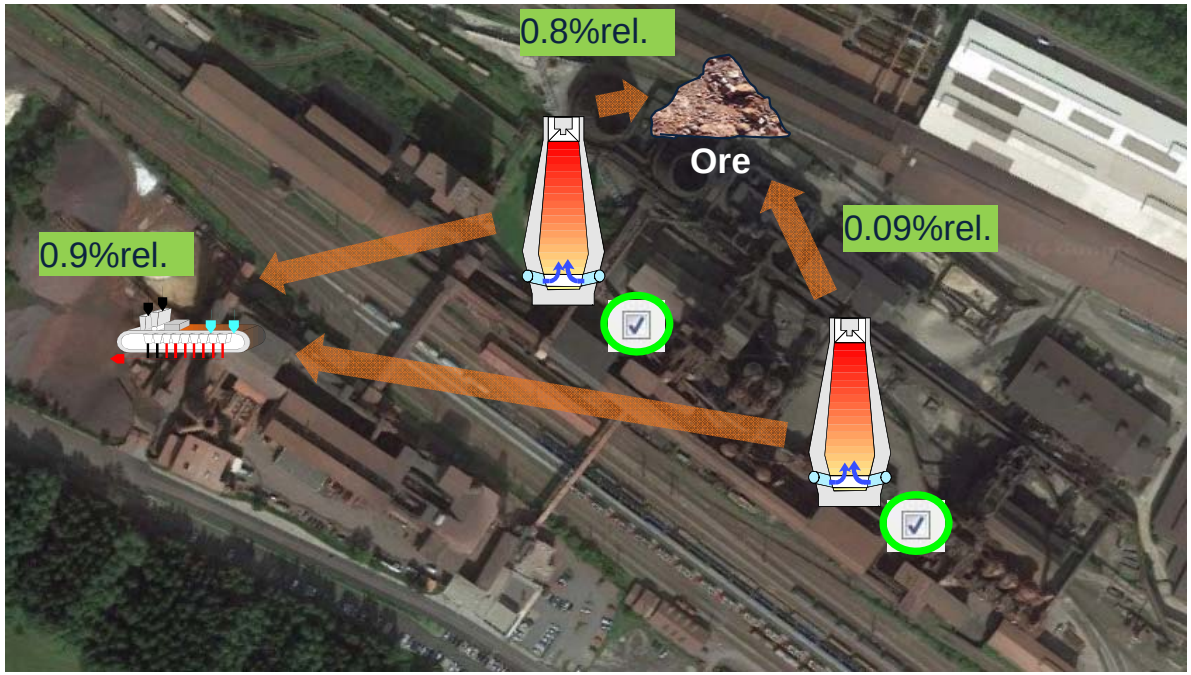
Flow Sheets/Models - Development

- Thermodynamics
  - Species extension nearly finished:
    - Providing 140+ species instead of 58
    - Coping with convergence issues/initialisation problems
    - Resigning on increased calculation times
  - Alternatives to multiphase equilibrium solvers/approaches

- Models
  - Additions of new models to the library is decreasing
  - Functionality extensions regarding
    - Better operation depiction – calculation accuracy
    - Better operation scenario depictions – plant start up/upset behavior

- Flow sheets
  - Elaboration of benchmark flow sheets for large scale integrated steel plants (13 sinter plants, 8 blast furnaces, etc.)
  - Implementing “smart” control modes
  - Enabling strategic planning functionality in flow sheets (including/excluding equipment in simulations, costs, optimization routines)

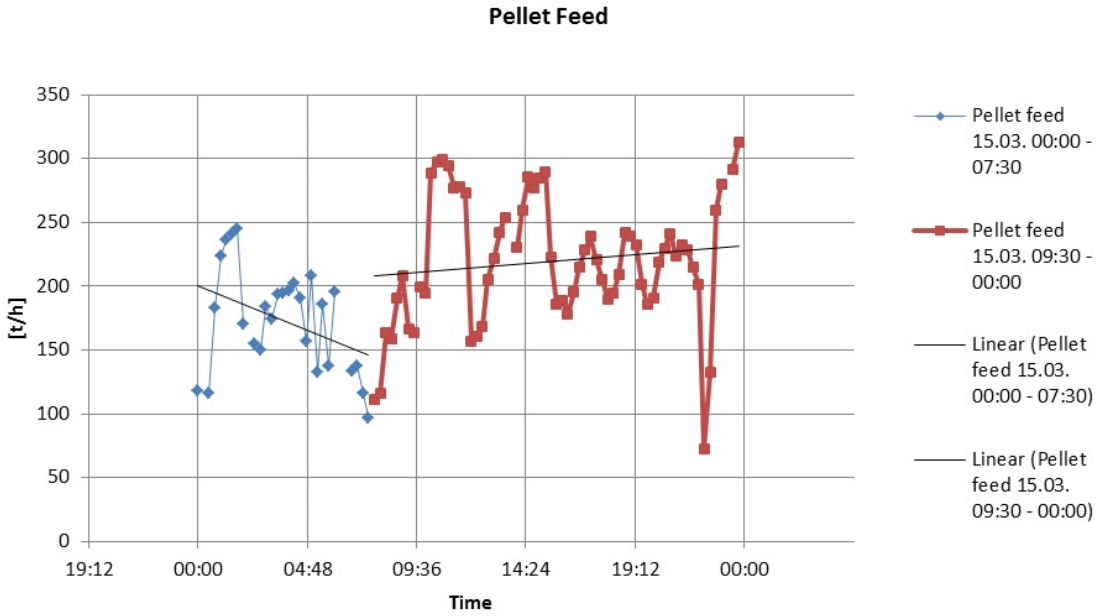
Validation – Reference Case

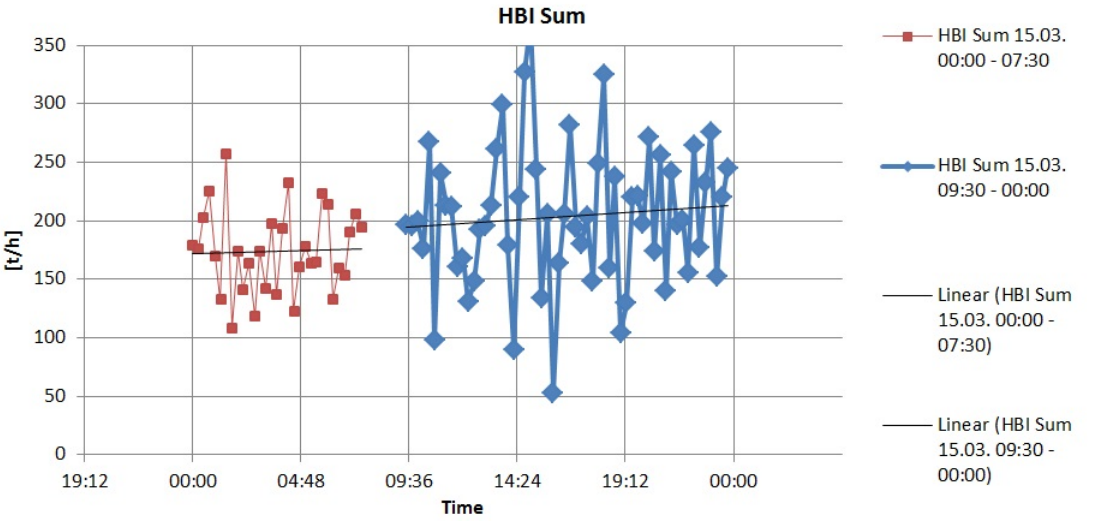


- Validation based on monthly operation data
  - Investigation of a period of constant/stable and representative production
  - Checking of averaged data on all raw material consumption figures and products
    - Collecting all relevant composition analyses – over several departments
    - Implementing species spatial maldistributions in return materials
    - Finding a common basis of communication for reference figures
    - And much more
  - Deviations for production depiction reduced to a level below of 1% relative
  - Example: Fixing production rates, calculation of lump ore and sinter amount

Validation – Challenge

- Start-up simulations
  - Plants still in commissioning phase
  - Unsharp measurements, repeated plant trips
  - Requirement for transient models

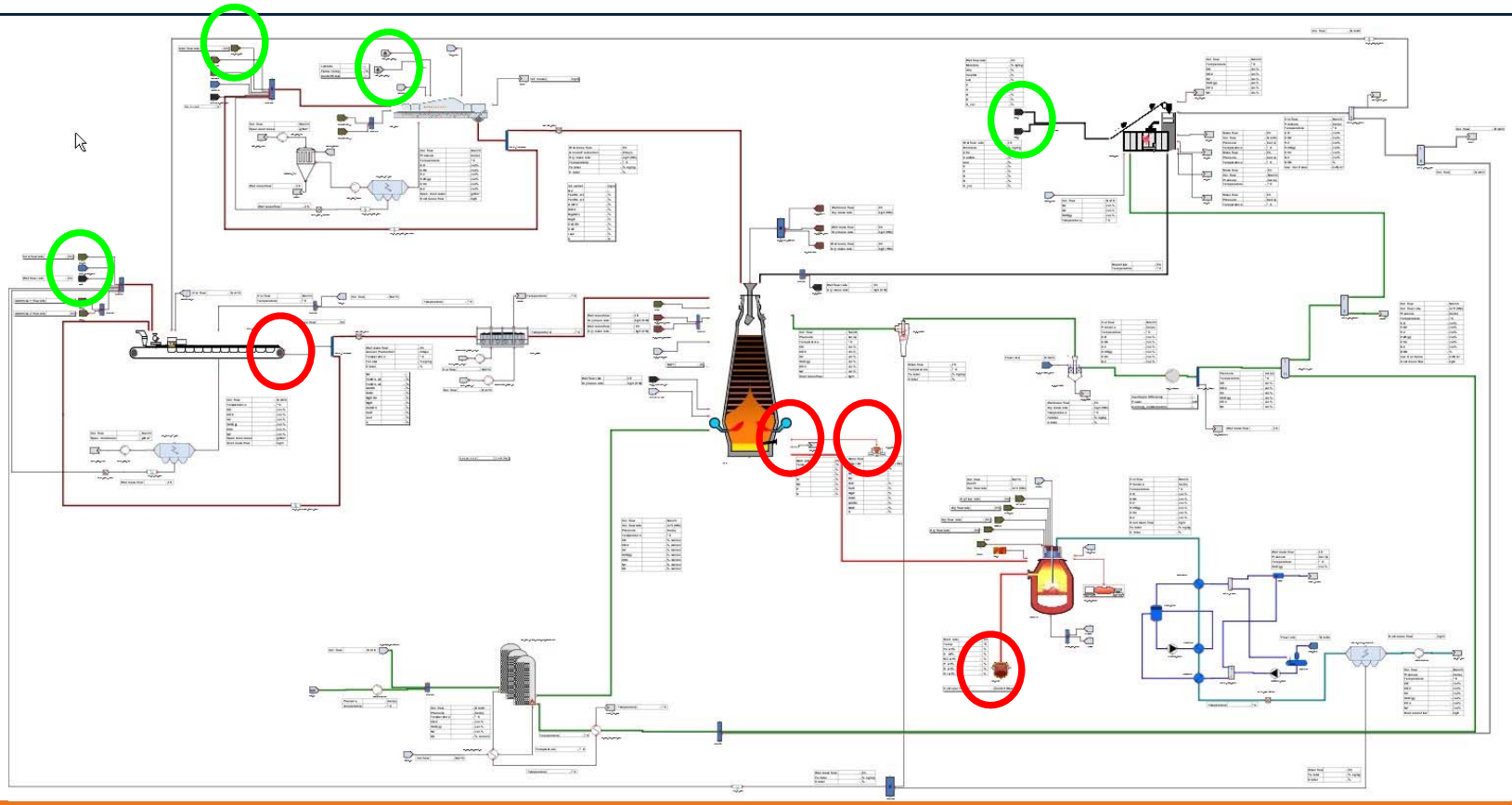




Optimization

- Solutions to be obtained – figures of interest
  - Reduction of production costs
    - Major influence – raw material prices
    - Significant influence – internal by-product usage
    - Significant influence – credits from by-products (power generation from residual calorific gases) or residuals recycles
  - Certain KPI´s, product amount, product quality
- Objective Function
  - Minimization of production costs, maximizing of profit, …
  - Product qualities/quantities
    - Maximizing production, maximizing amount of certain species in the product (eg. iron content)
    - Minimizing certain species in product (eg. problematic trace species like sulphur, phosphor, zinc, …)
- Controls
  - Variation of raw material mix
  - Variation of internal by-products usage, residuals recycles (eg. dusts)
  - Variation of operation philosophies
- Constraints
  - Operability KPI´s (slag basicities, off gas temperatures, …)
  - Product and by-product qualities (amounts of certain species, production rates, …)

Optimization



Example: Production costs before optimization 622 $/t

Production costs after optimization 619 $/t

Means for 12 MTPA integrated steel plant 36 Mio $ savings per year

Product Development - Application Areas

Operation Optimization

Material investigations
- Raw material influence
- Internal material stream analyses
- New recycles
- And much more

Process investigations
- Changes in operation philosophies
- Saving of plant tests and downtime
- Changes in equipment settings
- And much more

Investment Evaluations

Brown field
- Depiction of existing process routes
- Calibration on operation data
- Comparison with alternative process routes

Green field
- Flexible set up of possible process routes
- Comparison in one platform
- Changes and adaption fast feasible

Customized Solutions

Flexibility
- More than 250 models for integrated steel plant modelling
- Flow sheet platform for fast and multi-functional balance set-ups

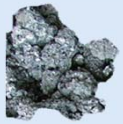
Adaptable
- Modifications easily implementable
- Enhancing process development capabilities
- Reducing process development efforts

Product Development - Operation optimization

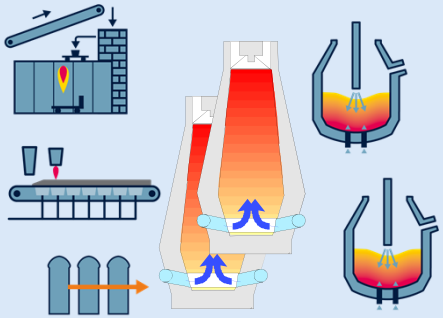

Ore


Coal + Coke

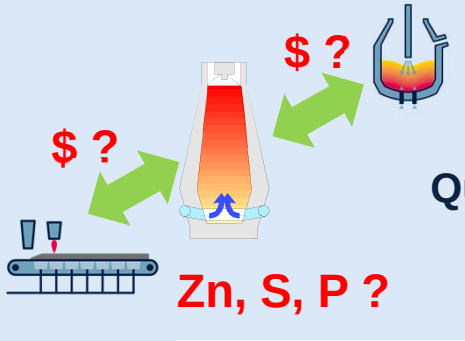

Pellets


Sinter

Raw Materials

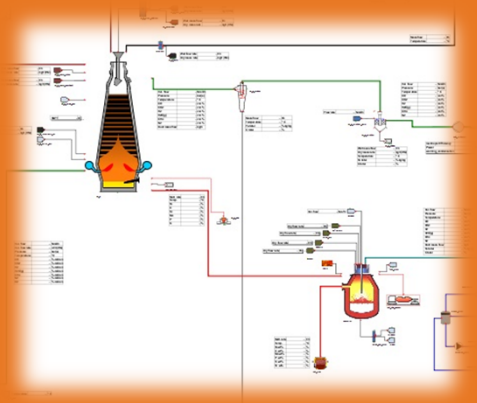


Plant Setup



Tasks Questions

Process Integration Platform



$$\sum \dot{m}_{in} - \dot{m}_{out} = \cdots$$

$$\sum \dot{H}_{in} - \dot{H}_{out} = \cdots$$

$$min \sum Costs = OPT$$

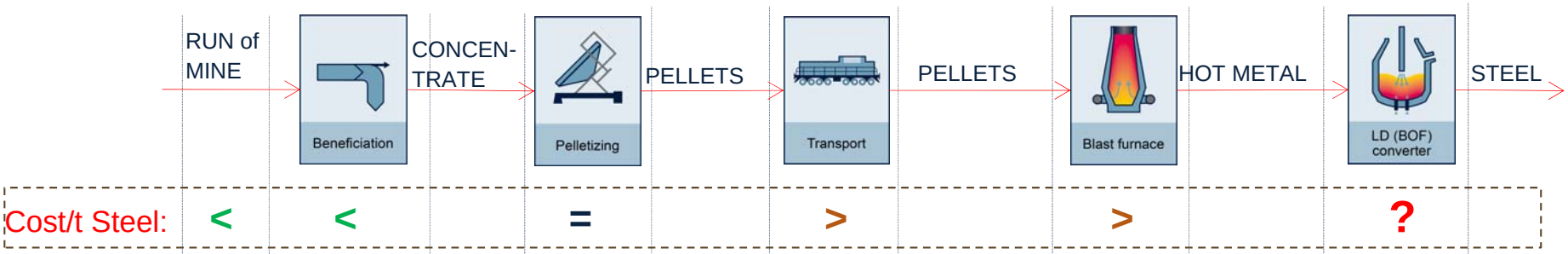
$$max \sum Profit = \mathrm{OPT}$$

Answers:

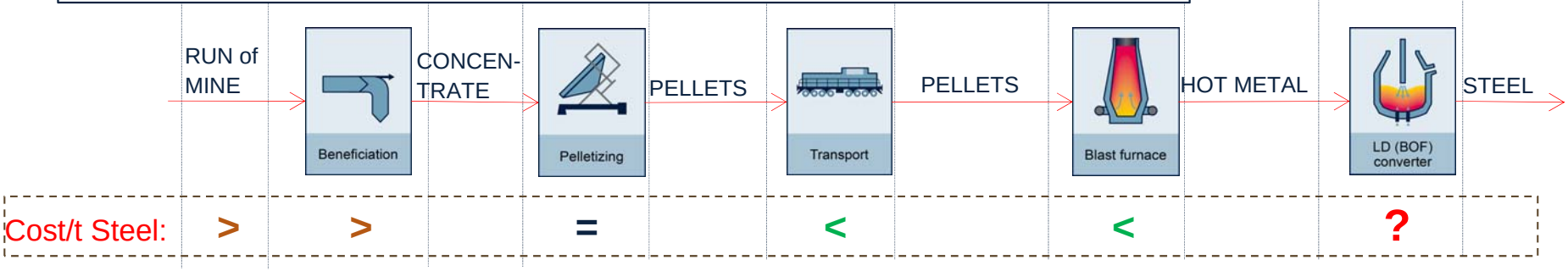
- Cost Optimization
- Profit Optimization
- Raw Material Mix Optimization
- Case Studies
- Species Distributions
- Operation Philosophies
- Recycle materials influence
- Etc

Evaluation of cases by variation of Fe-content in concentrate:

CASE 1: Low Fe contents after Beneficiation and Pelletizing
Higher Slag Rate in Blast Furnace



CASE 2: Higher Fe contents after Beneficiation and Pelletizing
Lower Slag Rate in Blast Furnace



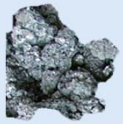
CONSTANT PRODUCTIVITY AND STEEL QUALITY

Product Development - Customer simulator

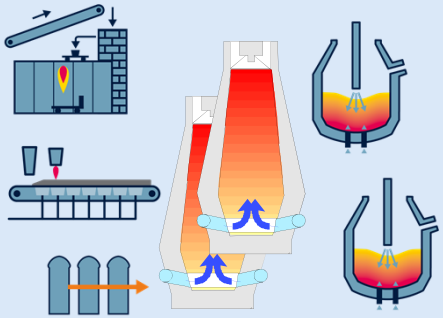

Ore


Coal + Coke


Pellets


Sinter

Raw Materials



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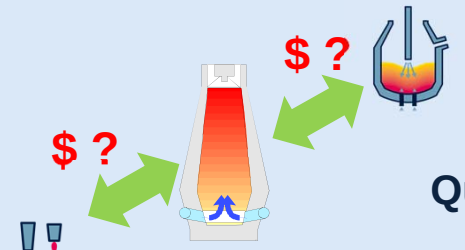
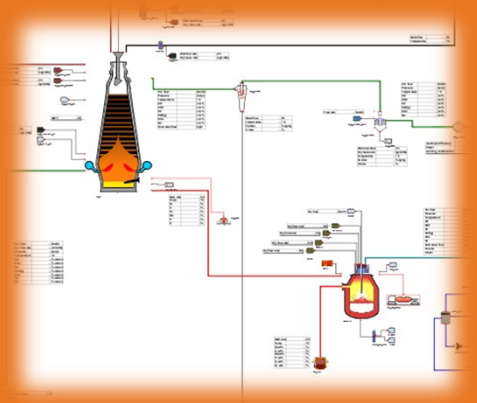


Tasks Questions

Process Integration Platform



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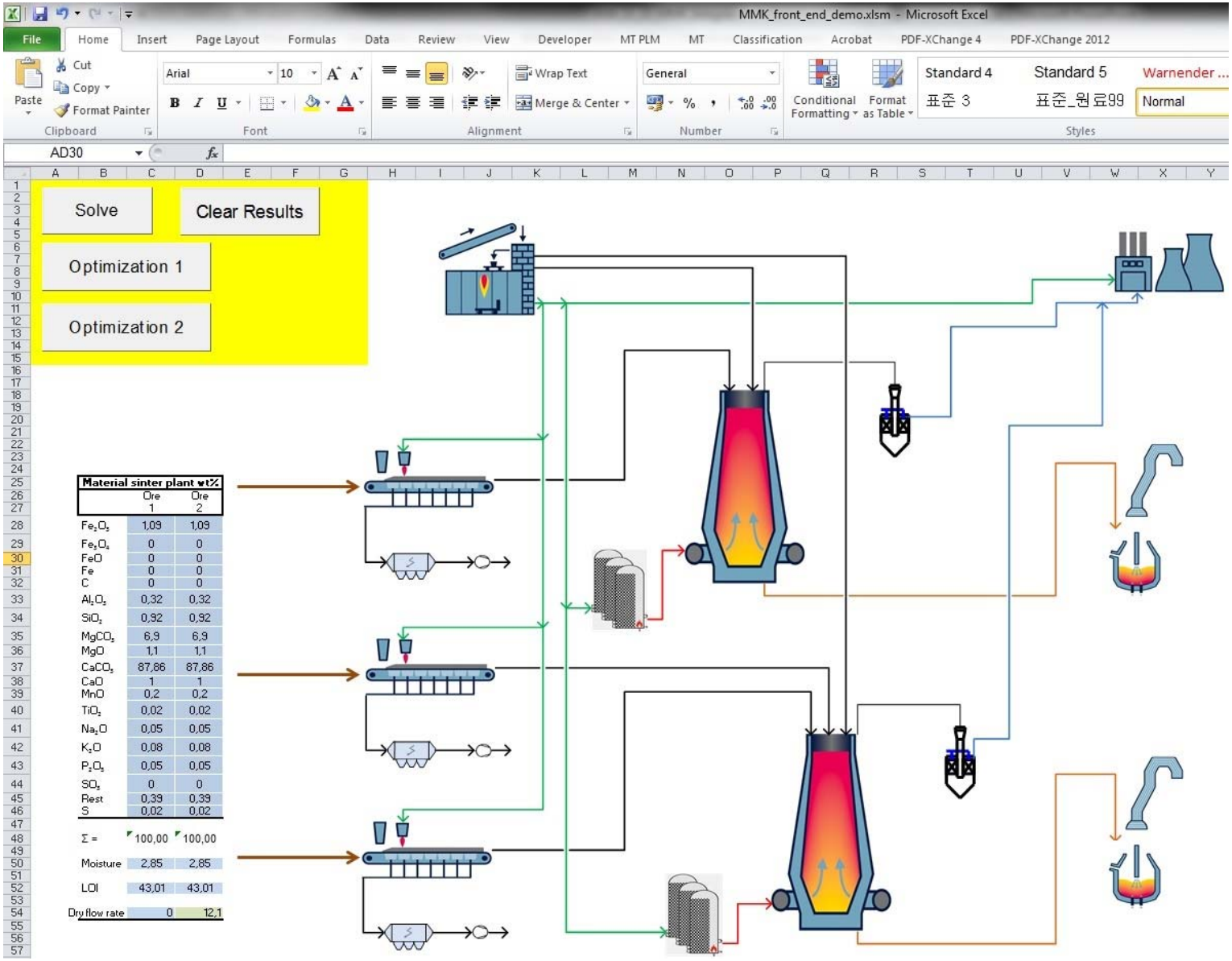
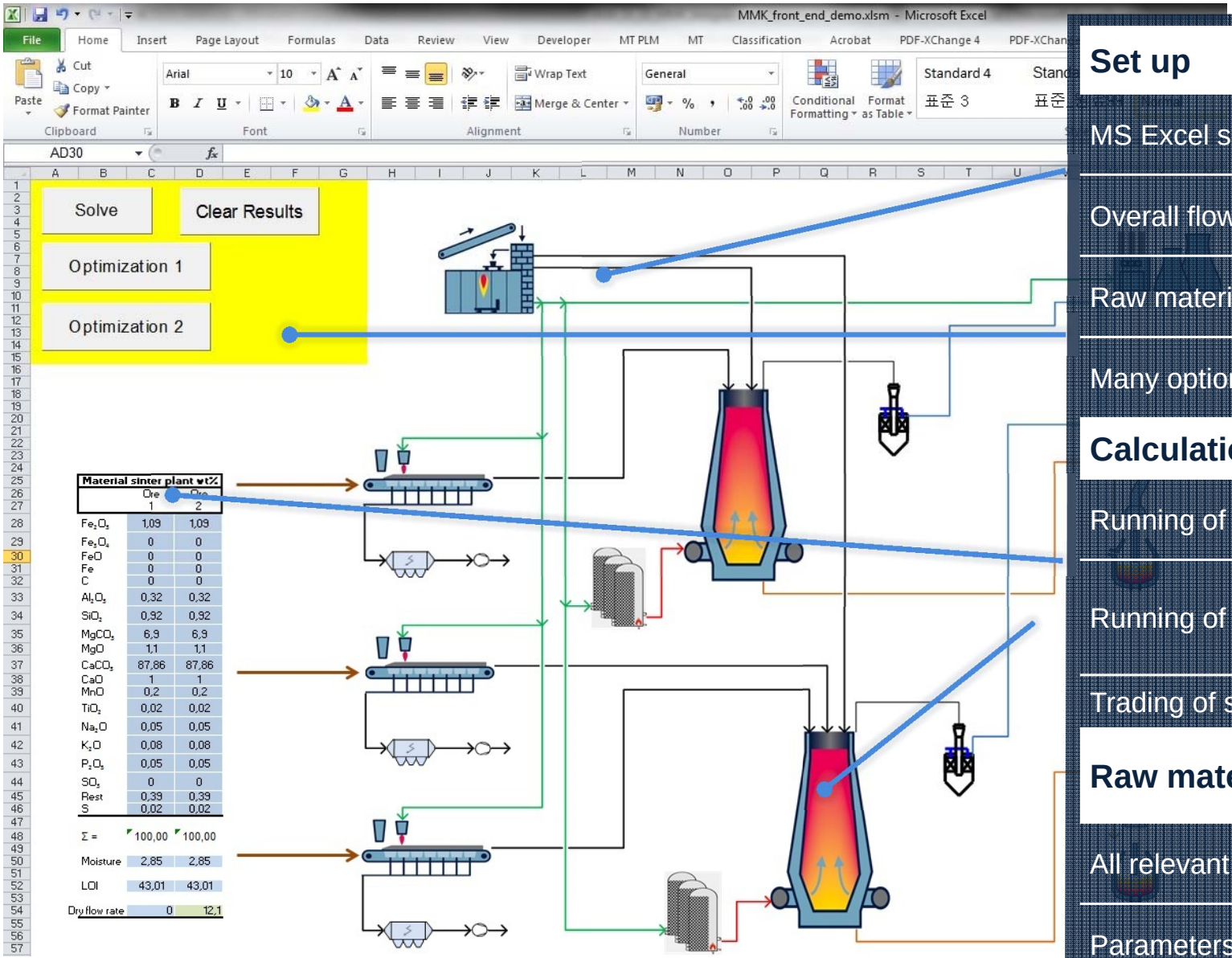


Product Development - Customer simulator



Set up

MS Excel simulator customizable

Overall flow sheet for main figures

Raw materials database

Many options for results depiction

Calculations

Running of simulations

Running of predefined optimizations

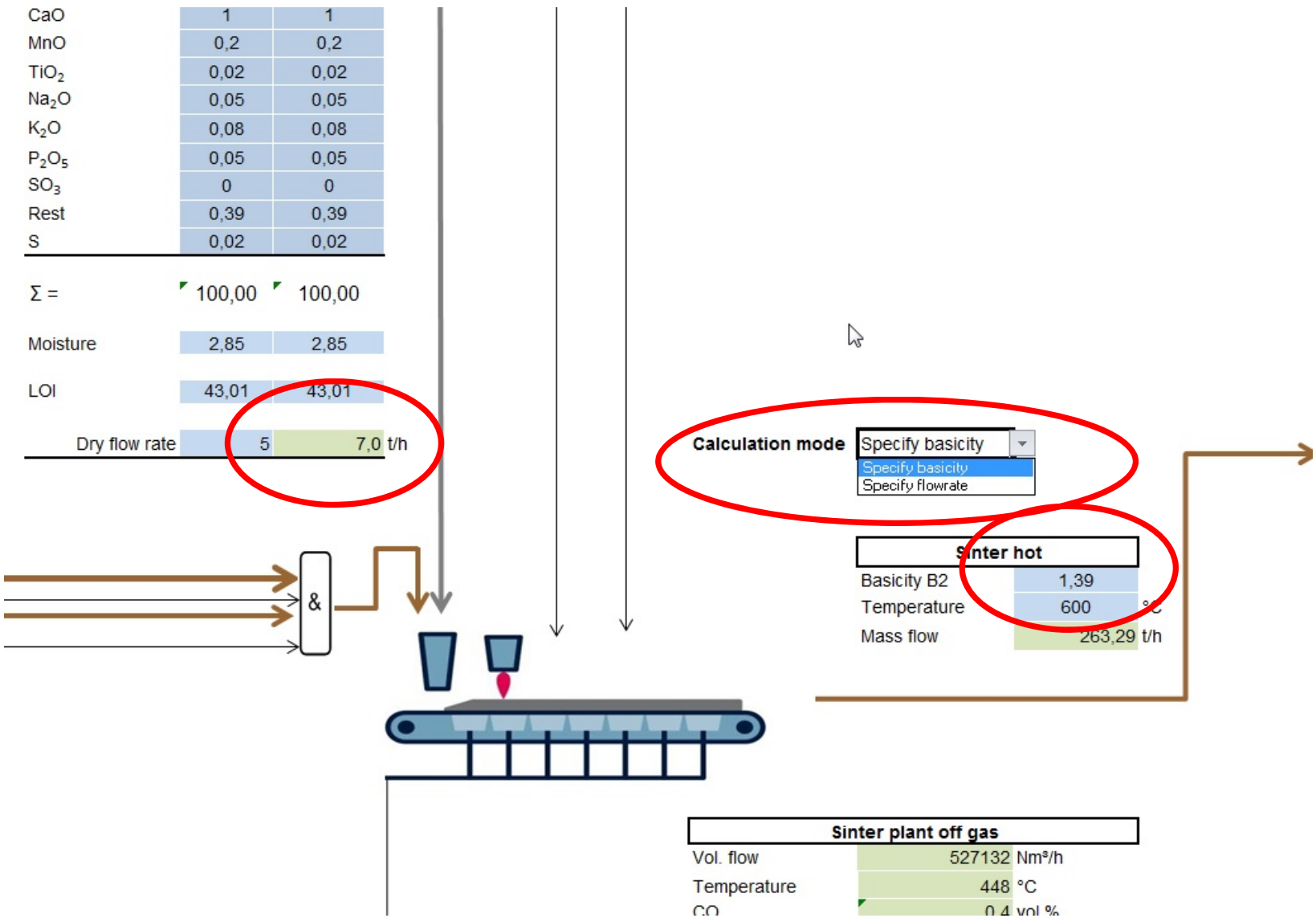
Trading of specifications

Raw material + equipment

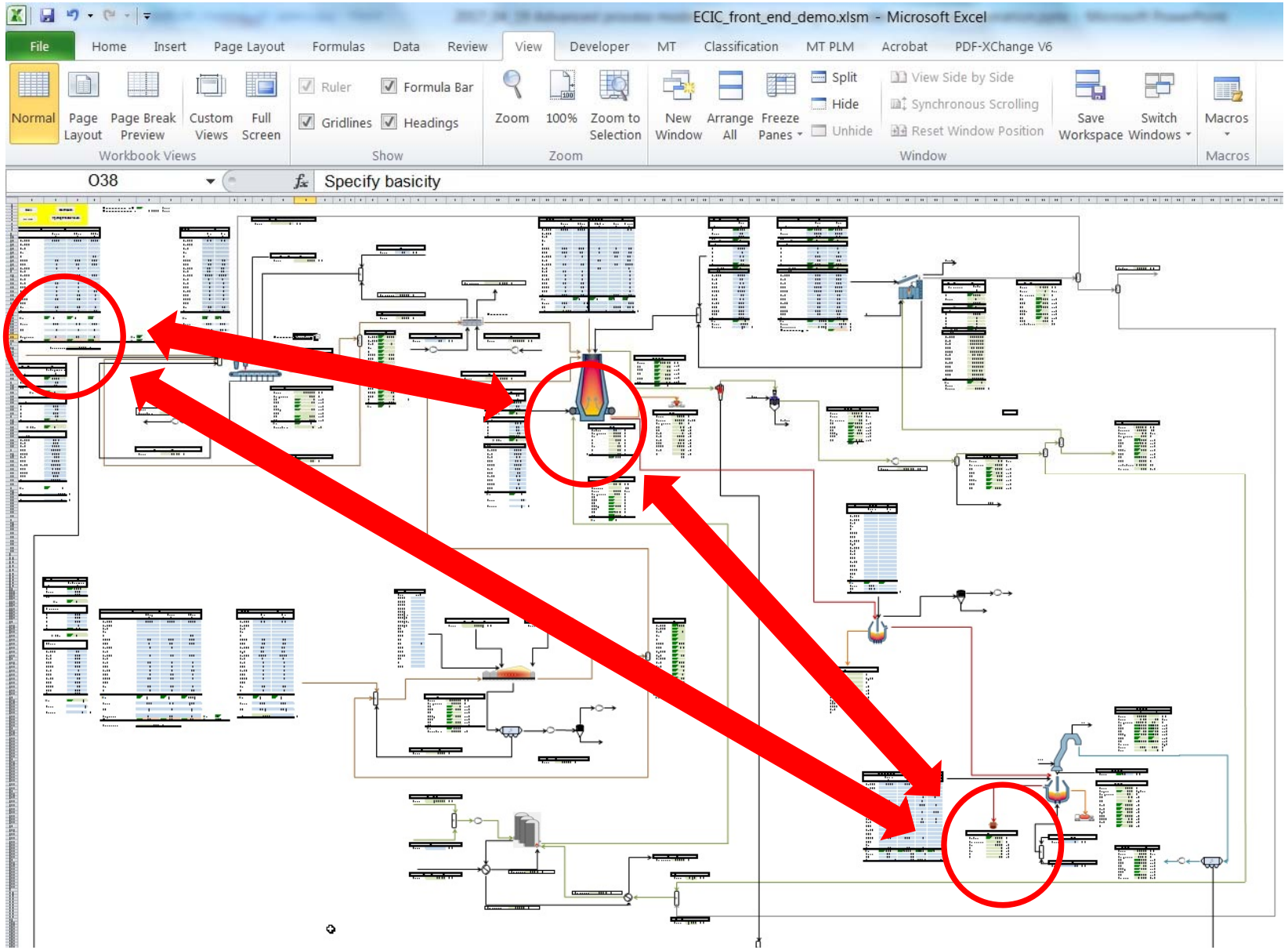
All relevant plants included

Parameters of plants editable

Product Development - Customer simulator



Product Development - Customer simulator



Outlook

- In general
  - Implementation of power generation and power plant models for integration in metallurgic flow sheets
  - Finalization of species extension
  - Model development for complex trace elements chemistry
  - gORUN implementation customer simulator

- Connection to control systems
  - Request by customers and exclusive feature compared to competitors
  - The idea is providing a platform for:
    - Selection, preparation and storage of operation data
    - Integrated steel plant simulations
    - Comparison of measured and calculated data

- Coke plant statistical models
  - Enhanced challenge to model physical and metallurgical parameters of produced coke from raw coal
  - Application of regression models on operation data
  - Providing predictive calculations for specific parameters of coke

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THANK YOU