ESTEP
European Steel Technology Platform

ESTEP Focus Groups
Smart Factory and
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Digital-4-Environment

ESTEP Workshop

Overview, recent developments and future trends

A Digital toolkit to investigate and guide the transition towards H_2-DRI-based steelmaking considering the effects on energy management

20th – 22nd February 2024

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- **MaxH_2DR**
- **Process chain multipurpose simulation toolkit**
  - **Gas and energy network models**
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  - **Models interactions**
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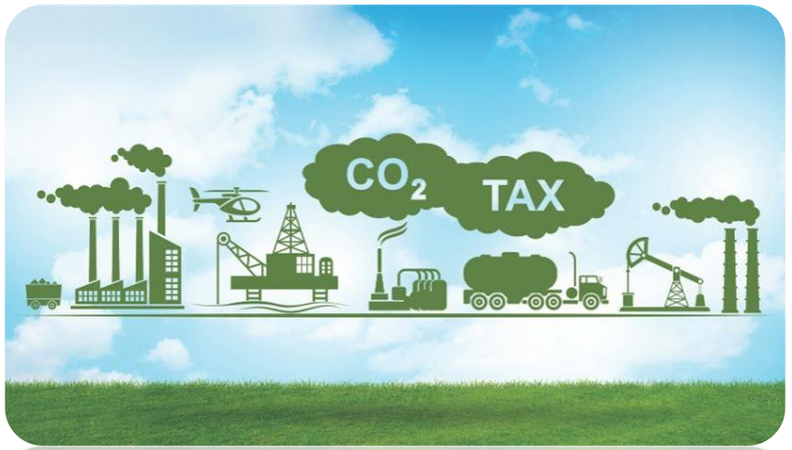
Steelmaking challenges

Today



EU steel production accounts for 20-25 % industrial CO_2 emissions covered by the Energy Taxation Directive (ETD)

Tomorrow

2030

Developing technologies **reducing CO_2 emissions from steel production by 50%**

2050

Developing **deployable technologies ultimately achieving climate neutrality**

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Steelmaking challenges

Activities and projects are ongoing for guiding steel industry during its transition towards C-lean processes

Hydrogen based Direct reduction is considered one of the most attractive and ground-breaking C-lean solutions

Uncertainties and lack of experience with H2 content >80% exist related to:

technological aspects	effects on the global management of facilities from the point of view of production processes, energy production, demand and distribution

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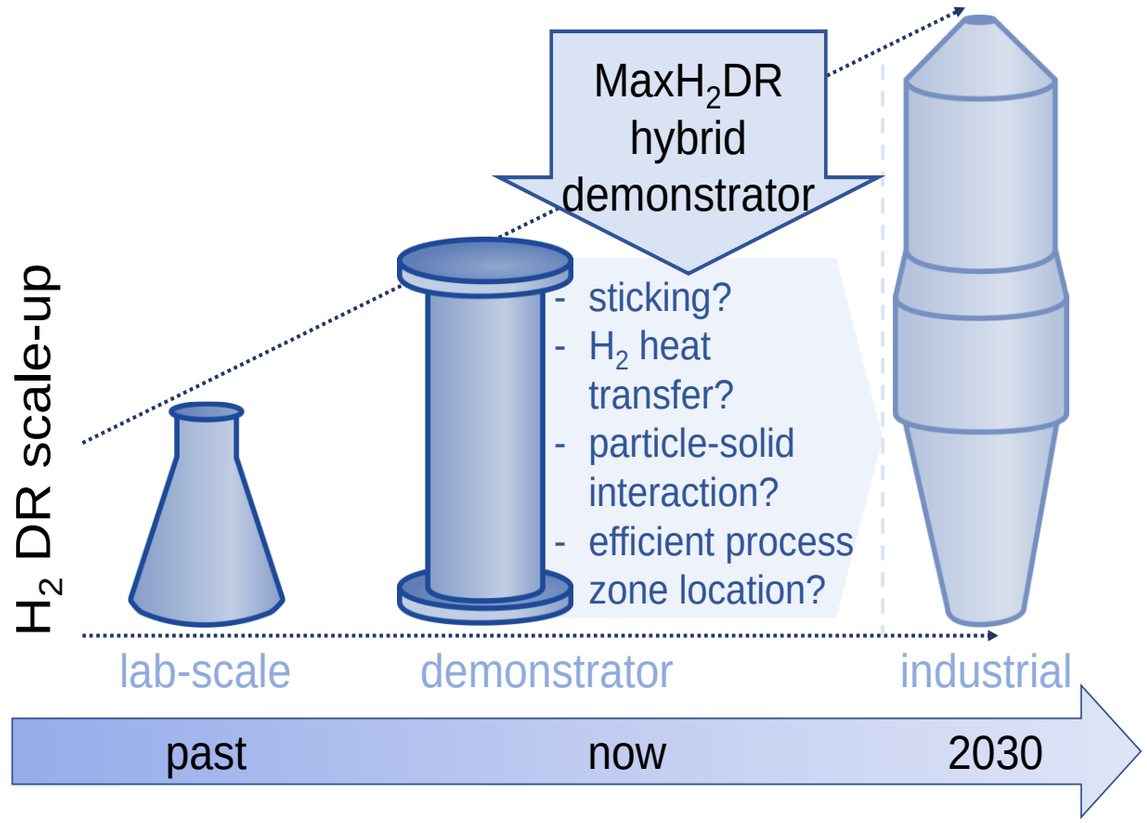
MaxH$_2$DR

« ***<u>from research to deployment</u>*** *of* ***<u>ground-breaking technologies</u>*** *for steel »*

Crucial aspects

- Flow distribution
- Uniformity of gas and burden
- Spatial differences
- Process stability and efficiency issues



MaxH$_2$DR will:

- close the current knowledge gaps hindering efficient scale-up
- deliver the tools needed for industrial implementation, process optimization, process integration and investment planning

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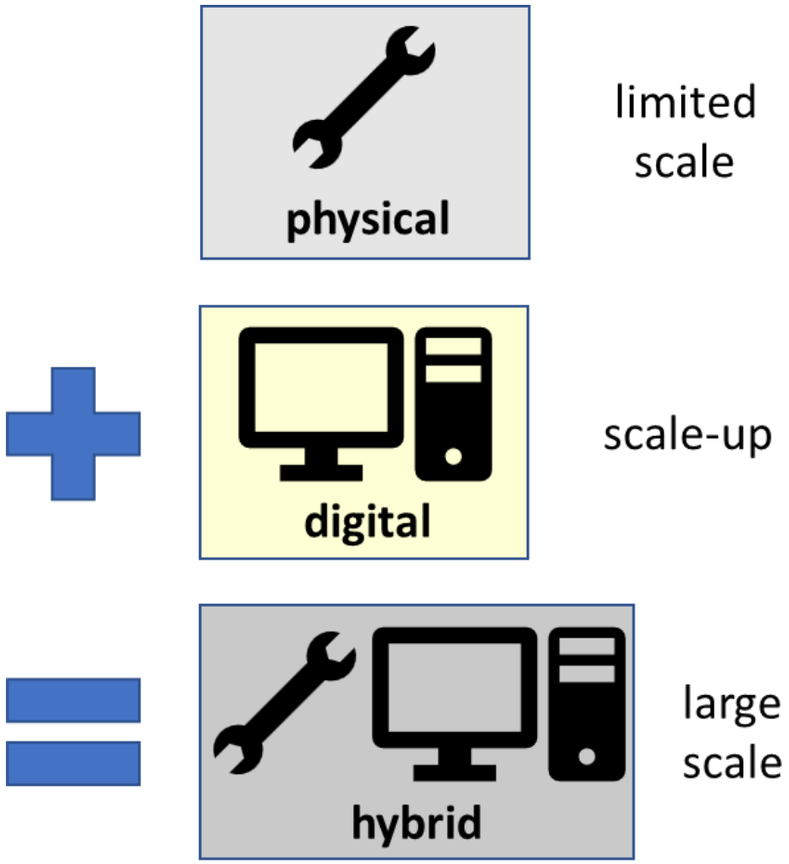
MaxH$_2$DR

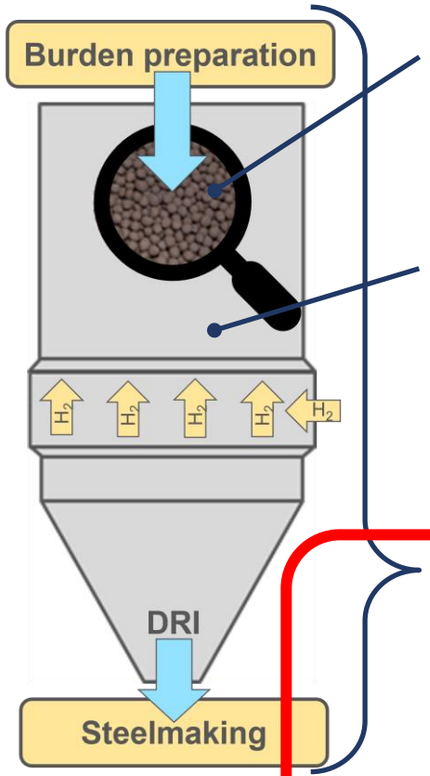
<u>Approach:</u> hybrid demonstration of steelmaking via H_2 based direct reduction

validating and fusing DR furnace models with physical demonstration into a “hybrid demonstrator”

<u>Hybrid Demonstration:</u>



<u>Three perspectives of investigation:</u>



“Particle scale”
- Laboratory experiments
- Kinetic sub-models

“DR shaft furnace scale”
- Bulk flow experiments (in demo plant)
- 3 detailed shaft furnace models
- Validation & process optimisation

“Steelmaking process chain scale”
- Stationary scenario analyses
- Dynamic investigations (flexibility)
- LCA, LCC, social impacts

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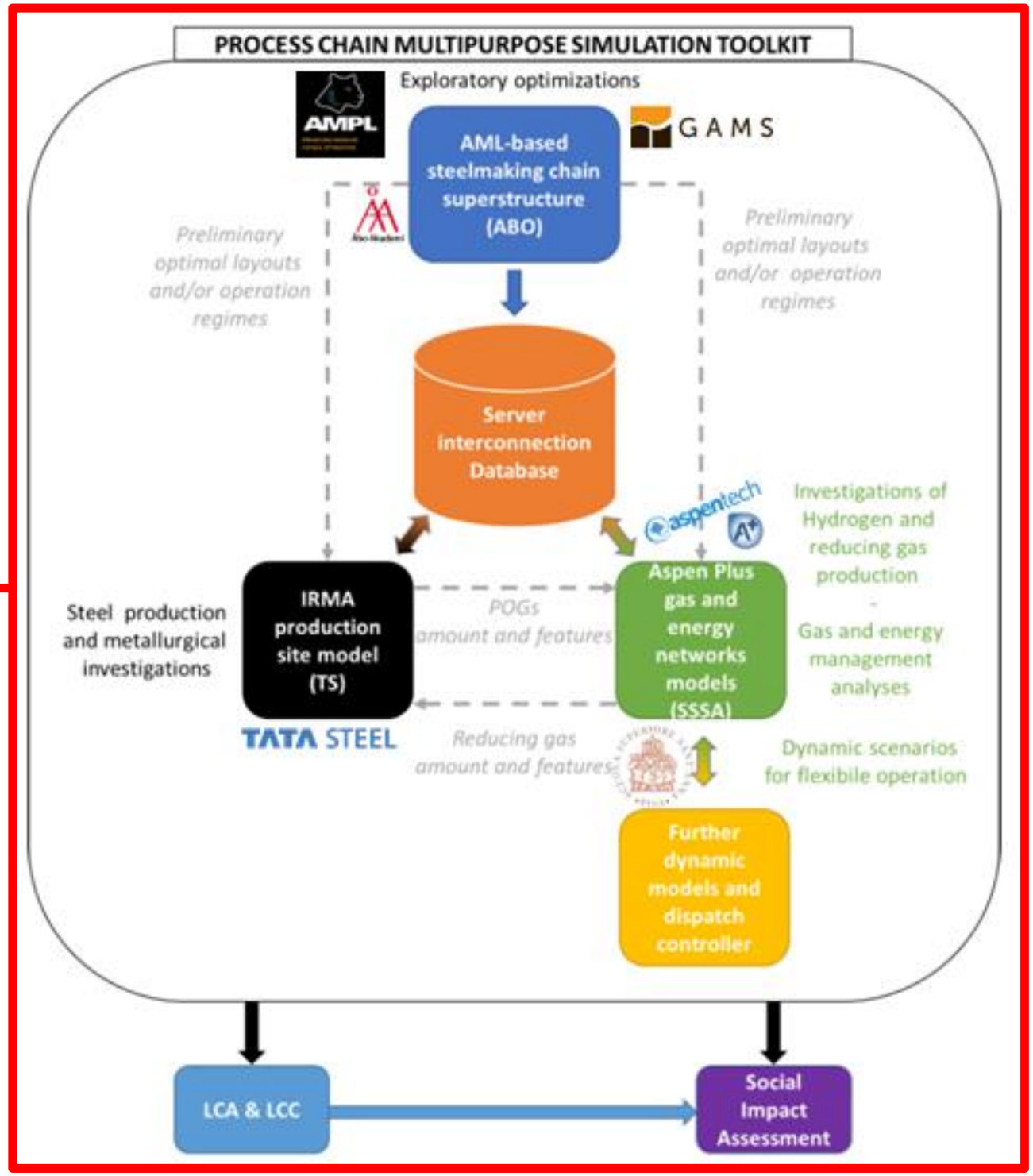
Process chain multipurpose simulation toolkit

- **Models for steelmaking process chain simulations** allowing:
  - **Scenario simulations** with different site configurations
    - **Starting route: standard integrated steelmaking**
    - **Intermediate route: mixed/hybrid configurations including CH_4/H_2 based DRI process**
    - **Target route: H_2-DRI-based steelmaking**
  - **Optimisation of DR process integration** in integrated plants



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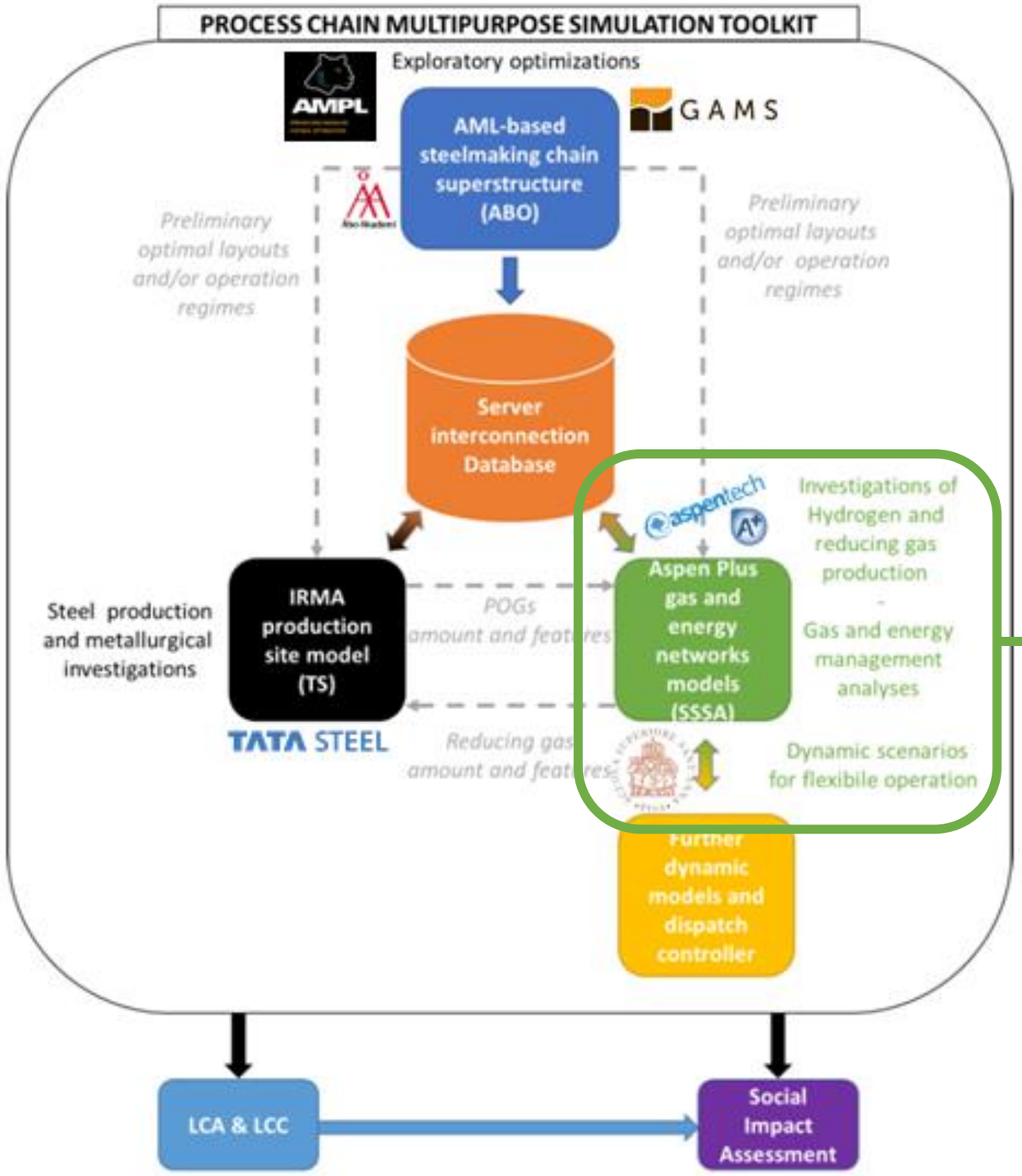
Gas and energy networks models



- **Models for simulating energy streams management**:
  - Gas cleaning and distribution *
  - Steam production and distribution *
  - Electricity production and distribution*

  *Distribution based on demand from upstream simulation/process

- **All the units models can receive and provide data from/to upstream models or directly from/to the plant through the "Server Interconnection Database"**

- Now:
  - **stationary models for all main units related to gas, steam and energy areas in standard integrated steelworks → starting point and reference for the investigation of a gradual transition**

- Future:
  - **new stationary units to simulate the changes related to the DRI-based route and the use of hydrogen in the process**
  - **Dynamic models**

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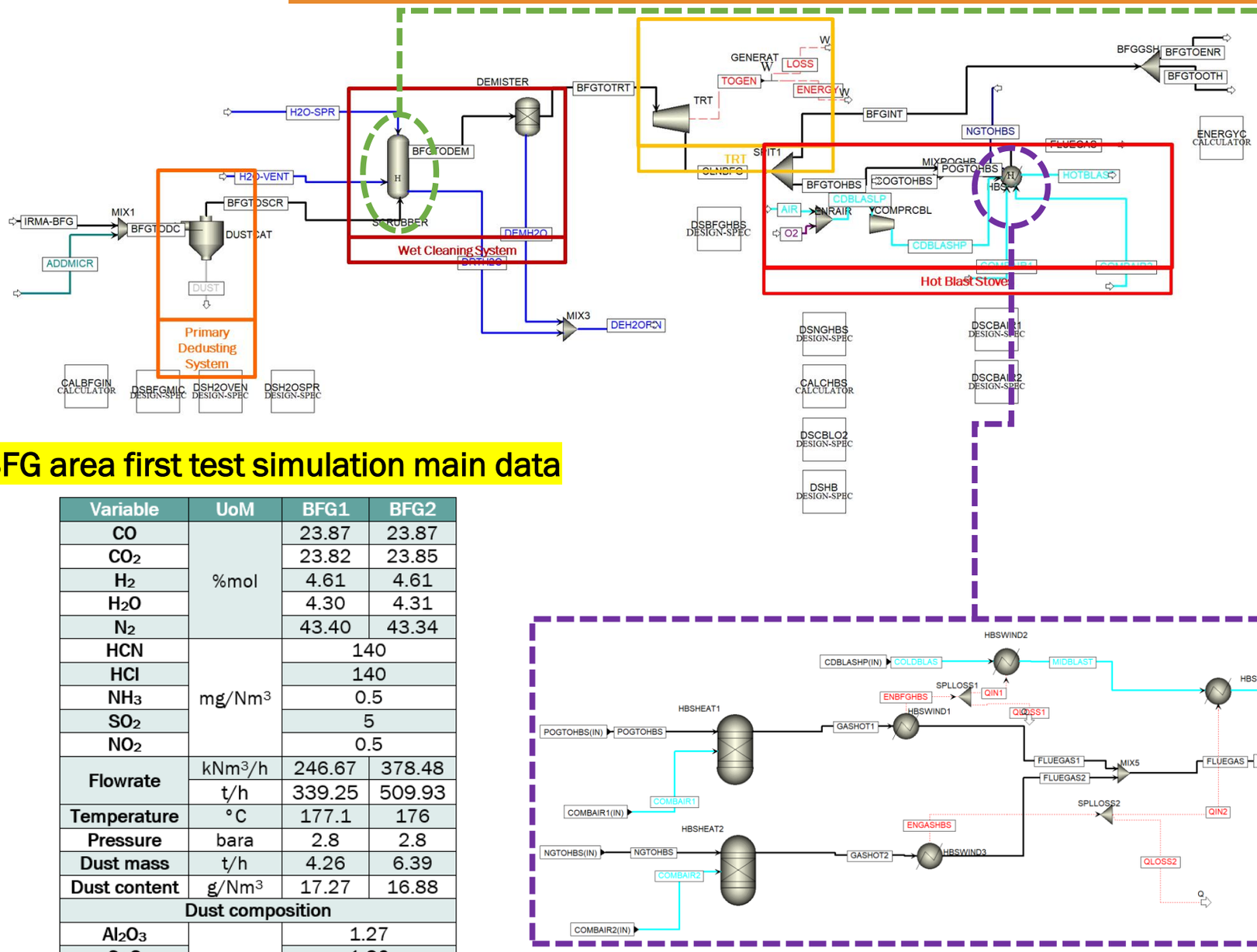
BFG area model



BFG area first test simulation main data

Variable	UoM	BFG1	BFG2
CO	%mol	23.87	23.87
CO_2		23.82	23.85
H_2		4.61	4.61
H_2O		4.30	4.31
N_2		43.40	43.34
HCN	mg/Nm³	140	
HCl		140	
NH_3		0.5	
SO_2		5	
NO_2		0.5	
Flowrate	kNm³/h	246.67	378.48
	t/h	339.25	509.93
Temperature	°C	177.1	176
Pressure	bara	2.8	2.8
Dust mass	t/h	4.26	6.39
Dust content	g/Nm³	17.27	16.88
Dust composition			
Al_2O_3	%wt	1.27	
CaO		1.86	
C		52.81	
Fe_2O_3		15.14	
FeO		24.63	
H_2O		0.29	
MgO		0.59	
S		0.34	
SiO_2		2.27	
Other		0.8	

Data are referred to a European integrated standardized steel mill (EU SSM) with 4 Mt_{HRC}pa capacity

Main outputs of BFG area model

Variable	UoM	BFG1	BFG2
Hot Blast			
Flowrate	t/h	189.29	289.30
Temperature	°C	1141	1141
Pressure	bara	4.4	4.4
N_2	%mol	70.76	70.76
O_2		28.00	28.00
CO_2		0.04	0.04
H_2O		1.20	1.20
BFG			
To HBS	%	21.90	21.98
	kNm³/h	52.11	79.58
	t/h	71.46	109.16
	GJ/h	191.21	292.10
To M&ES	%	73.02	72.95
	kNm³/h	173.73	264.14
	t/h	238.25	362.29
	GJ/h	637.48	969.51
Excess BFG	%	5.08	5.07
	kNm³/h	12.08	18.36
	t/h	16.56	25.19
	GJ/h	44.32	67.40
Flue Gas			
Flowrate	kNm³/h	112.37	171.72
	t/h	157.31	240.41
CO_2	%mol	24.41	24.42
CO		0.18	0.18
H_2O		6.81	6.82
N_2		66.30	66.28
O_2		1.78	1.78
NO	mg/Nm³	1242.27	1243.61
NO_2		1.52	1.52

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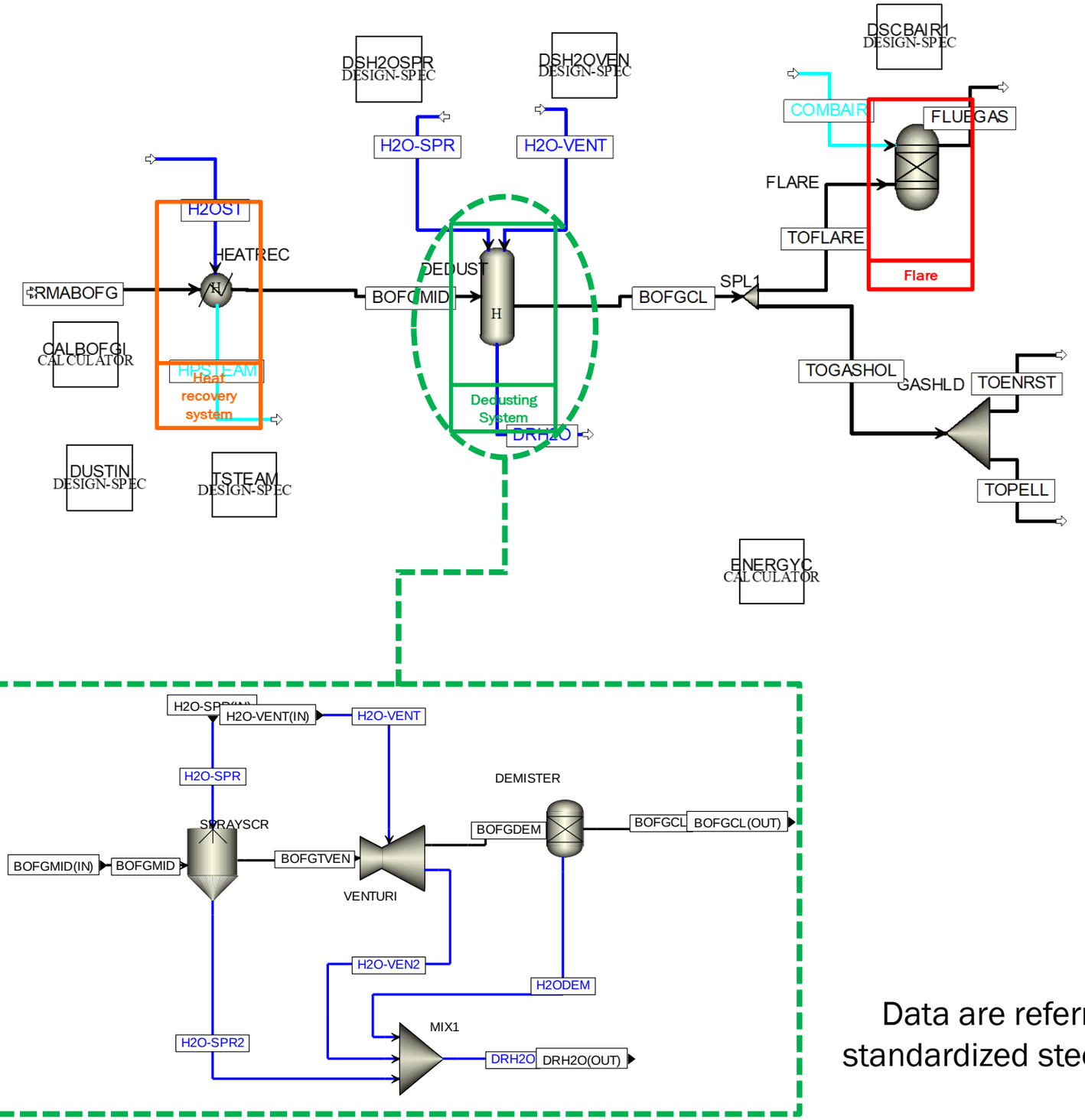
BOFG area model



BOFG area first test simulation main data

Variable	UoM	BOFG
CO	%mol	64.18
CO_2		14.27
H_2		3.39
O_2		0.59
N_2		17.58
Flowrate	kNm^3/h	42.63
	t/h	55.99
Temperature	°C	1650
Pressure	bara	1
Dust mass	t/h	3197.25
Dust content	g/Nm^3	75
Dust Composition		
Al_2O_3	%wt	3.8
CaO		1.1
Fe_2O_3		9.4
FeO		49.3
S		0.13
SiO_2		1.6
Fe		11.6
$CaCO_3$		23.2
Dust PSD		
0-0.5 µm	%wt	22
0.5-1 µm		16
1-3 µm		23
3-6 µm		16
6-10 µm		12
10-15 µm		11

Main outputs of BOFG area model

Variable	UoM	BOFG
Flowrate	kNm^3/h	42.80
	t/h	56.12
CO	%mol	63.93
CO_2		14.21
H_2		3.38
H_2O		0.38
N_2		17.51
O_2		0.59
BOFG Distribution		
To M&ES	%	79.79
	kNm^3/h	34.15
	t/h	44.78
	GJ/h	287.84
To Pellet Plant	%	20.21
	kNm^3/h	8.65
	t/h	11.34
	GJ/h	72.91

Data are referred to a European integrated standardized steel mill (EU SSM) with 4 $Mt_{HRC}pa$ capacity

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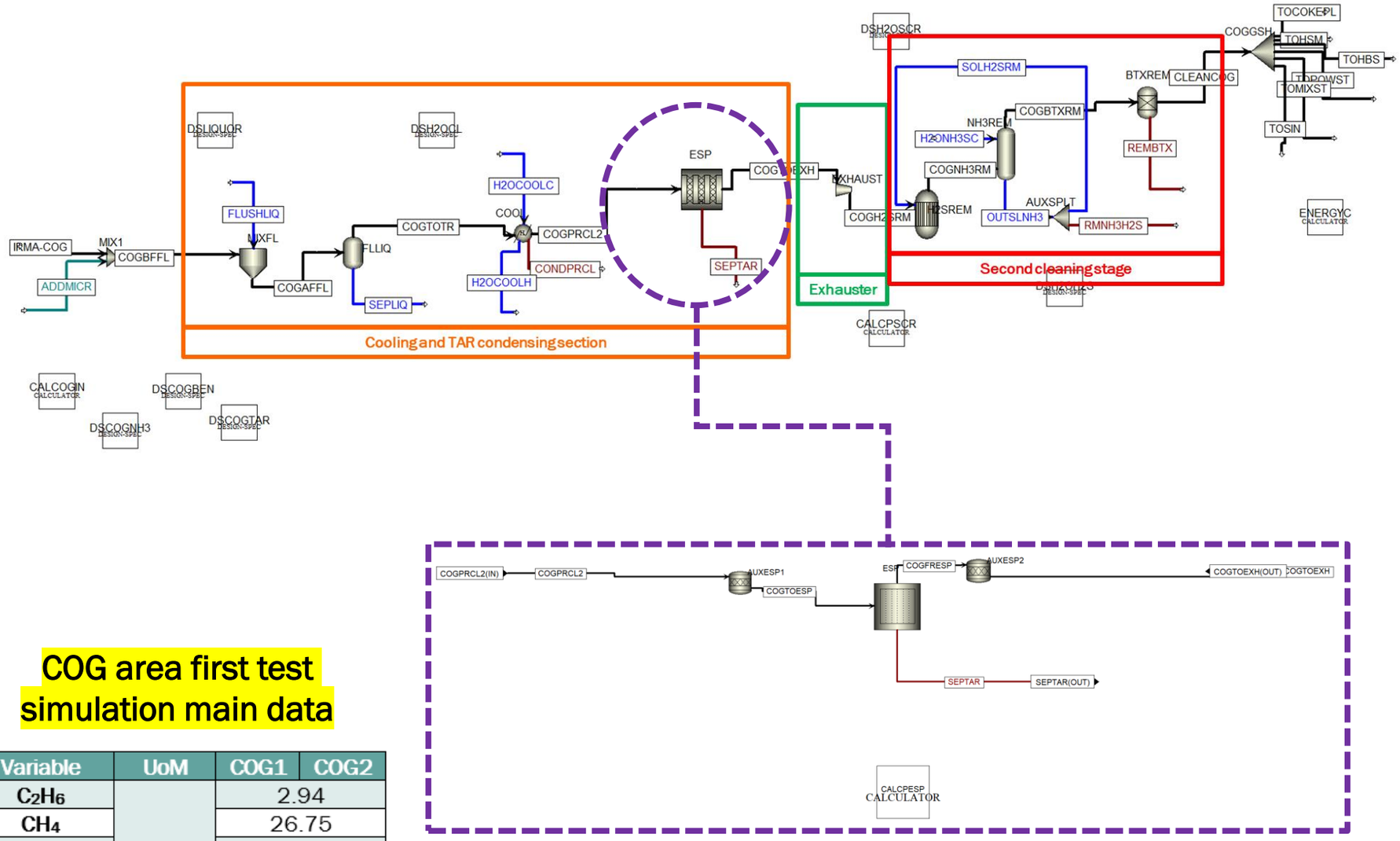
COG area model



COG area first test simulation main data

Variable	UoM	COG1	COG2
C_2H_6	%mol	2.94	
CH_4		26.75	
CO		4.43	
CO_2		0.04	
H_2		65.34	
N_2		18.55	
Flowrate	kNm³/h	21.66	33.16
	t/h	7.60	11.64
Temperature	°C	1100	
Pressure	bara	1	

Main outputs of COG area model

Variable	UoM	COG1	COG2
Flowrate	kNm³/h	22.35	34.24
	t/h	8.26	12.63
C_2H_6	%mol	2.86	2.85
CH_4		25.95	25.96
CO		4.30	4.30
CO_2		0.04	0.04
H_2		63.39	63.38
H_2O		2.78	2.79
N_2		0.18	0.18
COG Distribution			
To Coke Plant	%	25	
	kNm³/h	5.59	8.56
	t/h	2.06	3.16
	GJ/h	105.36	161.30
To Hot Rolling Mill	%	51	
	kNm³/h	11.40	17.46
	t/h	4.21	6.44
	GJ/h	214.94	329.05
To HBS	%	18	
	kNm³/h	4.02	6.16
	t/h	1.49	2.27
	GJ/h	75.86	116.14
To Power Station	%	0	
	kNm³/h	0	
	t/h	0	
	GJ/h	0	
To M&ES	%	3	
	kNm³/h	0.67	1.03
	t/h	0.25	0.38
	GJ/h	12.64	19.36
To Sinter Plant	%	3	
	kNm³/h	0.67	1.03
	t/h	0.25	0.38
	GJ/h	12.64	19.36

Data are referred to a European integrated standardized steel mill (EU SSM) with 4 $Mt_{HRC}pa$ capacity

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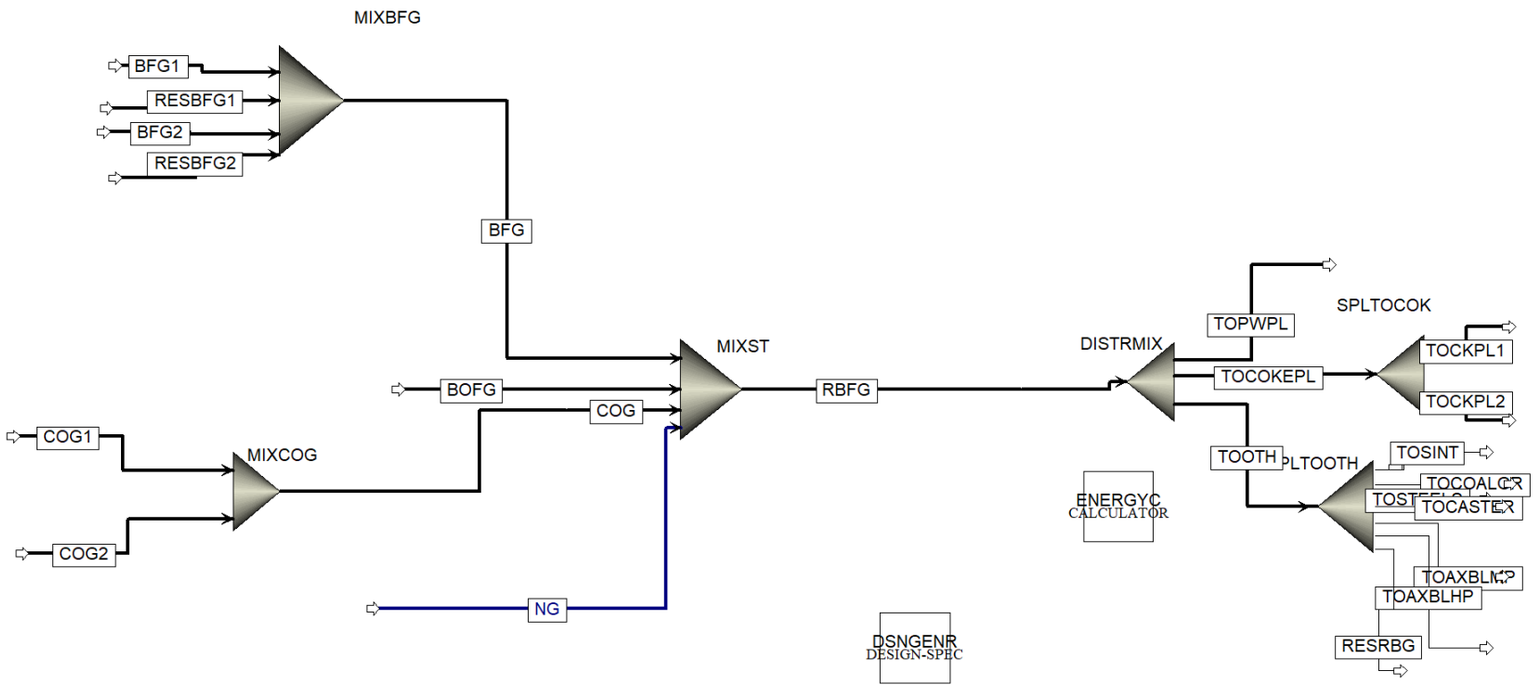
Mixing and Enrichment Station



Simulated rBFG distribution

User	UoM	rBFG
Power Plant	%	65.00
	kNm³/h	327.70
	t/h	446.99
	GJ/h	1324.55
Coke Plant 1	%	5.54
	kNm³/h	27.92
	t/h	38.08
	GJ/h	112.84
Coke Plant 2	%	8.39
	kNm³/h	42.31
	t/h	57.71
	GJ/h	171.00
Sinter Plant	%	0.19
	kNm³/h	0.94
	t/h	1.28
	GJ/h	3.80
Coal Grinding Line	%	1.38
	kNm³/h	6.95
	t/h	9.47
	GJ/h	28.10
Steelshop	%	2.83
	kNm³/h	14.25
	t/h	19.44
	GJ/h	57.60
Caster	%	0.30
	kNm³/h	1.51
	t/h	2.06
	GJ/h	6.10
Auxiliary Boiler (MP steam)	%	22.15
	kNm³/h	11.16
	t/h	15.23
	GJ/h	45.13
Auxiliary Boiler (HP steam)	%	0
	kNm³/h	0
	t/h	0
	GJ/h	0
Residual rBFG	%	14.16
	kNm³/h	71.41
	t/h	97.41
	GJ/h	288.65

Data are referred to a European integrated standardized steel mill (EU SSM) with 4 Mt_{HRC}pa capacity

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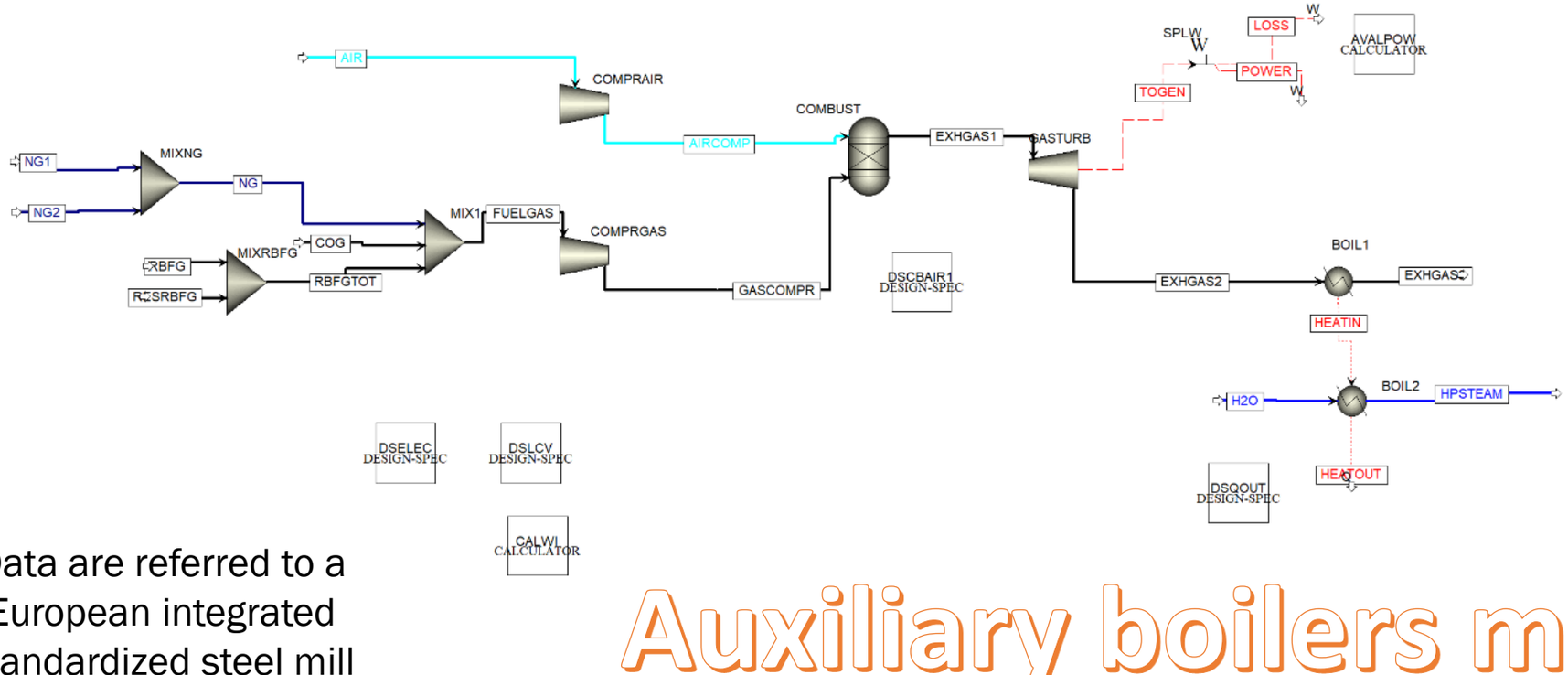
Power Plant & Auxiliary boilers models

Power Plant model

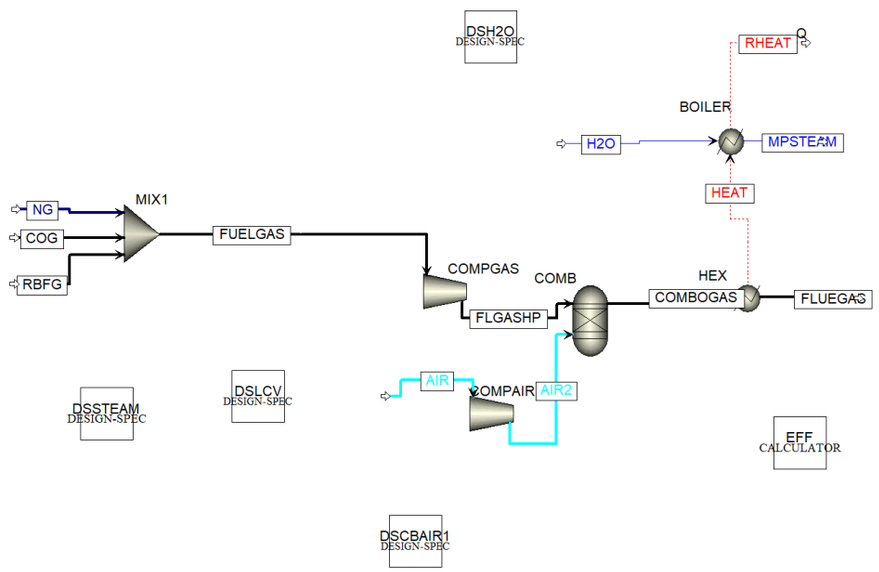


Main inputs and outputs of Power plant model

Variable	UoM	Value
rBFG	kNm³/h	399.11
	t/h	544.18
NG	kNm³/h	1.14
	t/h	0.88
Fuel Gas WI	MJ/Nm³	4.38
Produced electric power	MW	129.82
Produced HP steam	t/h	351.74

Auxiliary boilers model

European integrated standardized steel mill (EU SSM) with 4 $Mt_{HRC}pa$ capacity



MP steam of 15.3 t/h is produced by using an amount of 11.16 kNm^3/h (152.15 t/h) of rBFG.

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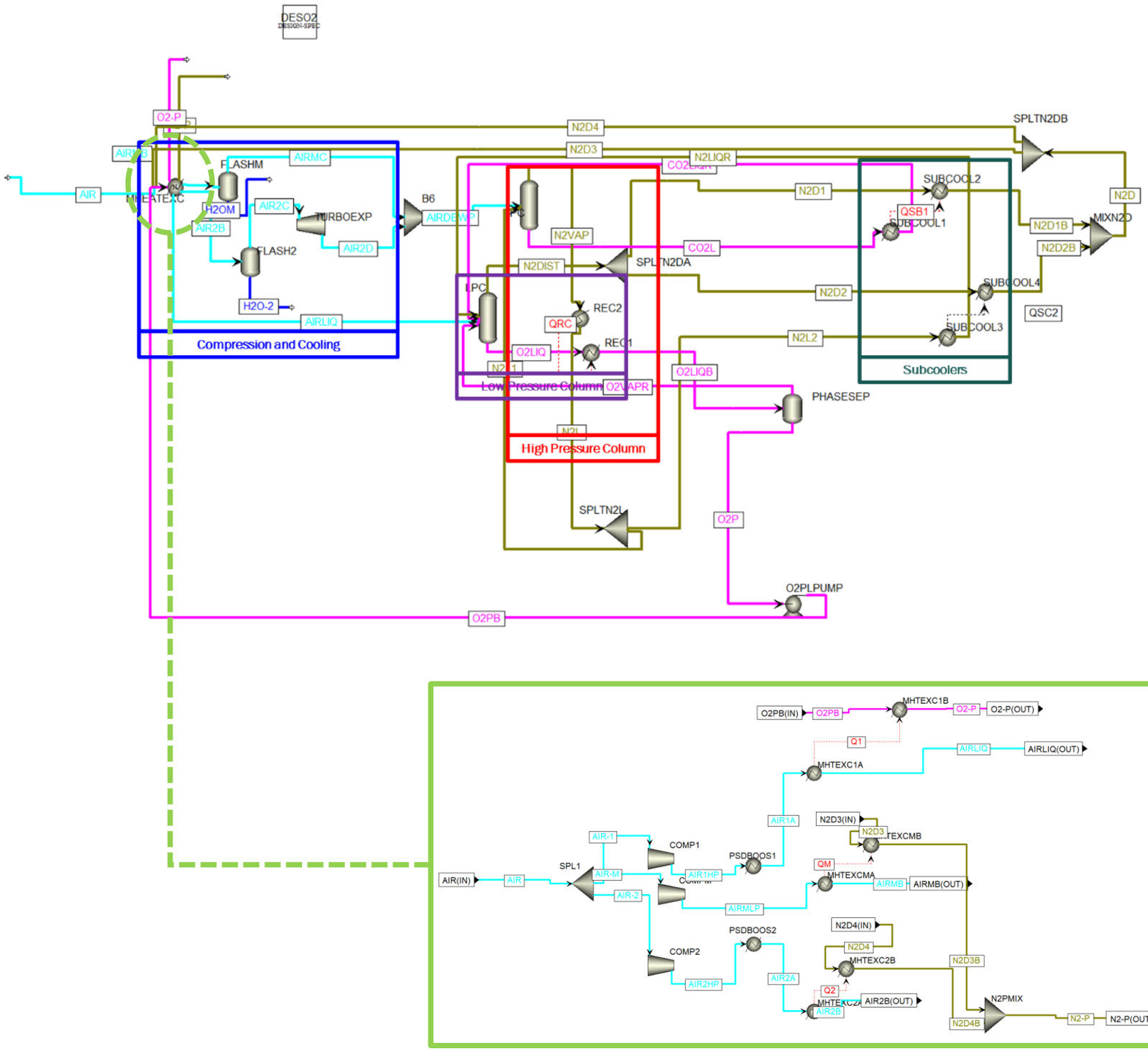
ASU model



Main outputs of ASU model

Variable	UoM	Value
O_2	kNm³/h	57.34
	t/h	81.15
	%mol (purity)	95.64
N_2	kNm³/h	210.26
	t/h	262.95
	%mol (purity)	99.57

Data are referred to a European integrated standardized steel mill (EU SSM) with 4 Mt_{HRC}pa capacity

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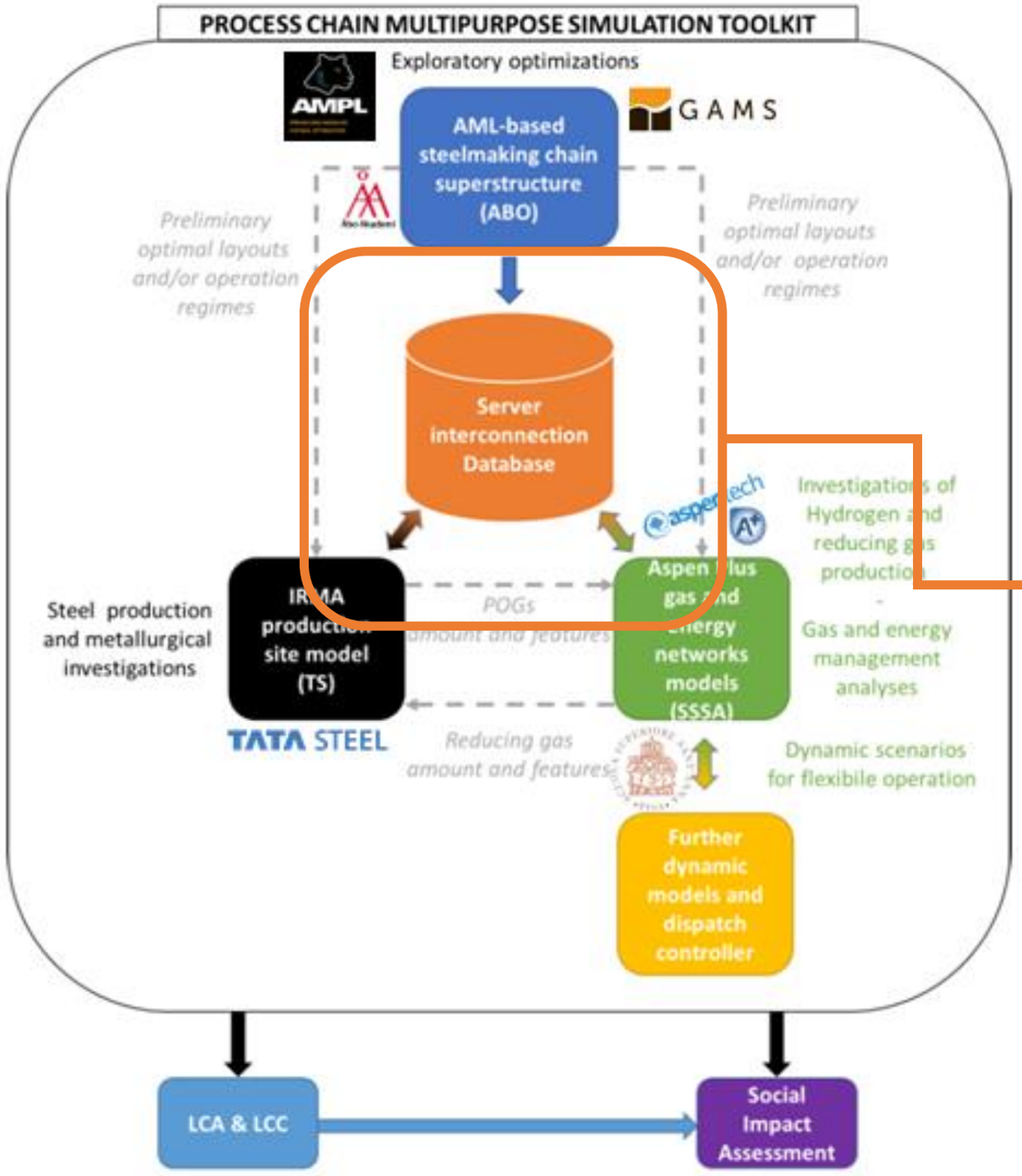
Server interconnection Database



- **Complex IT architecture for allowing the connection of the energy network models to upstream process models or directly to plant/pilots**:
  - Receiving data
  - Using data
  - Making automatic investigations
- It includes:
  - **Dedicated PostgreSQL relational database**
  - **Stored procedures**
  - **Further methods**

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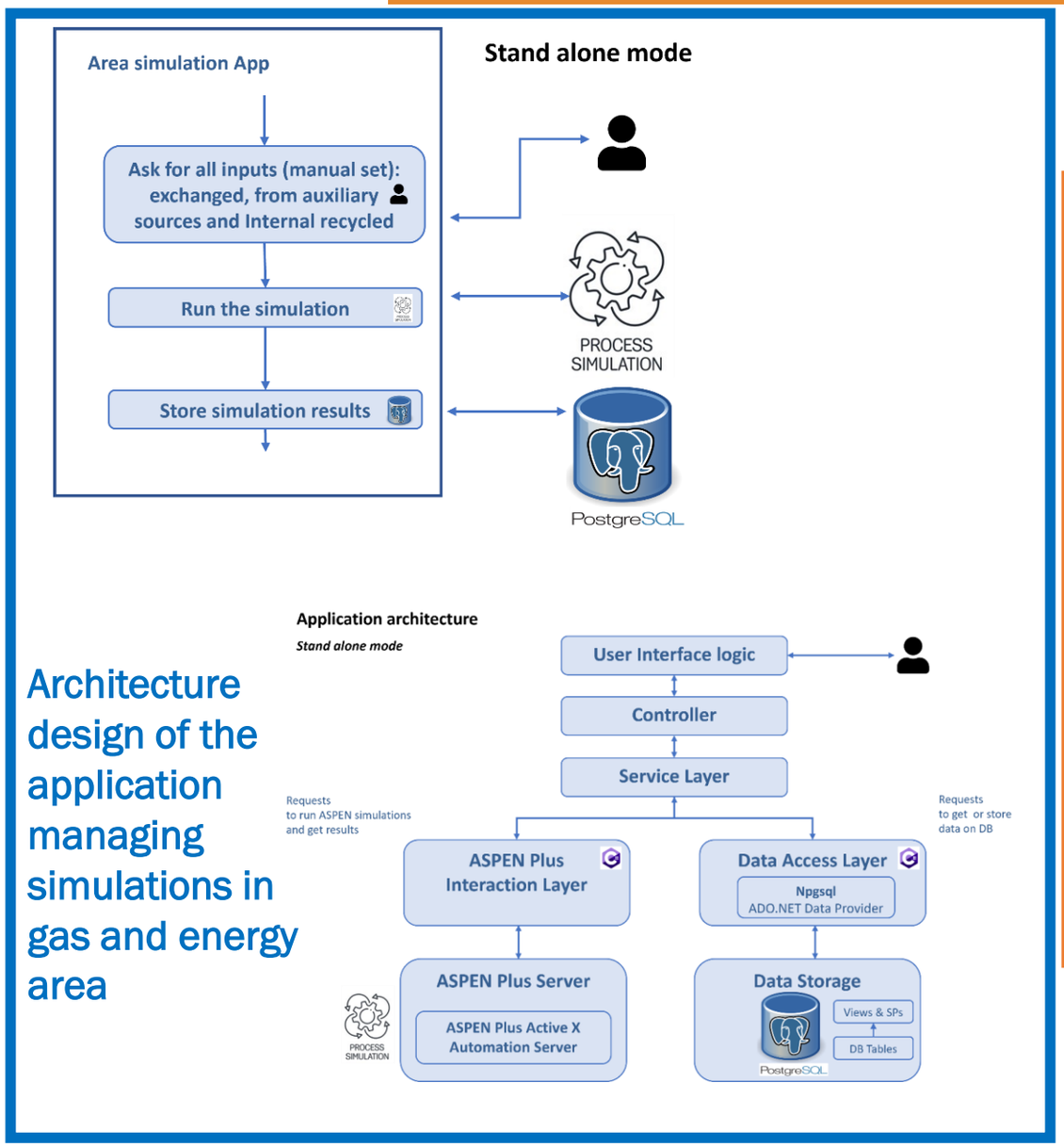
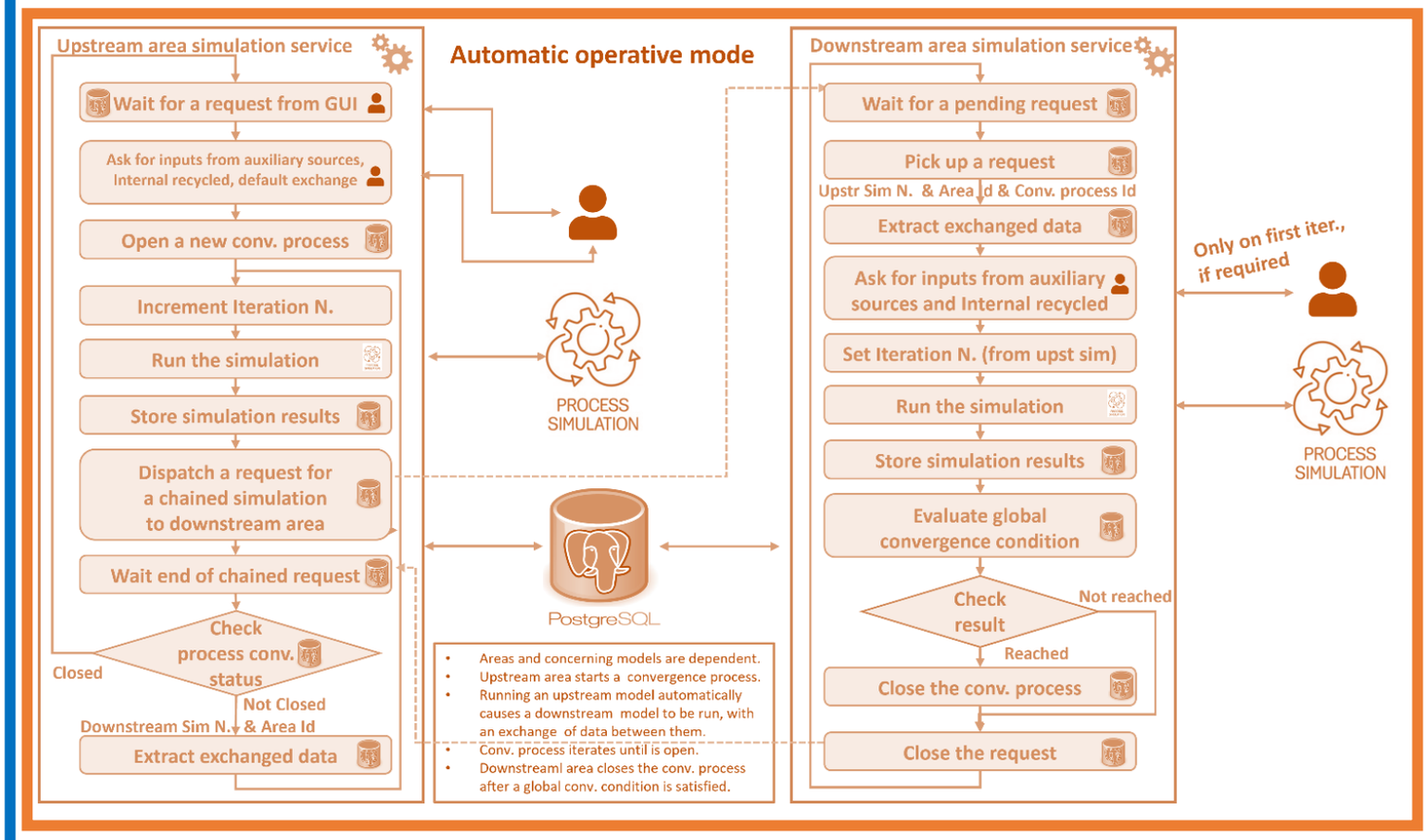
Server interconnection Database



Architecture design of the application managing simulations in gas and energy area



Two modes of operation of the system are envisaged:

- **stand-alone mode** → each model is considered as independent
  - Possibility to use user settled data or real industrial data
- **automatic mode** → the different area models are dependent and connected within a global process

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Models interaction

Correct interaction between process models and gas and energy network models have been demonstrated through the right satisfaction of balances and heat and energy demands

User	Heat Demand by gas	Gas distribution				
	GJ/h	BFG	rBFG	BOFG	COG	NG
		GJ/h (t/h)				
Coke Plant 1	218.20		112.84 (38.08)		105.36 (2.06)	
Coke Plant 2	332.30		171.00 (57.71)		161.30 (3.16)	
Sinter Plant	35.80		3.80 (1.28)		32 (0.63)	
Pellet Plant	72.90			72.91 (11.34)		
Coal Grinding Line	28.10		28.10 (9.47)			
Blast Furnace 1 (for HBS)	267.07	191.21 (71.46)			75.86 (1.49)	
Blast Furnace 2 (for HBS)	408.24	292.10 (109.16)			116.14 (2.27)	
Steelmaking Shop	57.60		57.60 (19.44)			
Casters	6.10		6.10 (2.06)			
Hot Rolling Mill	630.10				543.99 (10.65)	86.11 (1.86)
Power Plant	1653.94		1613.2 (544.4)			40.74 (0.88)
Auxiliary Boilers (MP+HP)	45.13		45.13 (15.23)			

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Models interaction

Correct interaction between process models and gas and energy network models have been demonstrated through the right satisfaction of balances and heat and energy demands

User	Electricity Demand	Total Electricity Demand	Electricity distribution		
	GJ/h		Power Plant	TRT	External Grid
			GJ/h (%)		
Coke Plant 1 + exhauster	10.70+0.83	542.51	467.34 (86.14)	28.08 (5.17)	45.98 (8.69)
Coke Plant 2 + exhauster	16.30 + 1.27				
Sinter Plant	59.20				
Pellet Plant	19.90				
Coal Grinding Line	10.80				
Blast Furnace 1 (cold blast compressor)	33.42				
Blast Furnace 2 (cold blast compressor)	51.07				
Steelmaking Shop	63.90				
Casters	21.10				
Hot Rolling Mill	141.41				
Auxiliary Boilers (MP+HP)	0.73				
ASU	111.880				

User	Steam Demand		Total Steam Demand		Steam Distribution	
	HP	MP	HP	MP	HP	MP
	t/h				BOFG Area + Power Plant + Auxiliary Boilers	Auxiliary Boiler
					t/h (t/h of residual steam)	
Coke Plant 1	4.2	0	10.7	15.3	10.7 (361.07)	15.3
Coke Plant 2	6.5	0				
Sinter Plant	0	0.7				
Pellet Plant	0	0.2				
Coal Grinding Line	0	0				
Blast Furnace 1	0	1.0				
Blast Furnace 2	0	1.6				
Steelmaking Shop	0	8.6				
Casters	0	0.5				
Hot Rolling Mill	0	2.7				

User	Demand		Total Demand		Distribution	
	O_2	N_2	O_2	N_2	O_2 (from ASU)	N_2 (from ASU)
	t/h				t/h (t/h of residual)	
Coal Grinding Line		3.40			81.15 (0)	3.80 (259.15)
Blast Furnace 1 (for cold blast O_2 enrichment)	20.39					
Blast Furnace 2 (for cold blast O_2 enrichment)	31.16					
Steelmaking Shop	29.60	0.20				
Hot Rolling Mill		0.20				

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Conclusions & Ongoing Work

- The transition towards H_2-DRI-based steelmaking requires closing the current knowledge gaps existing from the particle to the process chain scales
- Concerning process chain scale, modifications in process route can be translated in significant changes in energy streams managements
- During MaxH_2DR EU project, among the other activities of providing a hybrid demonstrator, a process chain digital toolkit including models for simulating gas, steam and all the energy streams management area is under development
- Models of units related to the management of gas, steam and energy streams in standard steelworks have been developed, showed and its interaction with process model demonstrated as starting point and reference for transitions simulations
- A complex IT asrchitecture has been developed for using the gas and energy network models linked to process chain models or by using directly plant data and allowing stand-alone or automatic modes
- Other models are under developments for considering new units for allowing the simulations of transition steps starting from standard integrated route, passing from mixed/hybrid route (BF/BOF+CH_4/H_2-DRI/EAF) and achieving full H_2-DRI steelmaking

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