PRIMETALS TECHNOLOGIES

Integrated Steel Plant Modelling in gPROMS

Advanced Process Modelling Forum 2016

Integrated Steel Plant Modelling in gPROMS

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Content

Motivation – Approach to gPROMS

Who are we?

Expert in technology, engineering and automation for metallurgical plants covering:

- New plants
- Modernization
- Service

What´s the gPROMS task?

Process + integrated plant simulations in the fields of:

- Sales
- Projects
- Consulting

What´s the challenge?

Linking calculations of

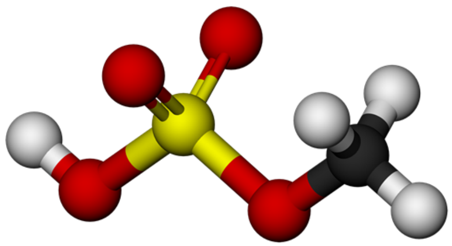
- Different departments
- Different platforms
- Different bases of design

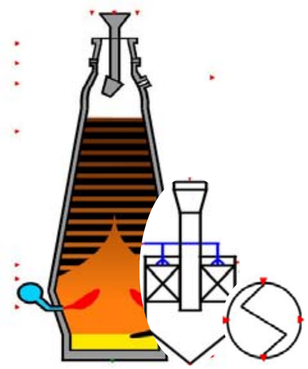
For steadily changing customer demands

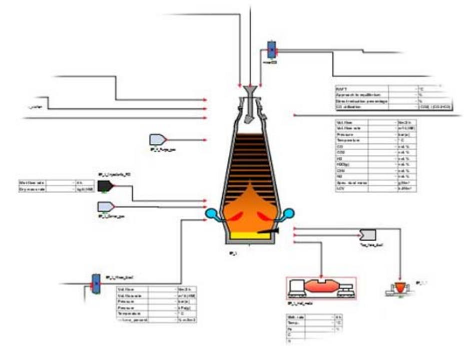
Motivation – Approach to gPROMS

- Summary of deliverables
- Evaluation on state of the art
- Result: customized tool necessary in a flexible platform

Motivation – Approach to gPROMS – Problems







Thermodynamics

Species
Generally main species in eg. DIPPR data base missing, no heterogeneous (solid, liquid, gas) metallurgical systems

Thermochemical properties
Not available in flow sheeting tools, temperature ranges not sufficient, functionalities missing

The result
Customized approach necessary

Models

Introduction of raw materials
Iron ores, coals, coke – solids – not covered in standard tools

Metallurgical models
Sinter machine, pelletizing plant, blast furnace, BOF, electric arc furnace, missing in standard tools

The result
Customized approach necessary

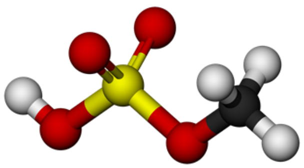
Flow Sheets

Metallurgical model library
No comprehensive metallurgical model library available

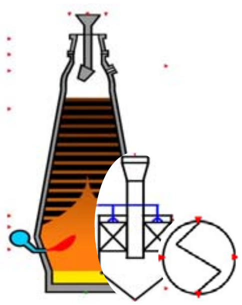
Metallurgical flow sheets
As no tool provides appropriate libraries and property-platforms – metallurgical flow sheet modelling not commercially available

The result
Customized approach necessary

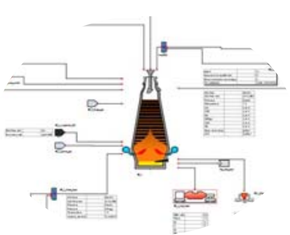
Motiviation - Implementations



Thermodynamics	
Enthalpies	Imported from HSC Chemistry®, routine with FO lookup table
Multiflash	Standard gPROMS linkage
IAPWS95	Via Multiflash linkage for steam tables

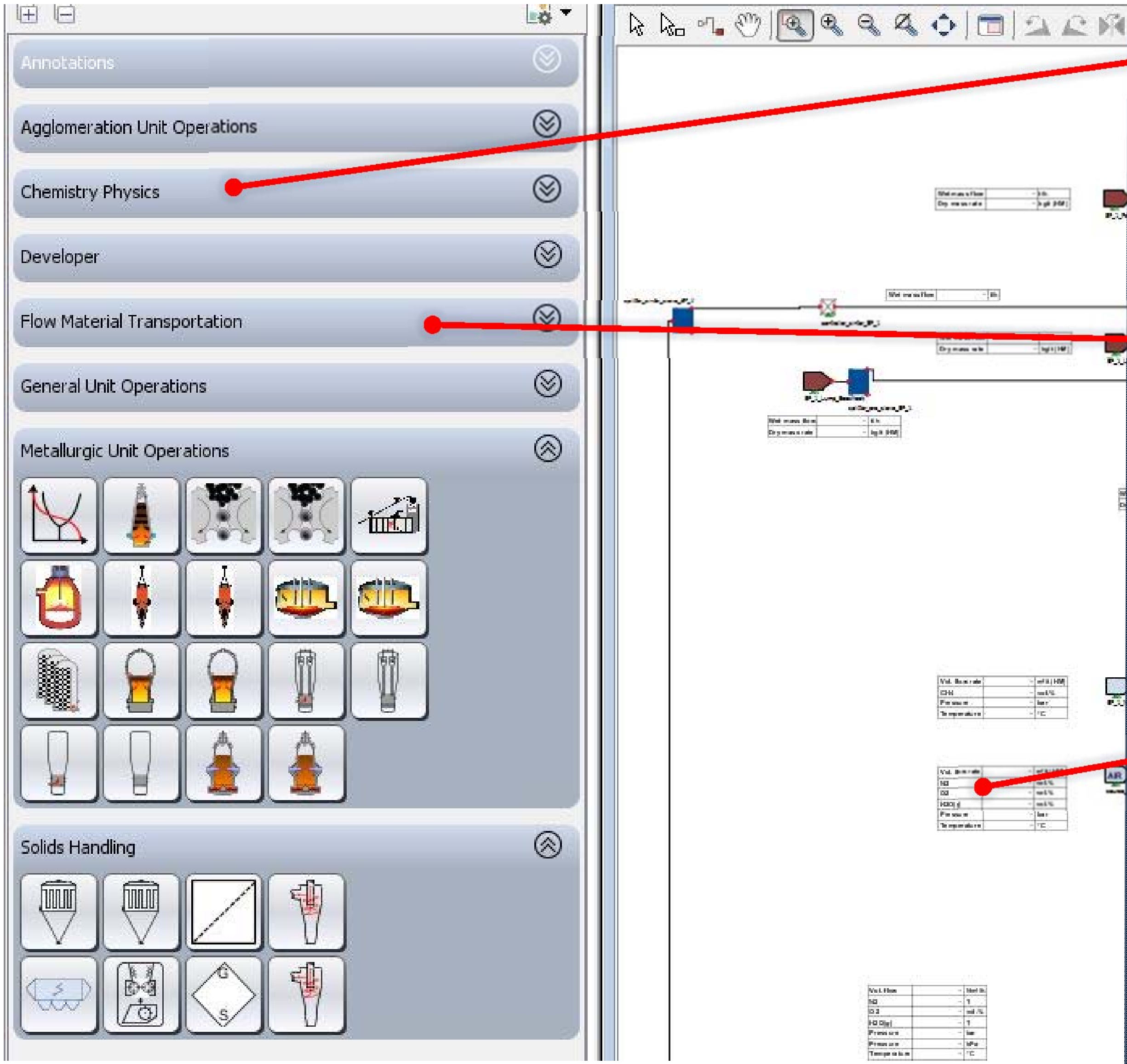


Models	
MS Excel migration	Implementation of established models in gPROMS
New models	Developments inhouse, universities, PSE
Validation	Benchmarking with operation data and established models



Flow sheets	
Portfolio processes	Set up of flow sheets in gPROMS
Validation	Based on operation data and established models
Sensitivity analyses	Investigation of system behavior

Motivation – Metallurgical Library



Chemistry + physics

- Physical properties collection
- Multiflash linkage and Gibbs minimization solver
- Various connection types

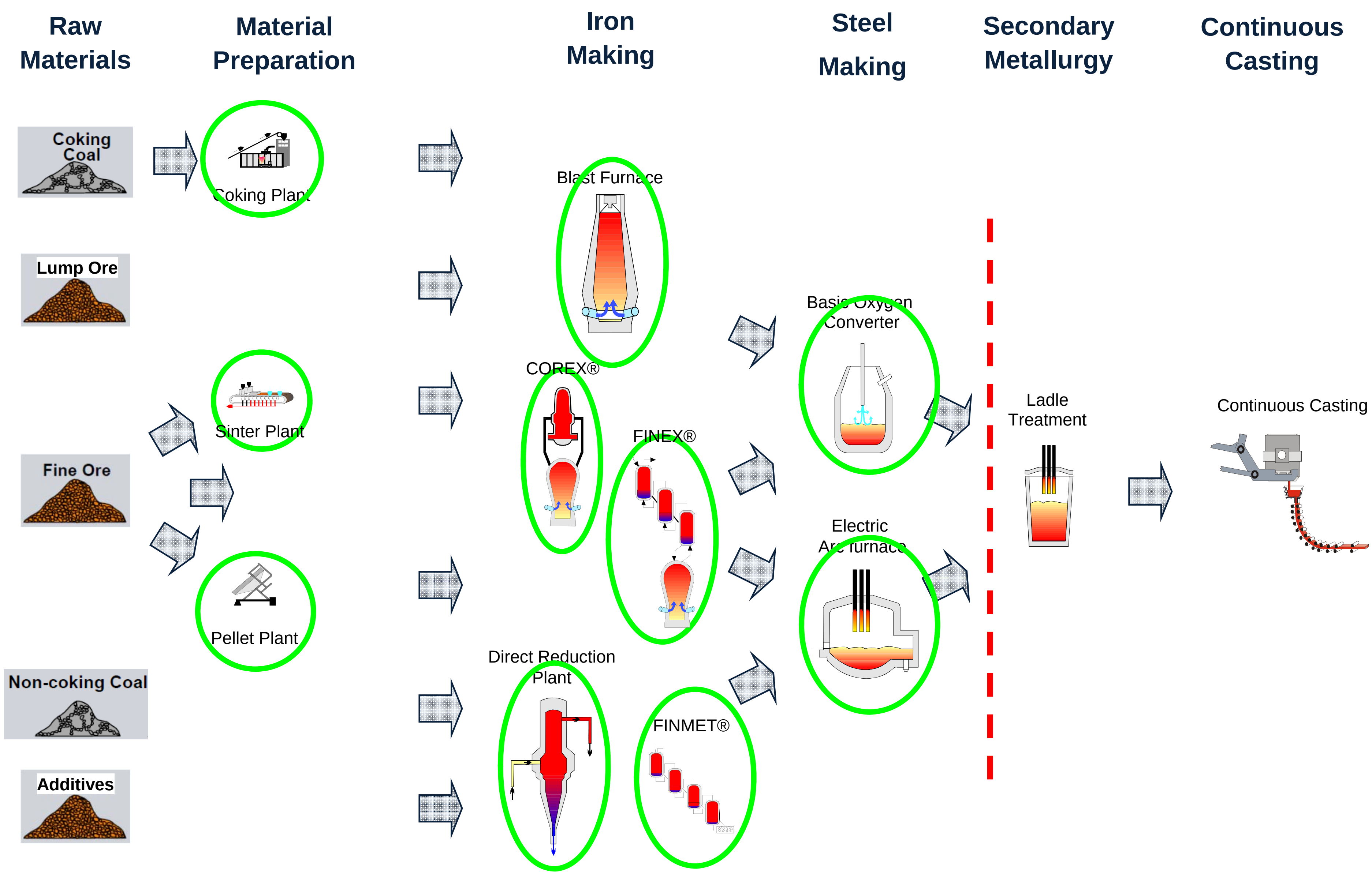
Process models

- Models collected according to chemical topics:
- General models
- Flow handling
- Metallurgical models
- Solids handling

Set up

- Hierachial approaches
- Steady state
- Utilization of MS Excel interface
- Control functionalities

Motivation – Metallurgical Library



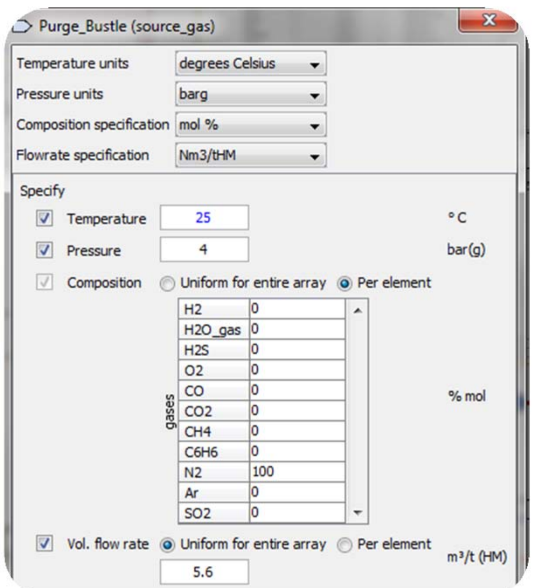
Motivation – Metallurgical Library

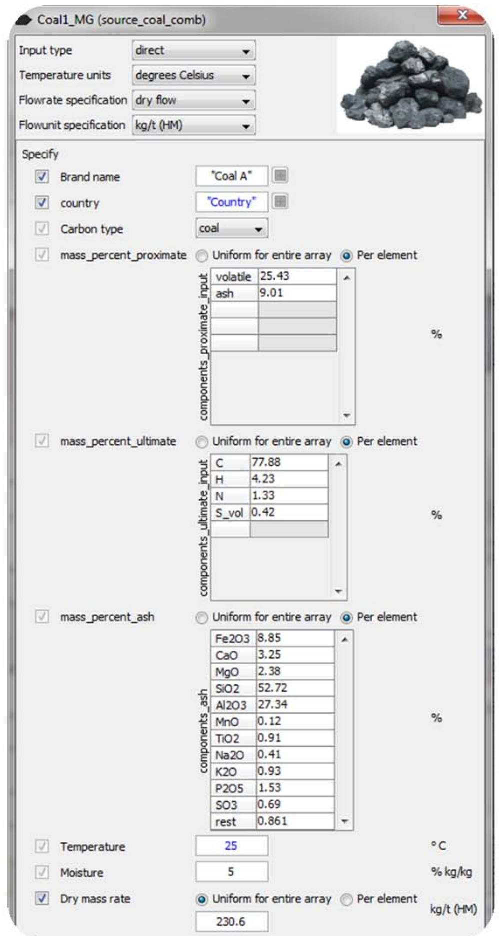
Raw material preparation	Iron + steel making route	Heat + waste heat integration	CO_2 – sequestration + ECO solutions
Beneficiation	Corex®	Directly + indirectly fired heaters	Pressue swing adsorption
Pelletizing plant	Finex®	Off gas waste heat recovery systems	CO_2 – Reformer
Sinter plant	Hot blast stoves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

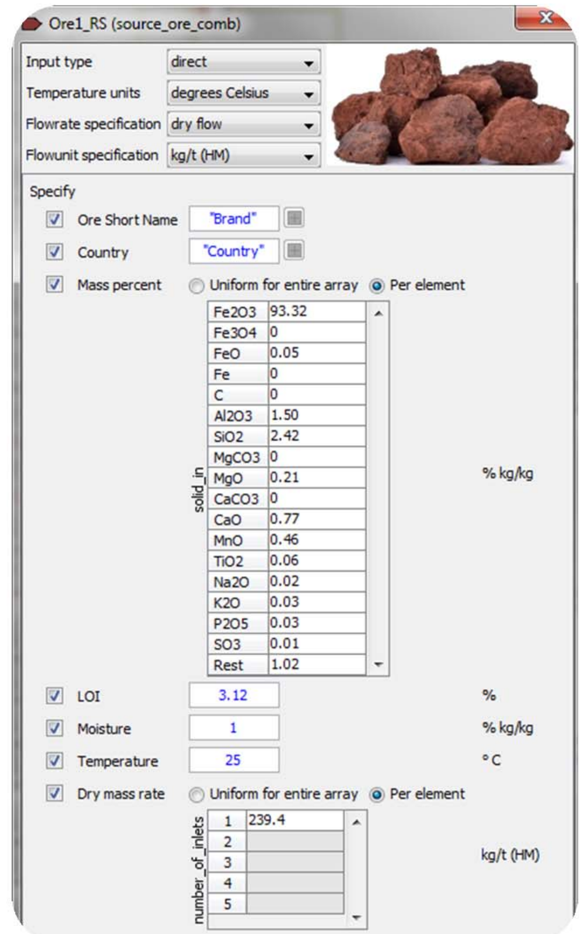
Over 250 models available for metallurgical process modelling

Achievements

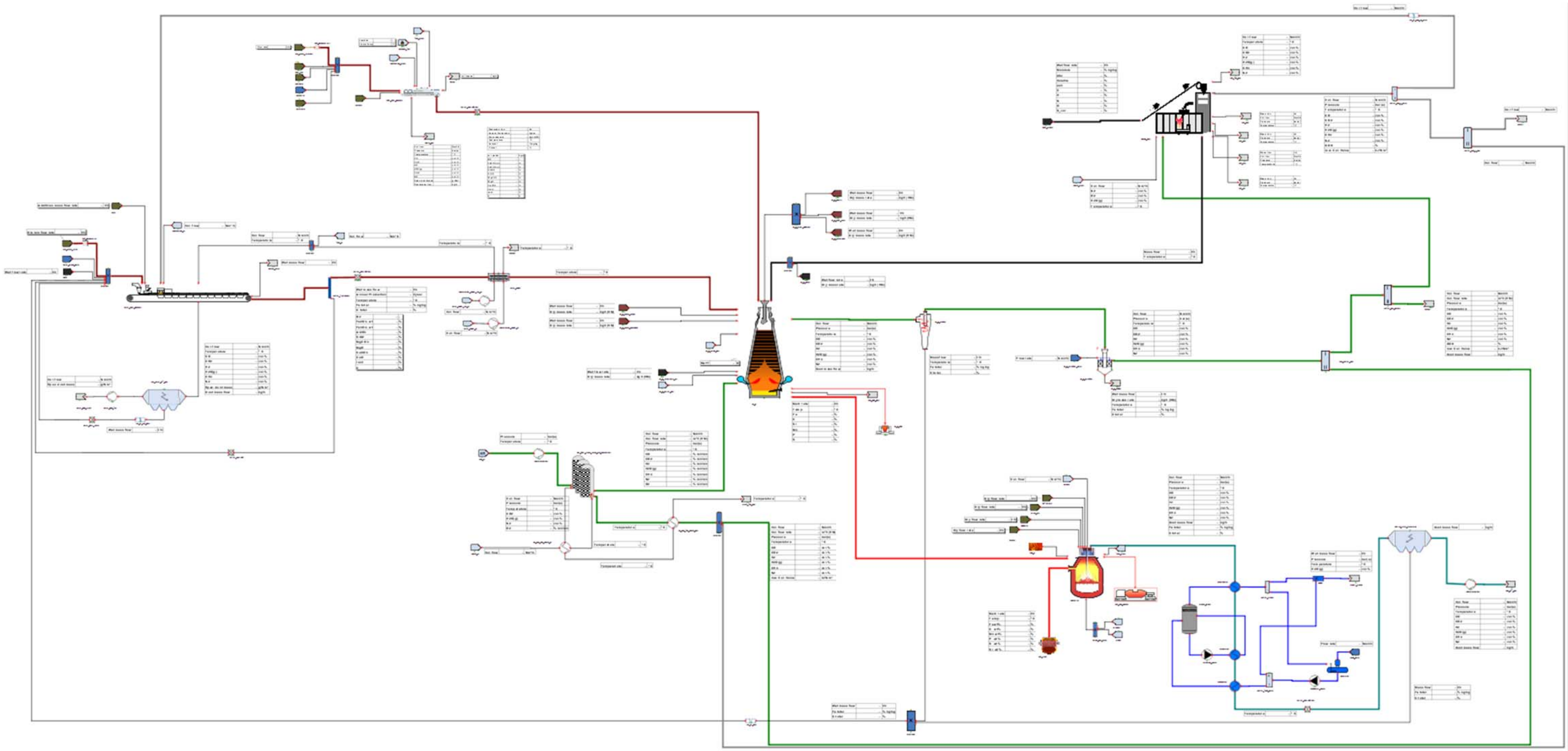
- Ore/additives/coal/coke/gas sources
- Direct entries/database (Excel) for stream analysis
- Flow values (absolute/on melting rate basis)
- Temperature + pressure



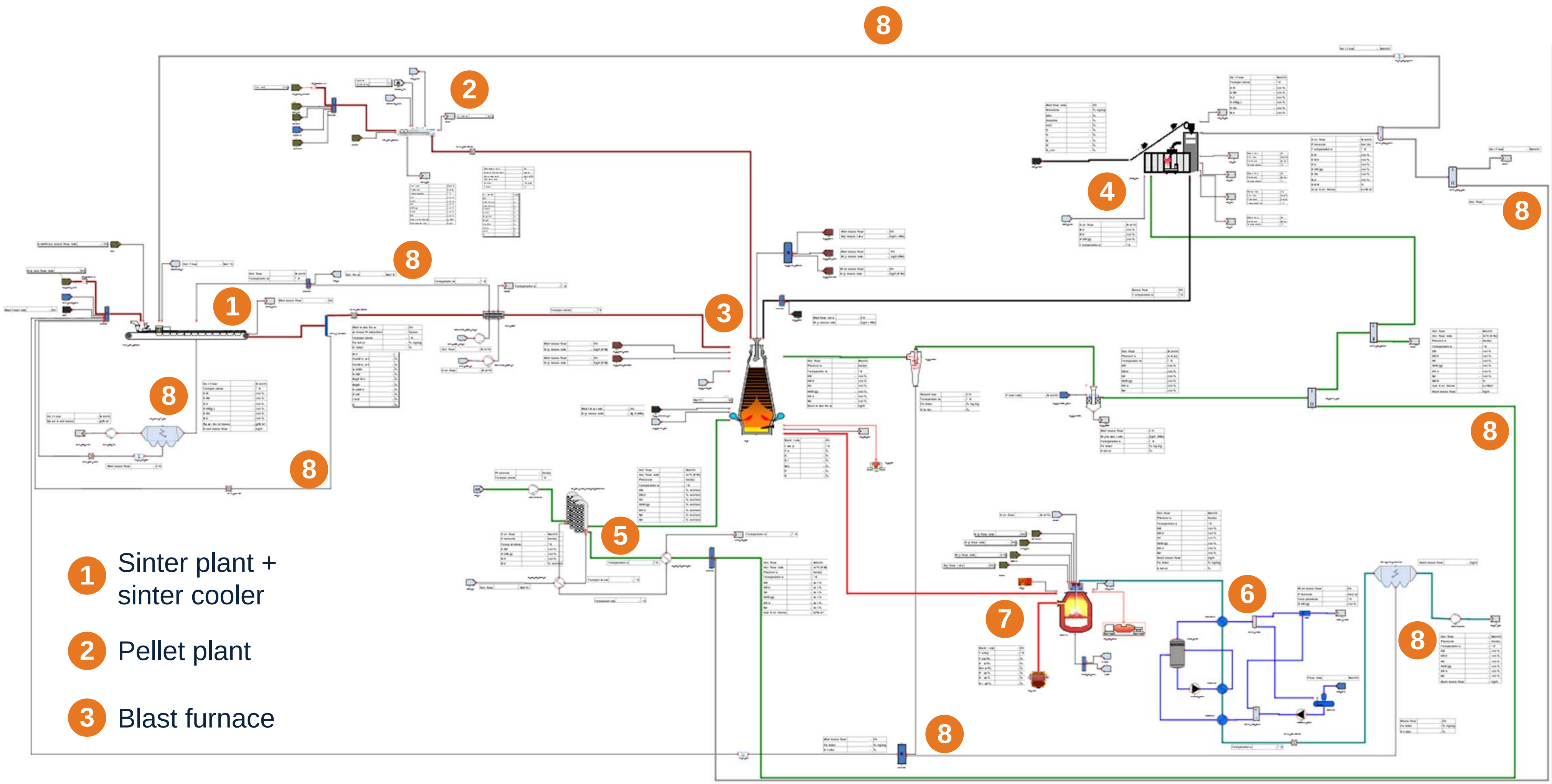




Achievements – Process Routes



Achievements – Process Routes



1 Sinter plant + sinter cooler

2 Pellet plant

3 Blast furnace

4 Coking plant

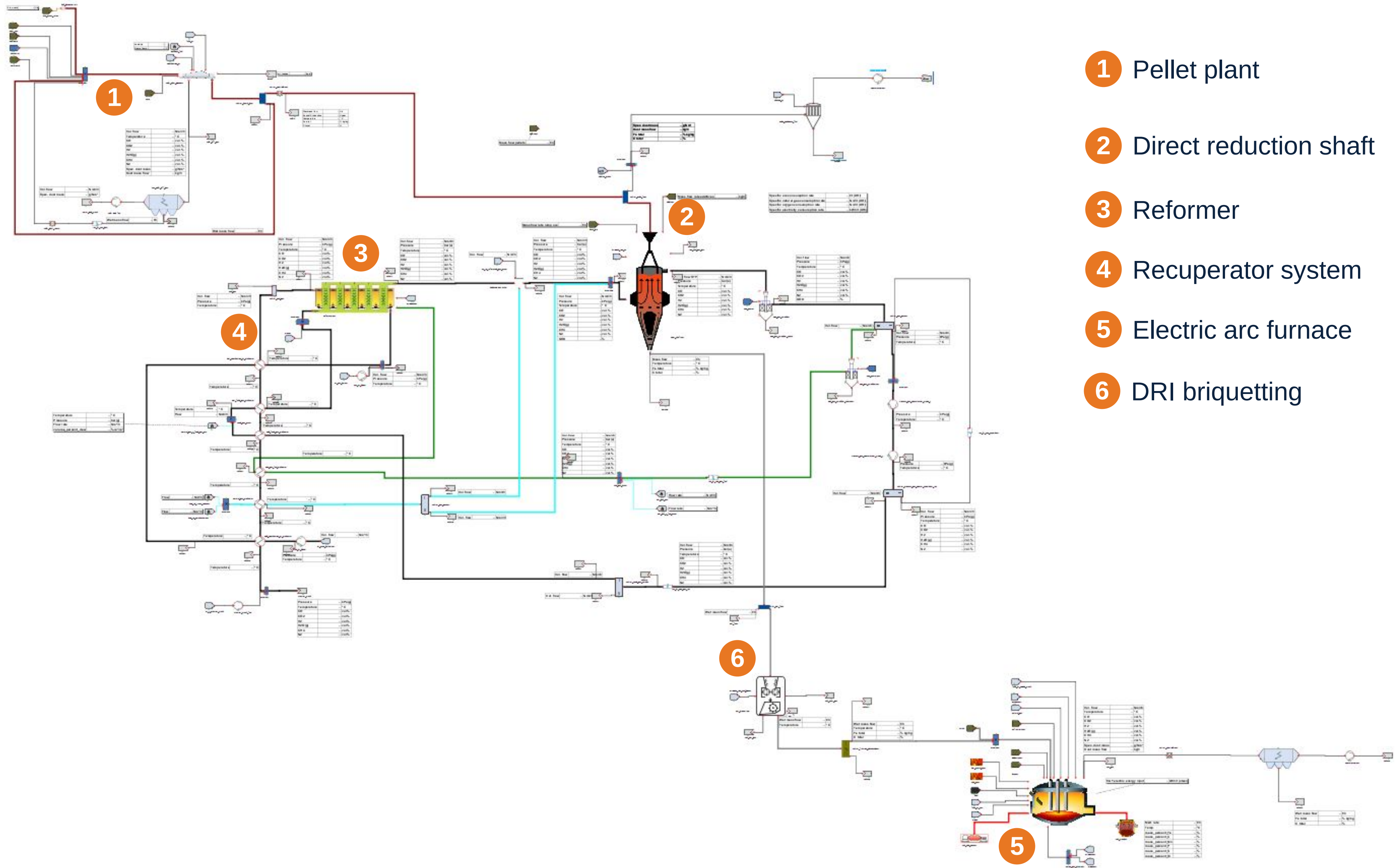
5 Hot blast stoves

6 Waste heat recovery system

7 Basic oxygen furnace

8 Recycles

Achievements – Process Routes



1 Pellet plant

2 Direct reduction shaft

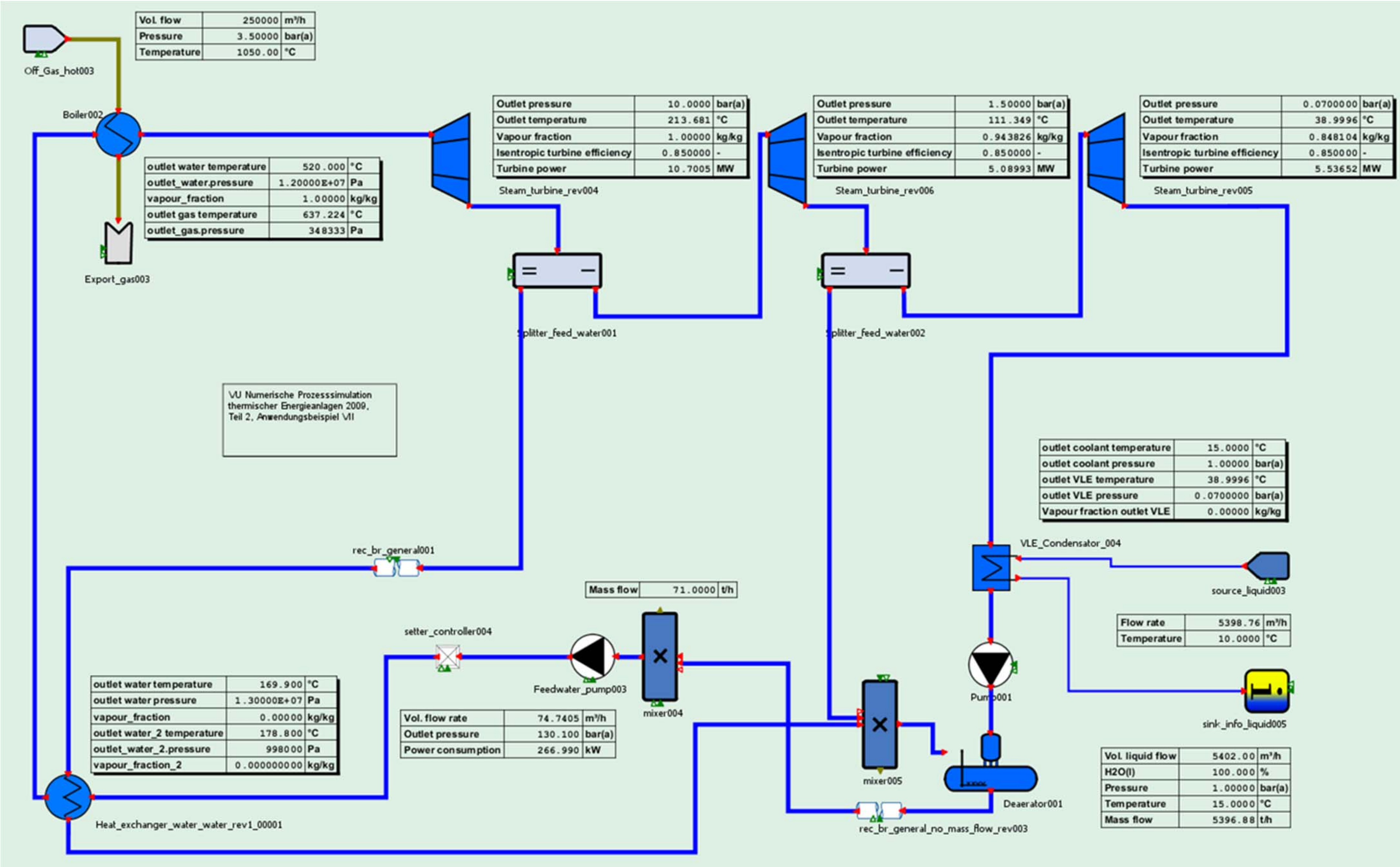
3 Reformer

4 Recuperator system

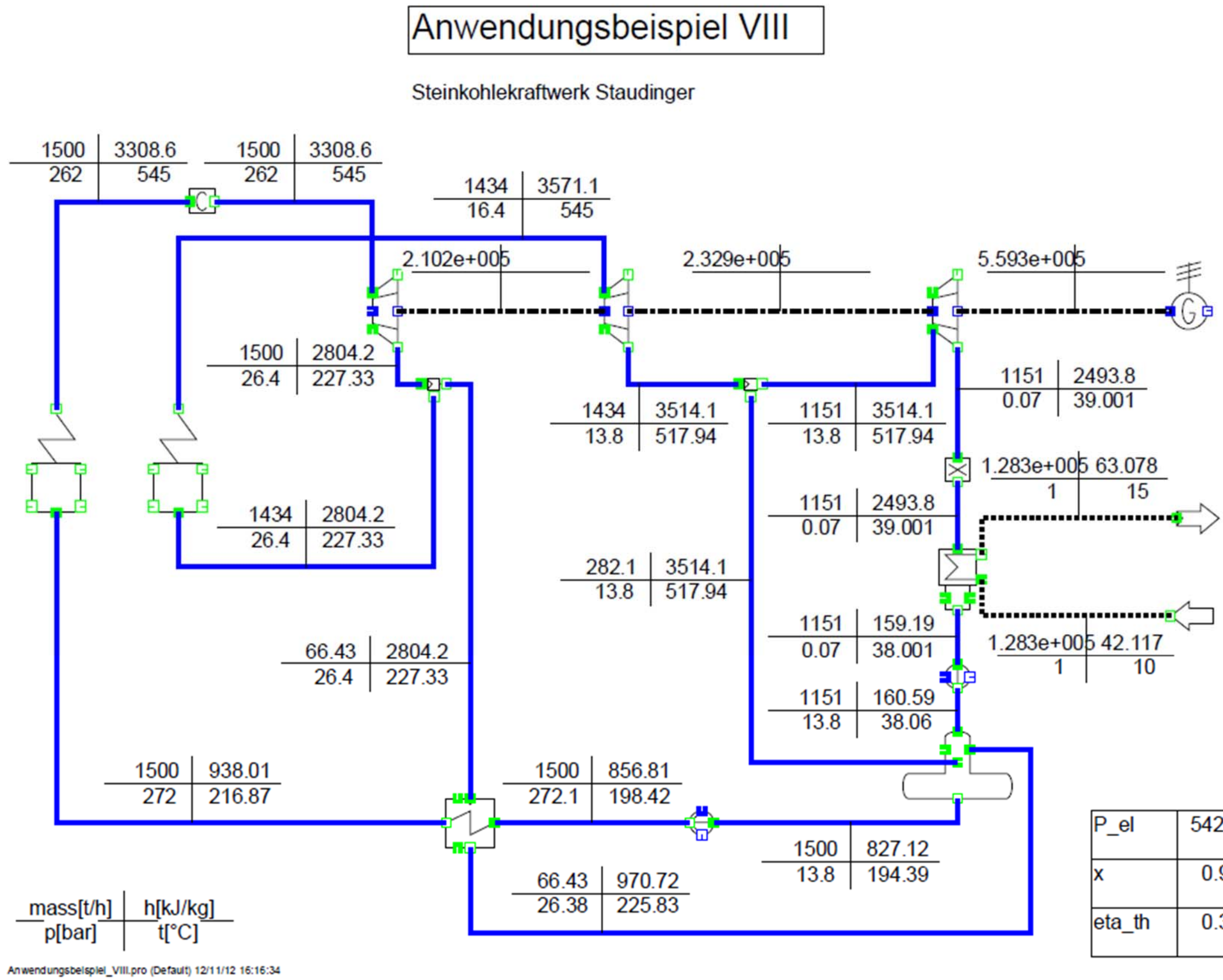
5 Electric arc furnace

6 DRI briquetting

Achievements – IPSEpro Functionality Covered

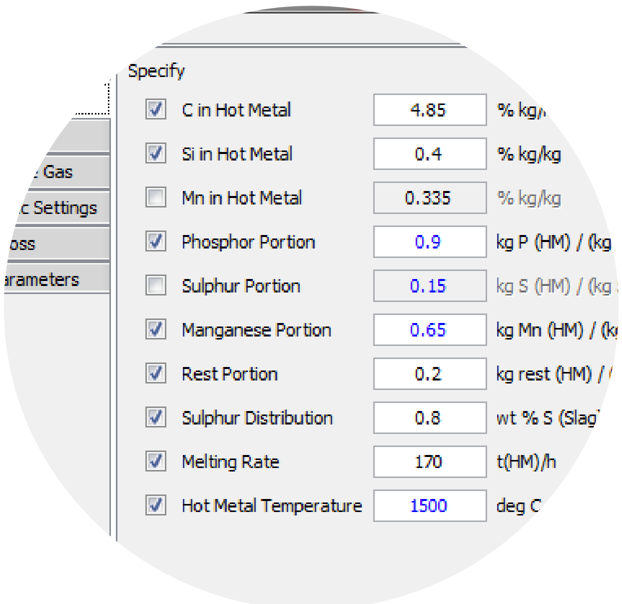


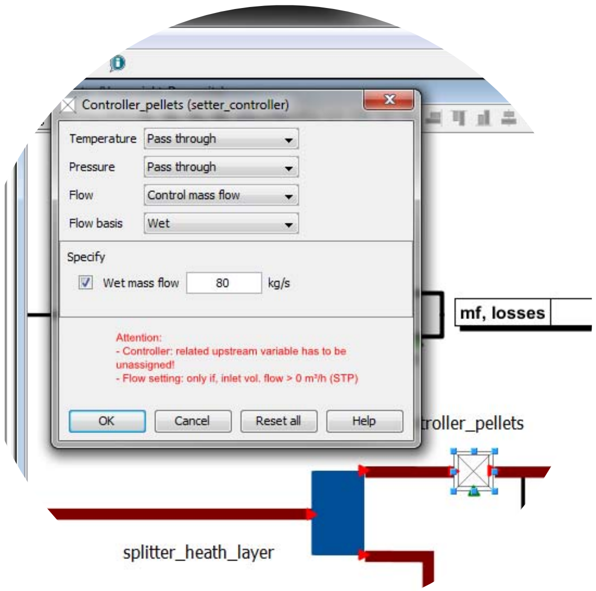
Achievements – IPSEpro Functionality Covered

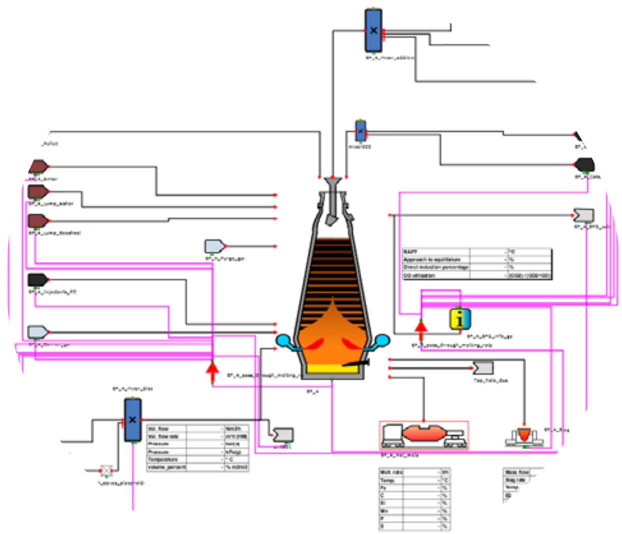


P_el	542.5870	[MW]
x	0.9676	[-]
eta_th	0.3965	[-]

Control Mechanisms



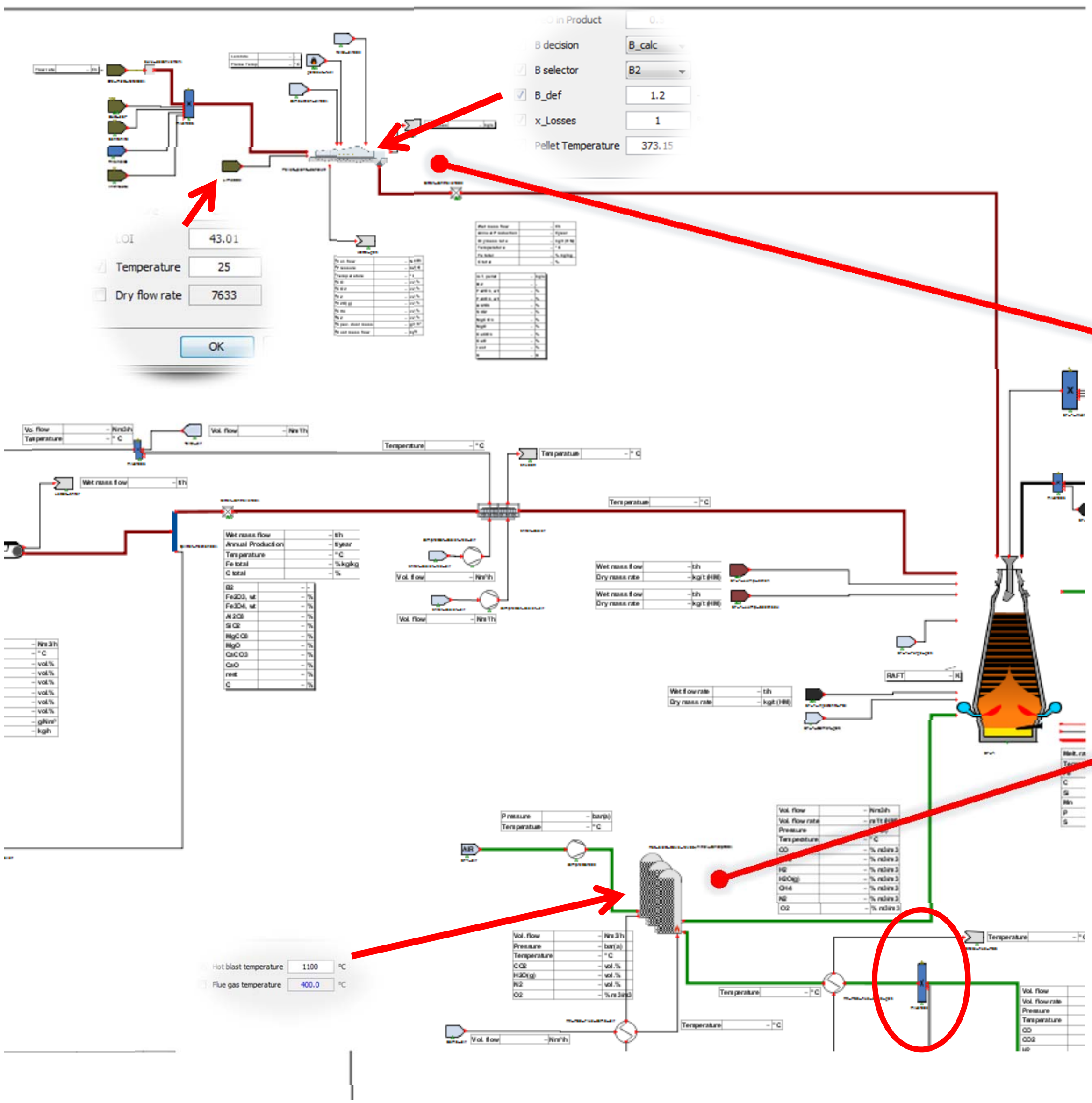




Control mechanisms implemented:

- Check boxes
- Controllers
- Signal port

Control Mechanisms – Check Boxes



Control by check boxes

Up stream or down stream variable definition

simple

Examples:

Pelletizing plant

Adjustment of basicity B2

B2 = wt % CaO / wt % SiO_2

B2 checked in pellet plant

Adjusted by additives flow rate

Flow rate in additives source unchecked

Hot blast stoves

Adjustment of hot blast temperature and efficiency by combustion gas mix

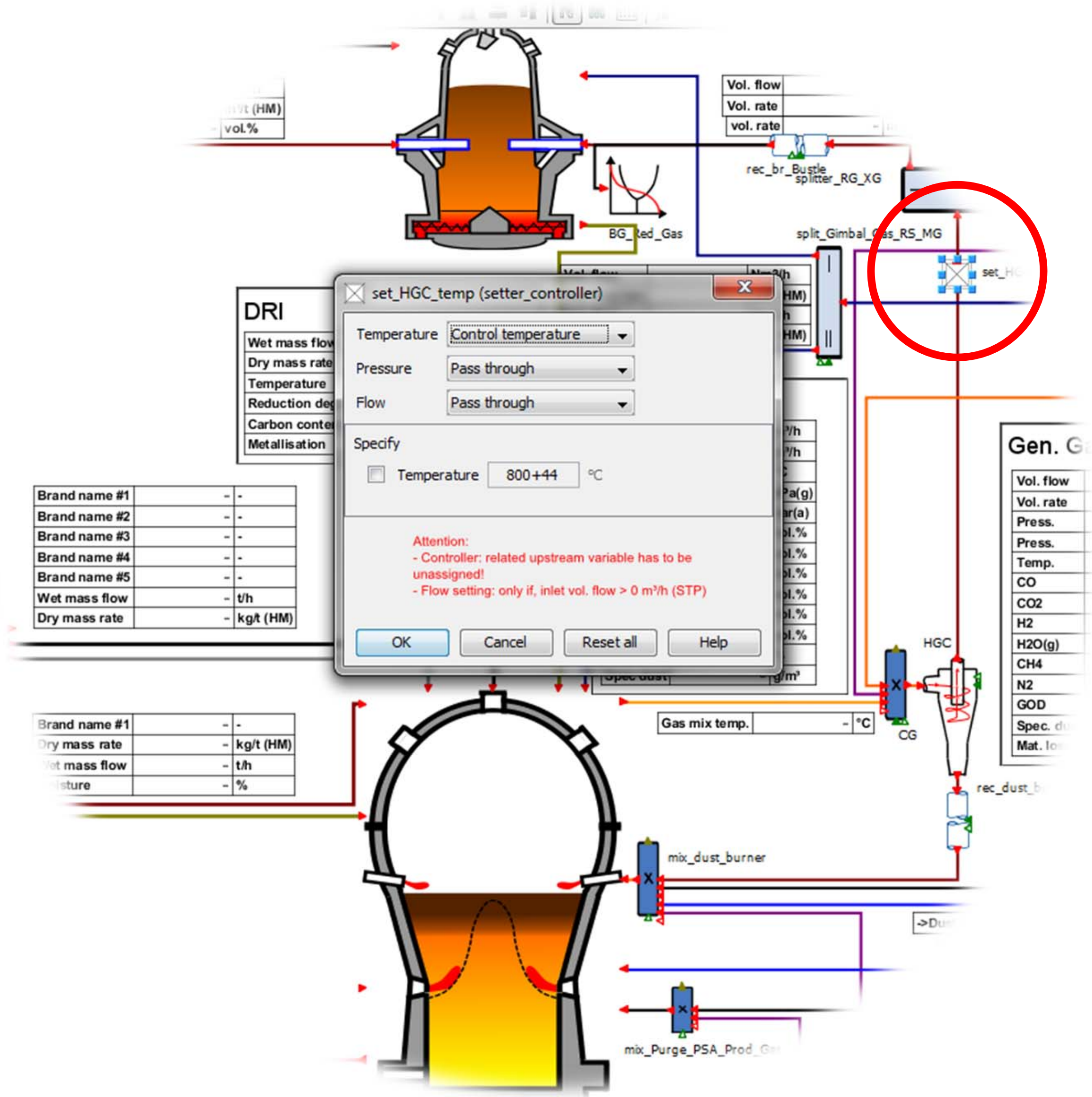
Calculated combustion gas mix to reach heating value for temperature adjustment

Control Mechanisms – Controller

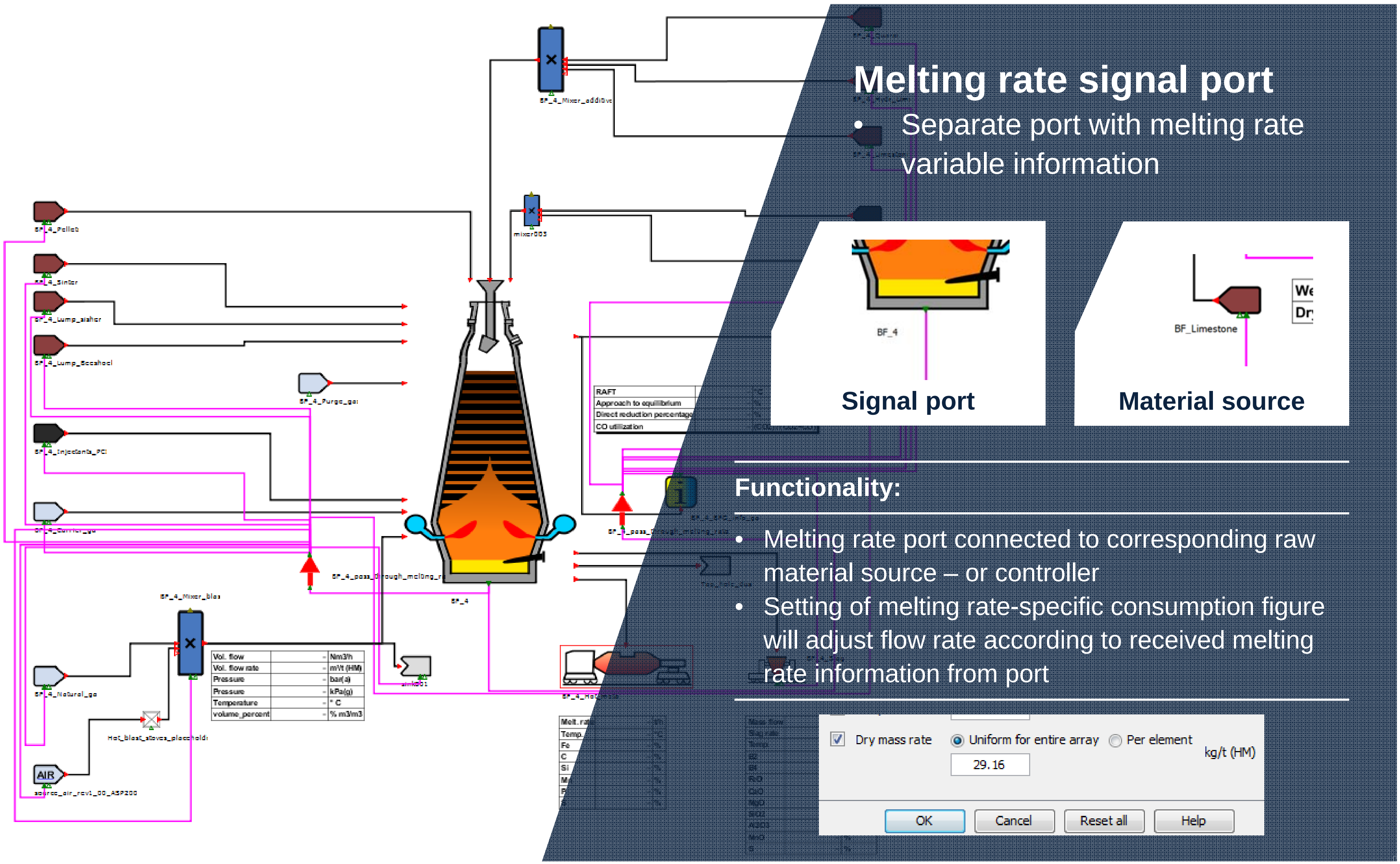
- Controller for stream variables
  - Comparable to check box control functionality, but providing stream variables
  - Temperature
  - Pressure
  - Flow
- Selection of functionalities
  - Passing through of stream information
  - Control variable directly
  - Set a difference
  - Set a outlet value
- Additionally
  - Control variable via input of specific consumption figure

  and

  - Melting rate information received via signal port



Control Mechanisms – Signal Ports



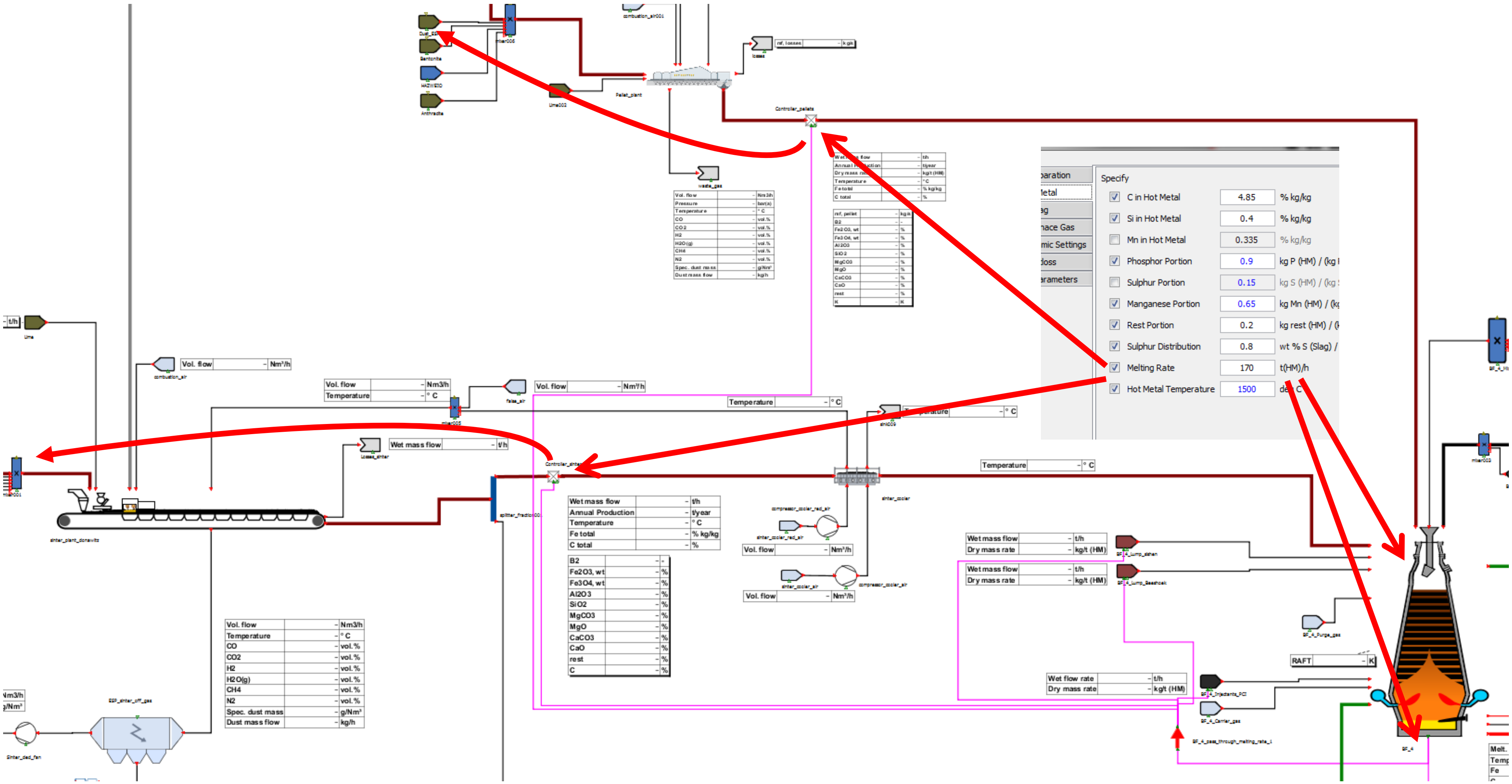
Melting rate signal port

- Separate port with melting rate variable information

Functionality:

- Melting rate port connected to corresponding raw material source – or controller
- Setting of melting rate-specific consumption figure will adjust flow rate according to received melting rate information from port

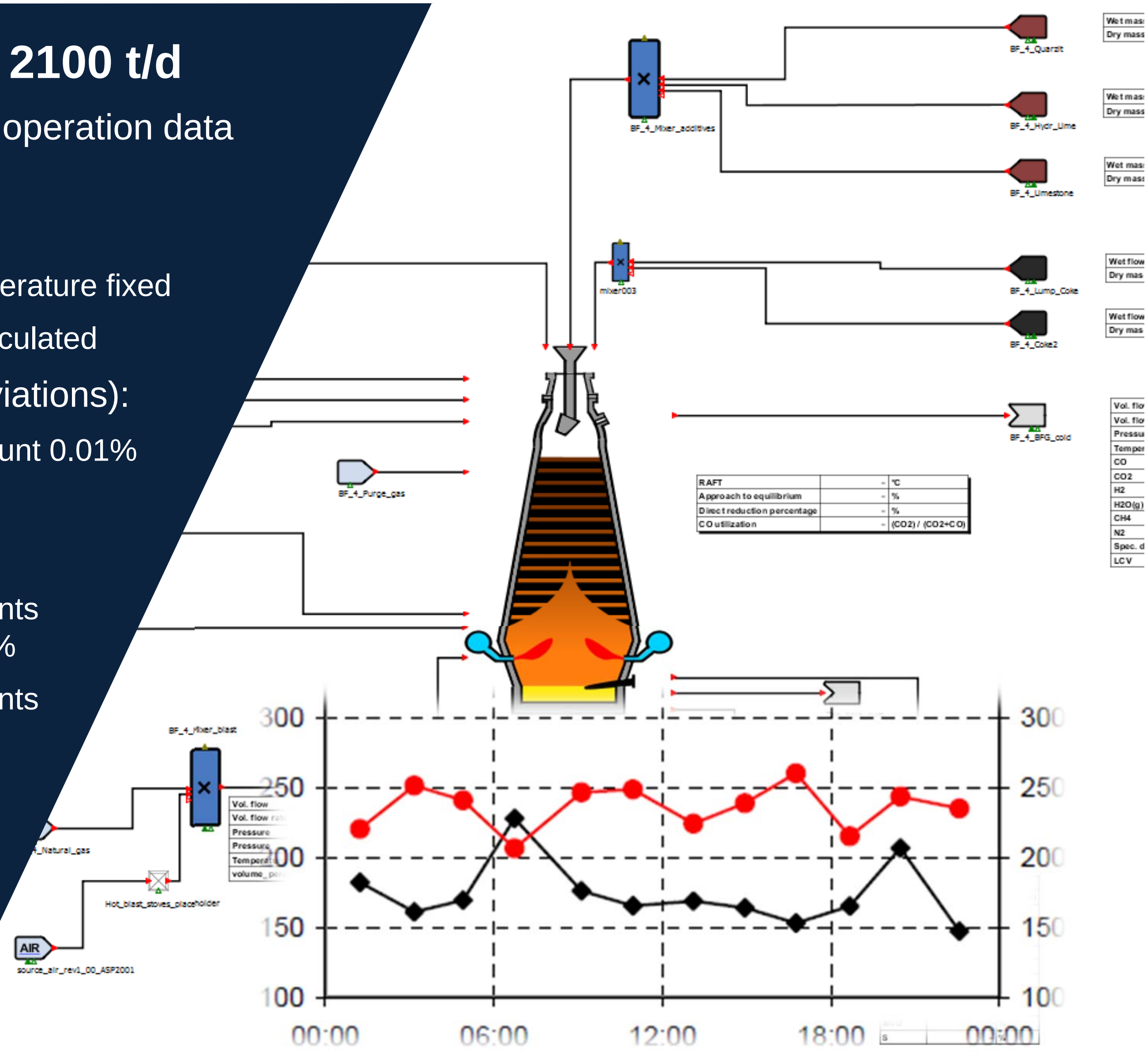
Control Mechanisms – Signal Ports + controller



Operation Data Analyses – Blast Furnace Daliy Basis

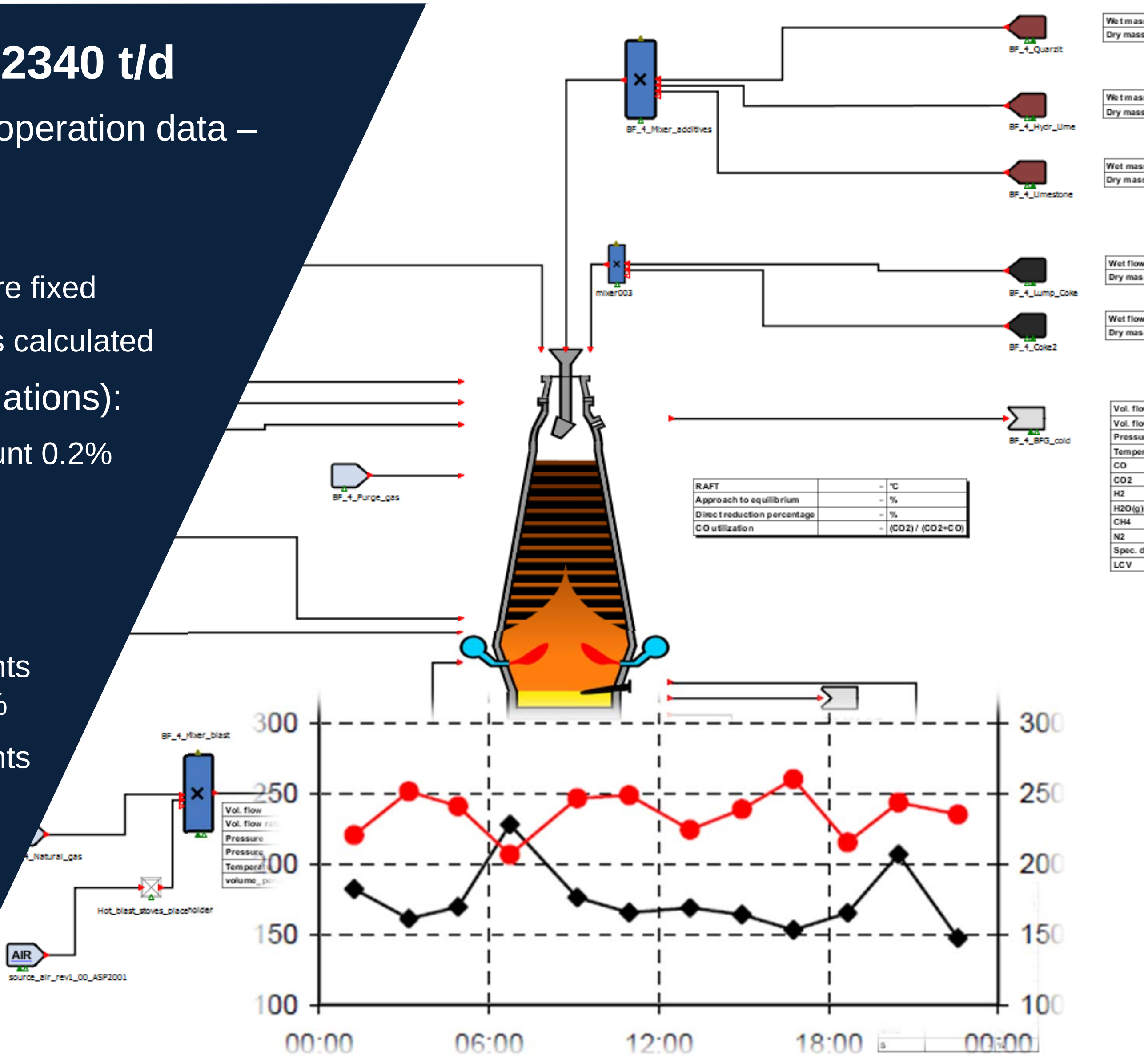
Blast furnace validation 2100 t/d

- Central European blast furnace operation data – daily basis
- Calculation settings:
  - Burden, fuel rate and top gas temperature fixed
  - Blast amount and melting rates calculated
- Accuracy achieved (relative deviations):
  - Blast amount 0.86%, Top gas amount 0.01%
  - Top gas species analysis 0.82%
  - Hot metal amount 0.68%
  - Hot metal analysis major components (> 0.6% content in hot metal) 0.13%
  - Hot metal analysis minor components (< 0.6% content in hot metal) 7%
- Problem:
  - Inconsistency in mass conservation of daily report due to burden residence time in blast furnace



Blast furnace validation 2340 t/d

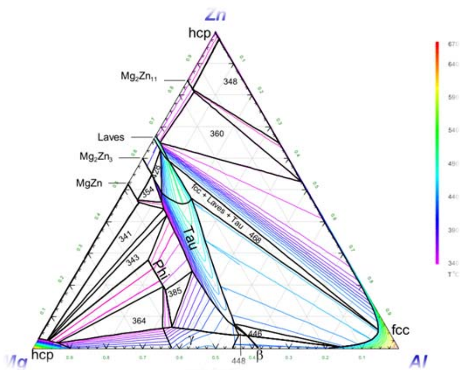
- Central European blast furnace operation data – annual basis
- Calculation settings:
  - Melting rate and top gas temperature fixed
  - Blast amount, fuel and burden rates calculated
- Accuracy achieved (relative deviations):
  - Blast amount 0.81%, Top gas amount 0.2%
  - Top gas species analysis 1.5%
  - Burden rate 2,5%
  - Fuel rate 2,1%
  - Hot metal analysis major components (> 0.6% content in hot metal) 0.14%
  - Hot metal analysis minor components (< 0.6% content in hot metal) 1.7%
- Problem:
  - Exact raw material analyses not known



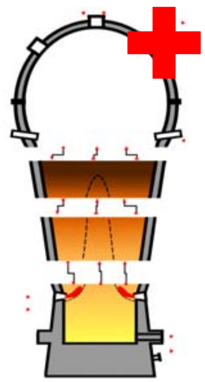
Benefits

- Faster adaption to customer needs in pre-projects
  - Significantly increased flexibility/velocity in calculations during process adaptions
  - Less internal working ours for handling of enquiries – shorter response times to enquiries
- Easier process development
  - gPROMS extends possibilities compared to former tools
  - COG based DR process development support for patent application
  - H_2 based Direct Reduction process
  - H_2 injection to blast furnace process
- Reduction of NCCs
  - Consortia projects – up to 3 or more external technology partners
  - Generation of lumped balances in former times not possible
  - Now most technologies are covered in gPROMS – lumped balances possible
- Metallurgical model library is currently not commercially available
  - Offering of studies/consulting to customers
- IPSEpro calculations possible in gPROMS

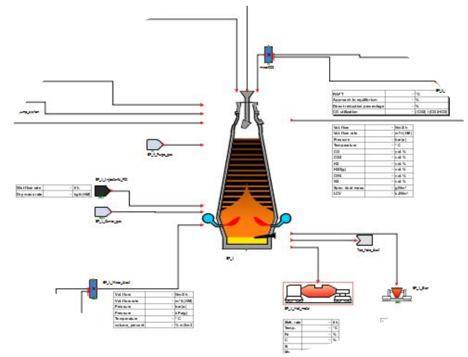
Challenges



Thermodynamics



Models



Flow Sheets

Species
Significant extension of species set for inclusion of problematic trace species

Thermochemical properties
Extension of functionalities in thermo-chemical properties, such as heats of solution, entropies, etc.

Challenges
Species definition
Data provision and validation
Calculation times

Introduction of new models
Continued extension of the metallurgical model library to cover more technologies

Development of models
Extensions for selected models to a higher degree of detailization, such as zone models for the extended species set

Challenges
Mullti-zonal model development
Initialisation procedures
Validation of models

Integrated steel plant modelling
More realistic depiction of process routes for increased knowledge output

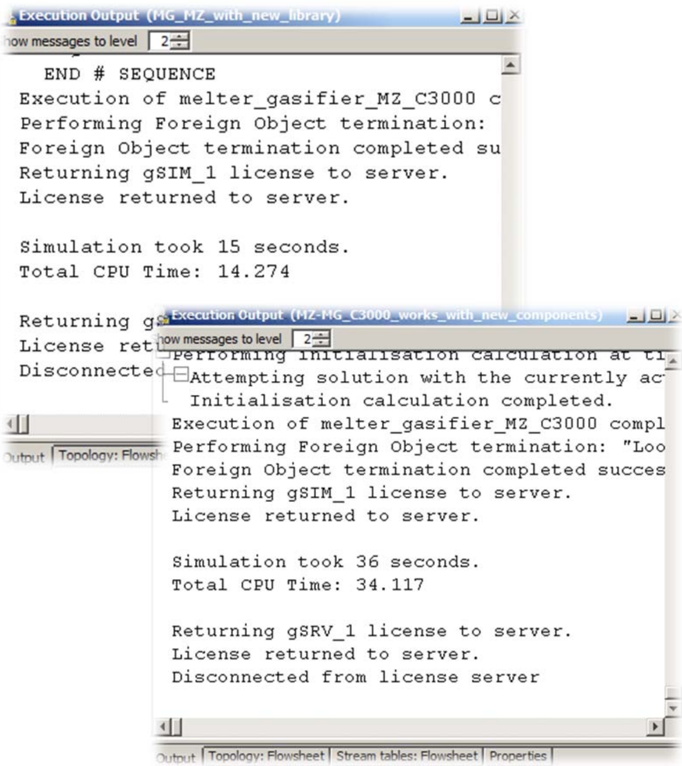
Tracing of problematic species
Using the extended species set and depicting recycles – figure out chances to treat trace materials correctly

Challenges
Initialisation procedures
Validation with measurement campaigns

Challenges - Thermodynamics

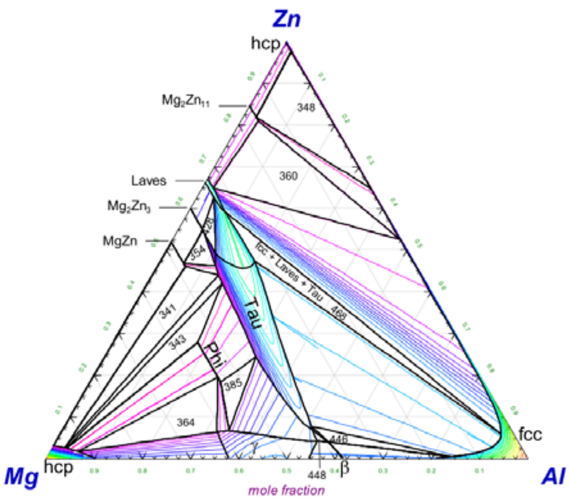
Species extension

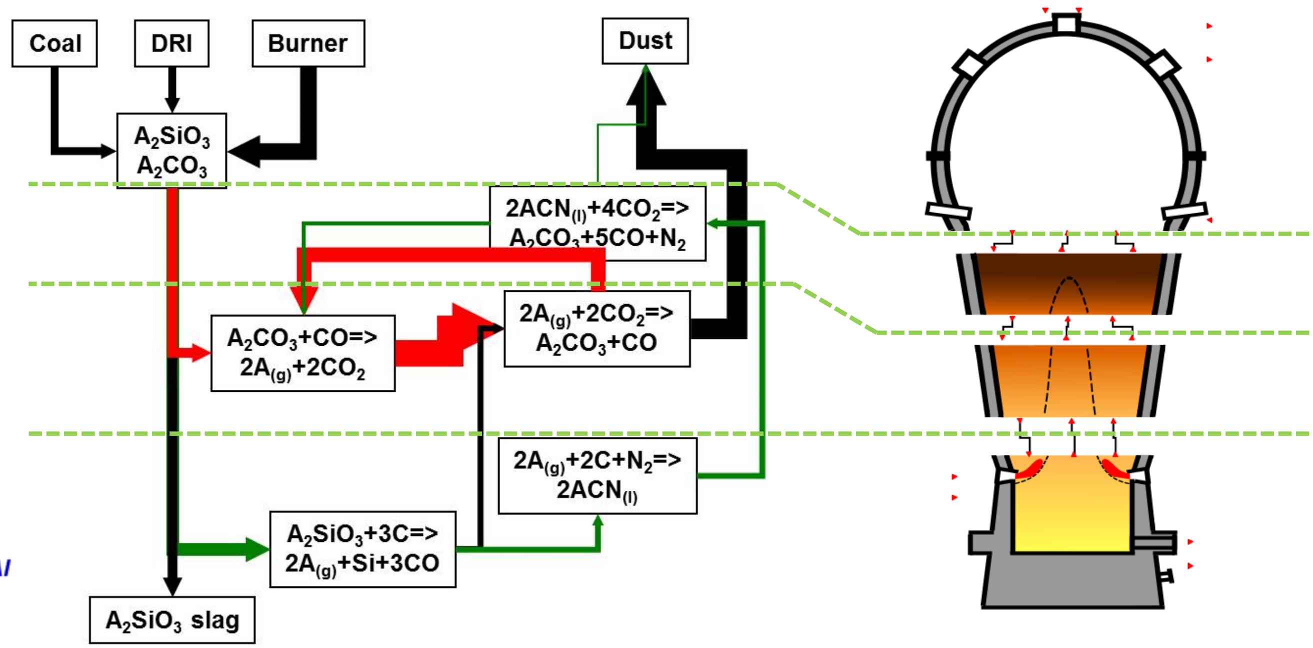
- Set to be more than doubled
- Going along with extension of thermodynamic data
- Significant increase of calculation times




```
alpy("ZnO")                              = (1/enthalpy_scale)
halpy("ZnCO3")                           = (1/enthalpy_scale)
chalpy("Zn")                             = (1/enthalpy_scale)
nthalpy("ZnCl")                          = (1/enthalpy_scale)
enthalpy("K2SiO3")                       = (1/enthalpy_scale)
_enthalpy("K2CO3")                       = (1/enthalpy_scale)
c_enthalpy("KCl")                        = (1/enthalpy_scale)
ic_enthalpy("Na2SiO3")                   = (1/enthalpy_scale)
fic_enthalpy("Na2CO3")                   = (1/enthalpy_scale)
ific_enthalpy("NaCl")                    = (1/enthalpy_scale)
cific_enthalpy("CaSO4")                  = (1/enthalpy_scale)
ecific_enthalpy("MgSO4")                 = (1/enthalpy_scale)
pecific_enthalpy("CaSO3")                = (1/enthalpy_scale)
_specific_enthalpy("MgSO3")              = (1/enthalpy_scale)
_specific_enthalpy("FeS")                = (1/enthalpy_scale)
s_specific_enthalpy("FeS2")              = (1/enthalpy_scale)
ss_specific_enthalpy("MgS")              = (1/enthalpy_scale)
ass_specific_enthalpy("CaS")             = (1/enthalpy_scale)
mass_specific_enthalpy("CaF2")           = (1/enthalpy_scale)
mass_specific_enthalpy("CaC2")           = (1/enthalpy_scale)
* mass_specific_enthalpy("Fe3C")         = (1/enthalpy_scale)
* mass_specific_enthalpy("Fe[C]")        = (1/enthalpy_scale)
) * mass_specific_enthalpy("Mg(OH)2")    = (1/enthalpy_scale)
e) * mass_specific_enthalpy("Ca(OH)2")   = (1/enthalpy_scale)
le) * mass_specific_enthalpy("V2O5")     = (1/enthalpy_scale)
ale) * mass_specific_enthalpy("V2O3")    = (1/enthalpy_scale)
scale) * mass_specific_enthalpy("Mn3O4") = (1/enthalpy_scale)
_scale) * mass_specific_enthalpy("Mn2O3") = (1/enthalpy_scale)
```

Challenges – Model Development + Extended Chemistry

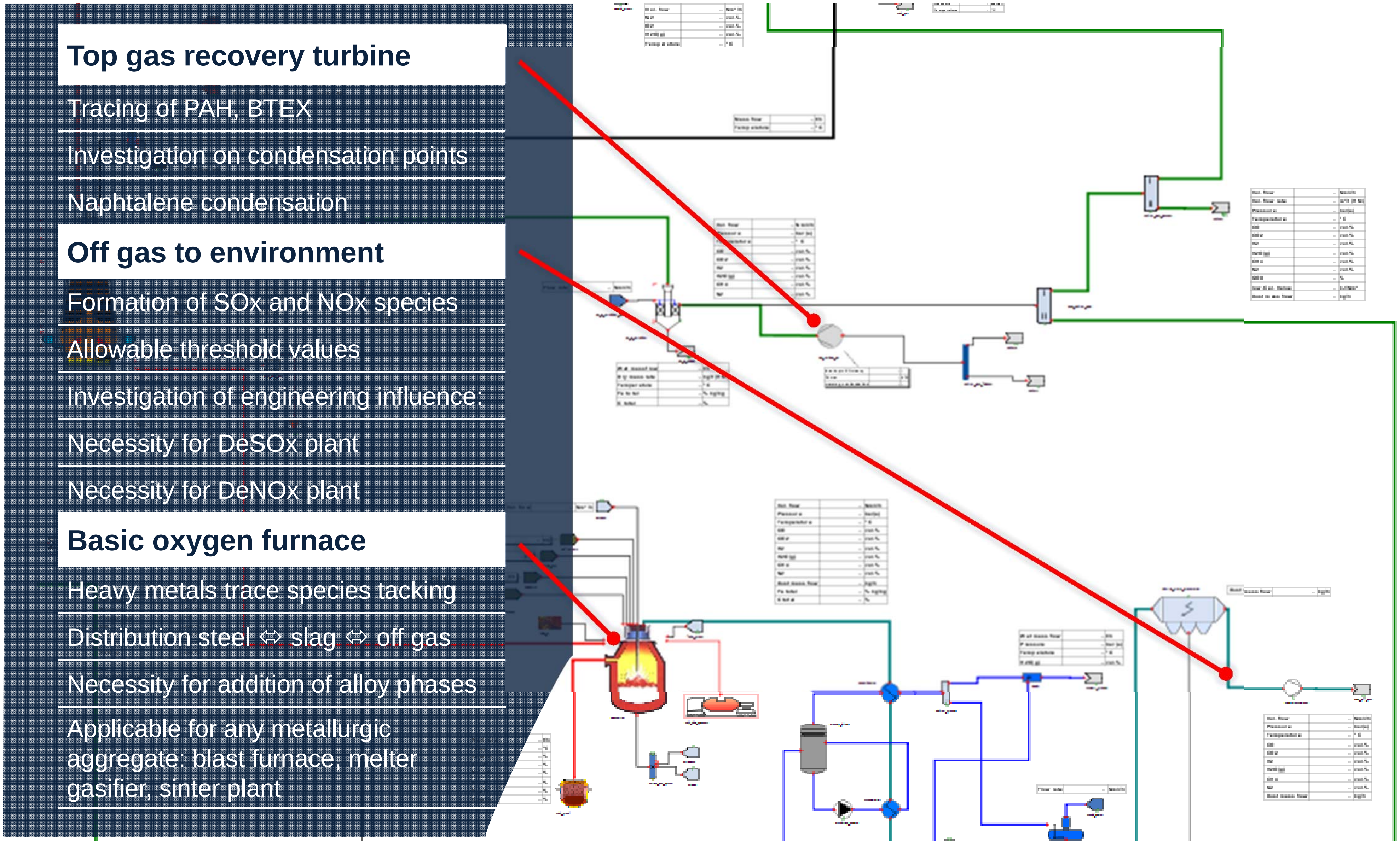




Aim – usage of

- Extended species sets
- For development of complex chemistry cycles
- To be implemented in selected models
- For high sophisticated flow sheet modelling

Challenges – Sophisticated Flow Sheet Modelling



Top gas recovery turbine

- Tracing of PAH, BTEX
- Investigation on condensation points
- Naphtalene condensation

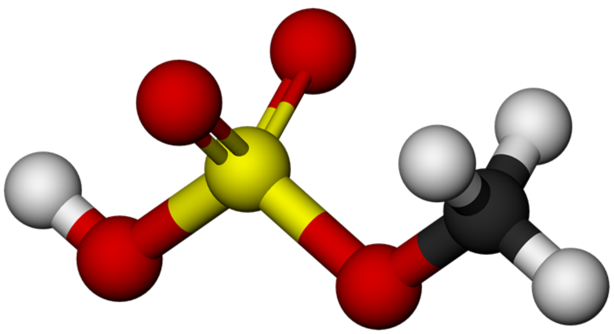
Off gas to environment

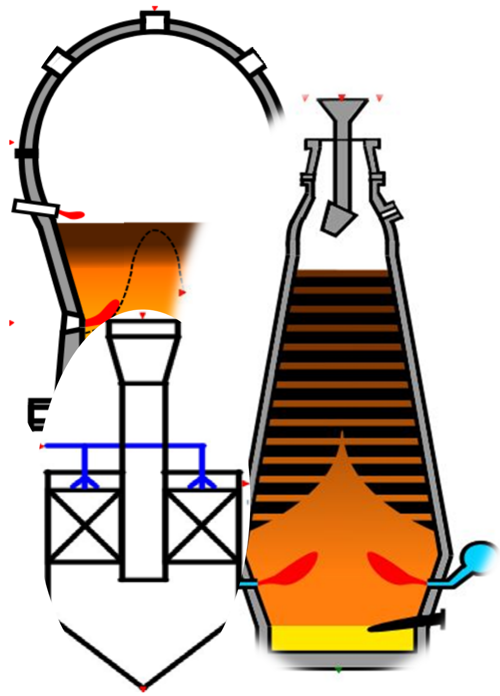
- Formation of SOx and NOx species
- Allowable threshold values
- Investigation of engineering influence:
- Necessity for DeSOx plant
- Necessity for DeNOx plant

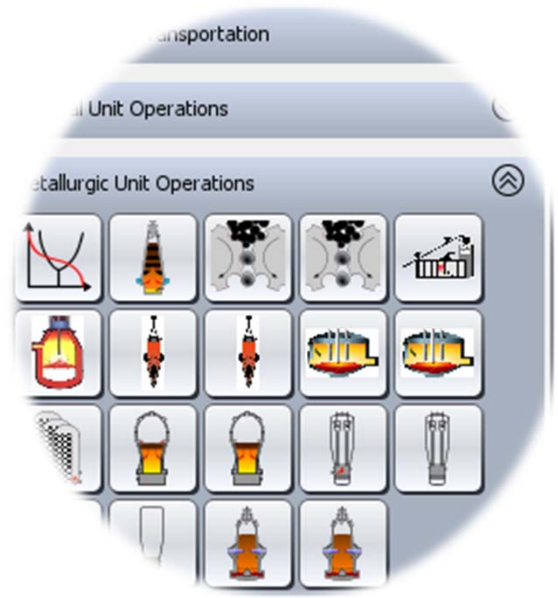
Basic oxygen furnace

- Heavy metals trace species tacking
- Distribution steel ⇔ slag ⇔ off gas
- Necessity for addition of alloy phases
- Applicable for any metallurgic aggregate: blast furnace, melter gasifier, sinter plant

Vision







The metallurgical model library is currently not commercially available and no established competitive tool known to Primetals

Start consulting services with a full life cycle process integration tool to integrated steel plant operators

Vision

Integrated steel plant

- 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

Operation interests

- Raw material influence on process and operation costs, operation planning
- Internal material recycles
- Saving of real plant tests due to simulations
- Analysis of operation data

Investment interests

- Brown field investment considerations
- Comparison of current integrated plant set-up and operation to new process routes
- Green field project development

Visions

Operation Analyses | **Investment Evaluations** | **Customized Solutions**

Material investigations
- Raw material influence
- Internal material stream analyses
- New recycles

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

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

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

Vision

Operation data validation	
Collection of operation data	Finding robust operation data for different operating modes, production capacities
Cross check	Conservation of mass fulfilled? Residence times of plants considered?
Raw material data	Collection of corresponding raw material analyses

Model calibration	
Stand alone mode	Starting with calibration of stand alone single plants
Constructing flow sheet	Constructing the integrated plant flow sheet by using the calibrated stand alone single plants
Flow sheet validation	Check of the correct depiction of the integrated steel plant in gPROMS, validation with overall operation data

Process calculations + consulting	
Define tasks	Changed raw material, equipment, new internal recycles
Sensitivity analyses	Generate robust and realistic results
Consult	Extract data, provide it to the customer

Contact

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