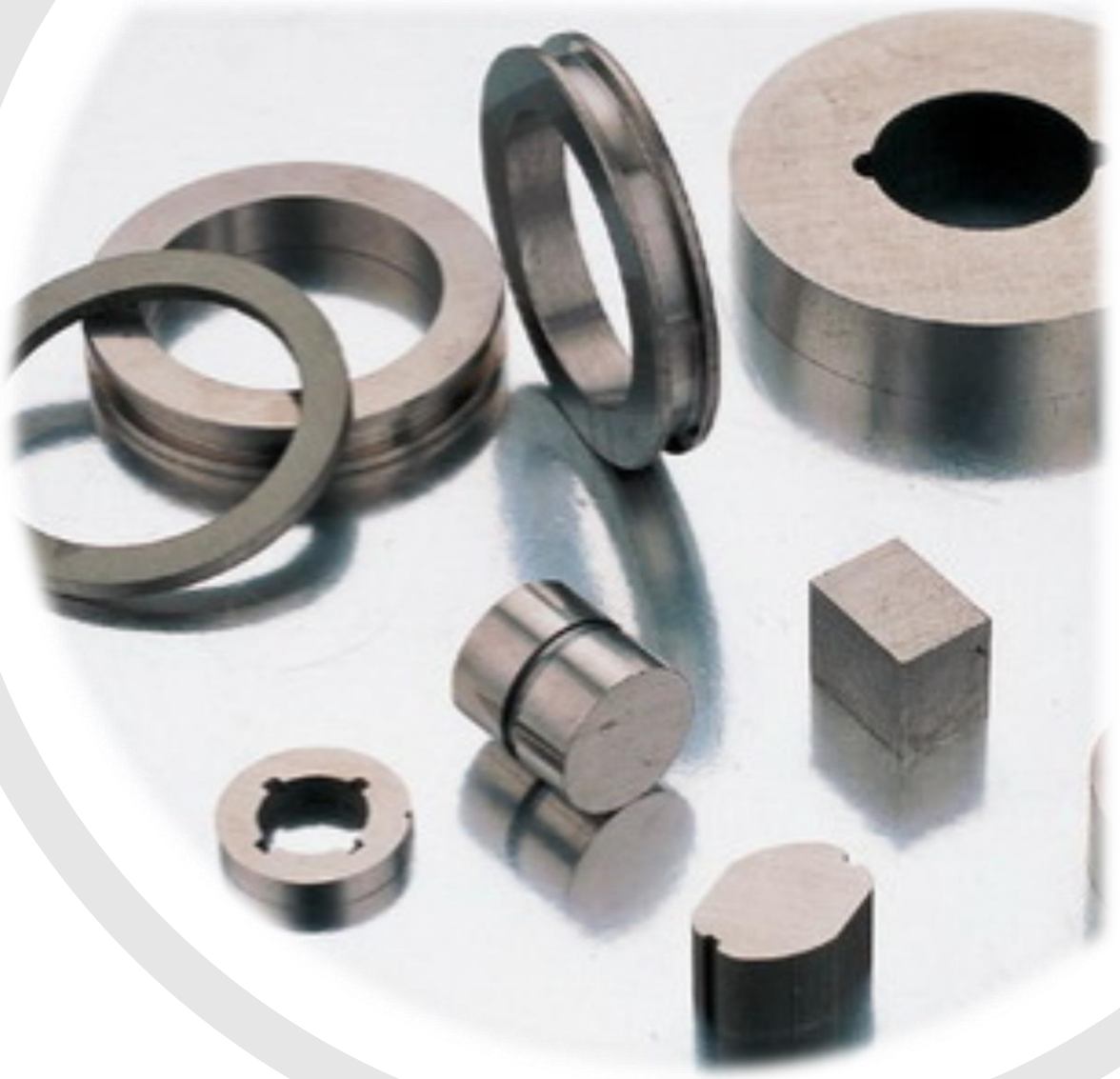
eit RawMaterials
Connecting matters

VALOMAG

2nd Seminar – Delft, the 6th December 2022

Mass and energy flow analysis



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Co-funded by the European Union

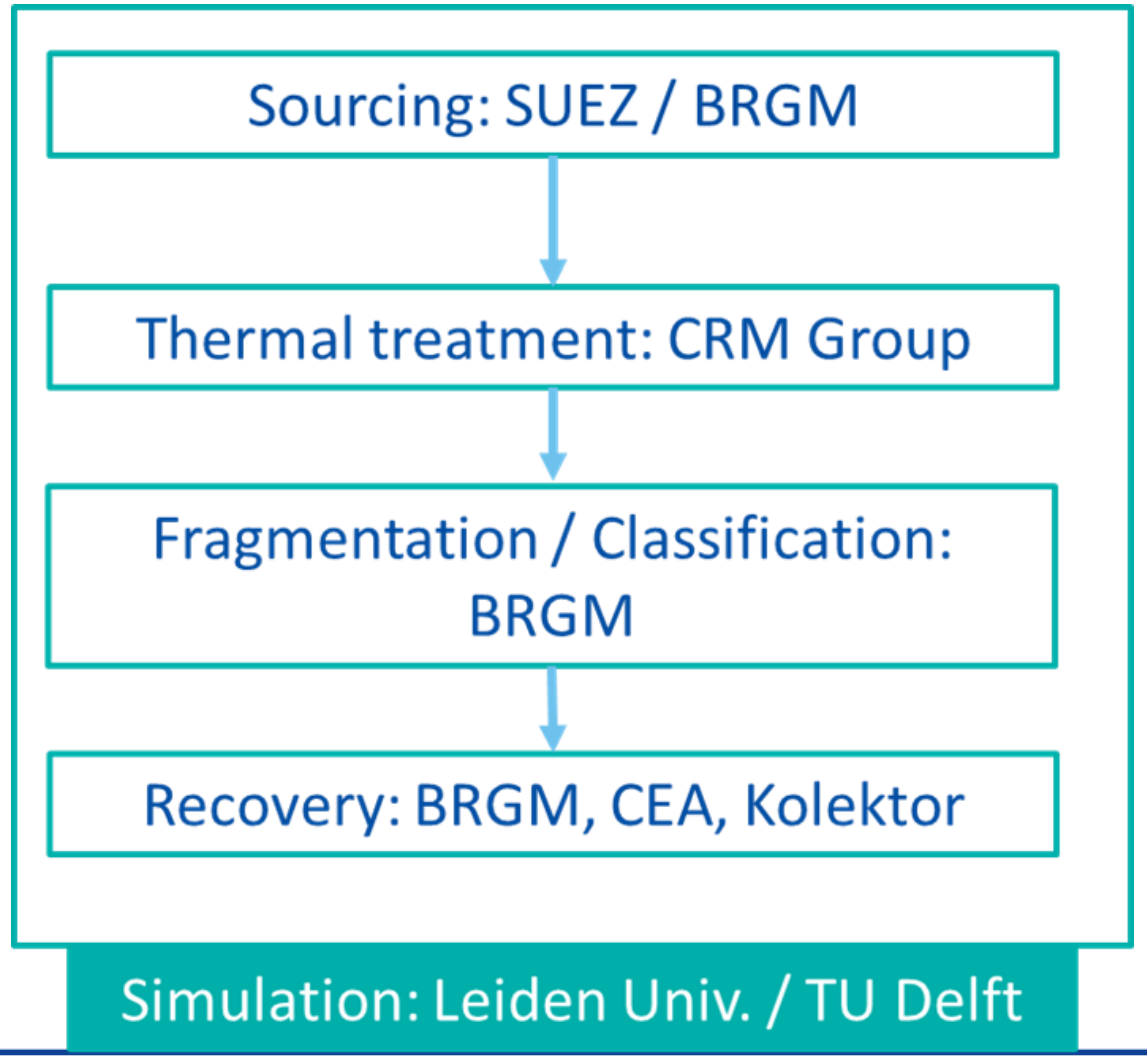
TU Delft

SUMMARY

1. Task of WP5
2. General VALOMAG Process Chart
3. Classification of magnet scrap
4. HSC software
5. Flowsheet integration
6. Strip casting for magnet production
7. Hydrometallurgical route
8. Conclusion

WP5 - PROCESS INTEGRATION AND LIFE CYCLE ASSESSMENT

- Task 5.4: Process integration and value chain analysis (M01- M36)
  - Subtask 5.4.1: Process integration with flowsheet simulation



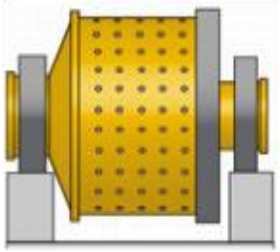
PROCESS CHART VALOMAG PROJECT

Collection
(SUEZ)

Manual
dismantling
(SUEZ)

Sorted HDD
(SUEZ)

Demagnetisation
(CRM)



Fragmentation and
classification
(BRGM)

High grade NdFeB
fraction

Low grade NdFeB
fraction

MAGNET SCRAP CLASSIFICATION

Direct recycling

High grade NdFeB fraction

Hydrogen Decrepitation / HDDR (CEA)

NdFeB Alloy

HDDR NdFeB Powder

Sintered Magnets (CEA)

Bonded Magnets (Kolektor)

Indirect recycling

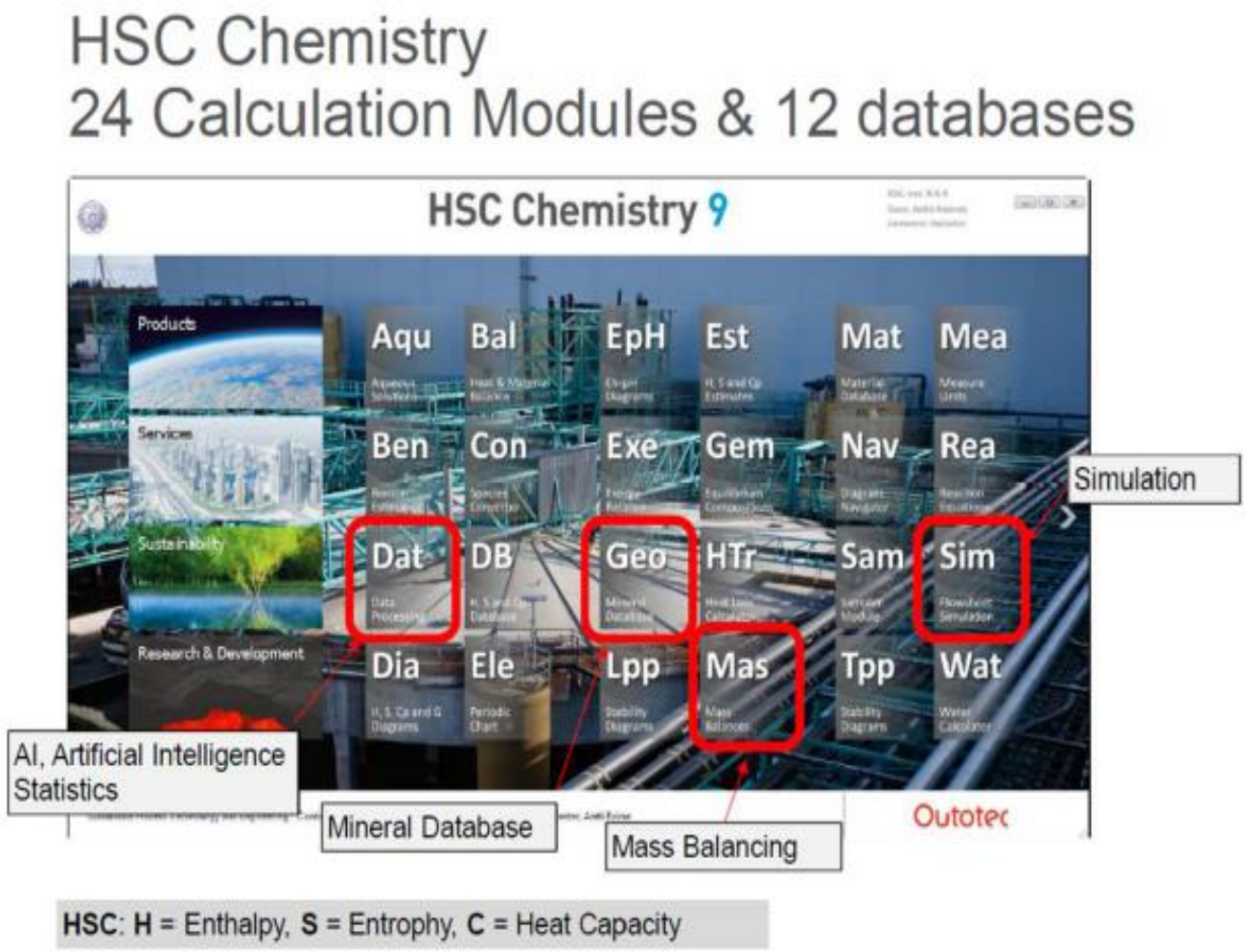
Low grade NdFeB fraction

Hydrometallurgy (BRGM)

REE oxide

WHY FLOWSHEET INTEGRATION?

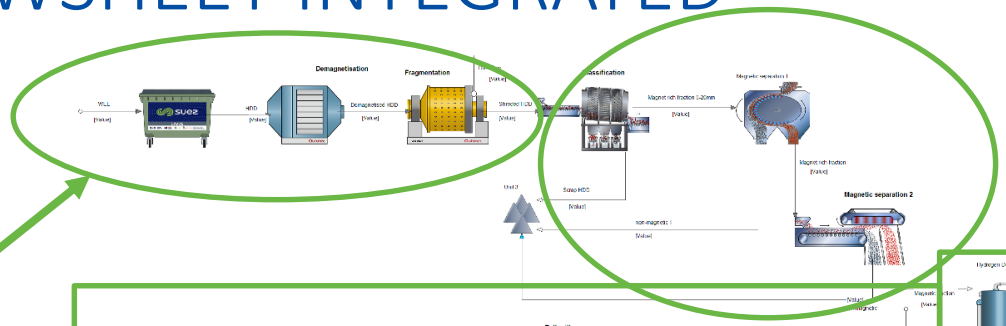
- Connecting different unit operations: whole value chain approach
- Mass and energy balance
- Process efficiency analysis
- Process cost/economic analysis
- Environmental analysis (support to LCA)

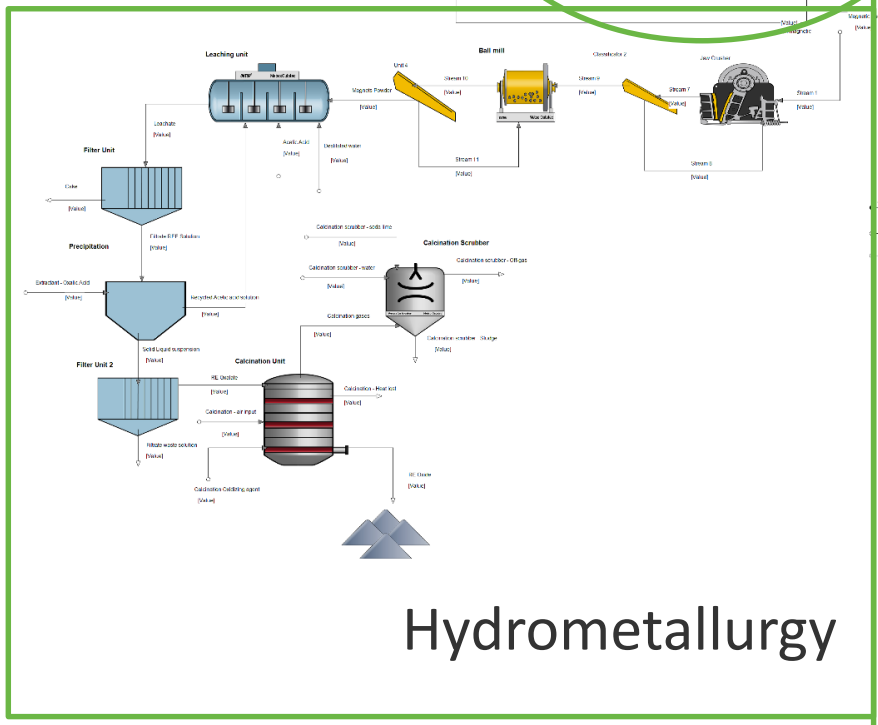


VALOMAG FLOWSHEET INTEGRATED

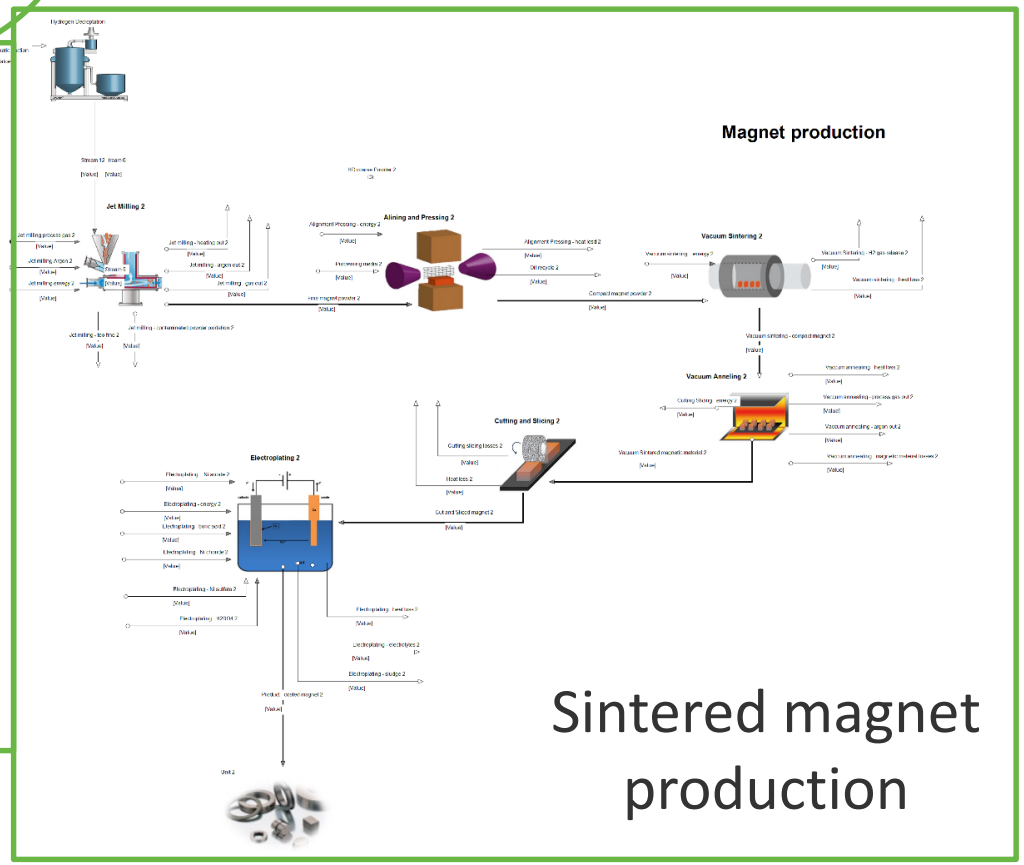
Classification of magnet scrap

Collection and pre-treatment



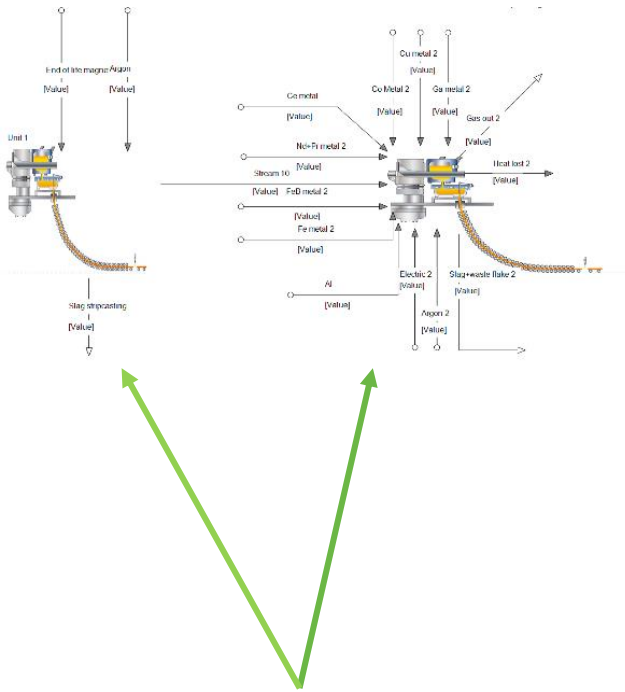


Hydrometallurgy



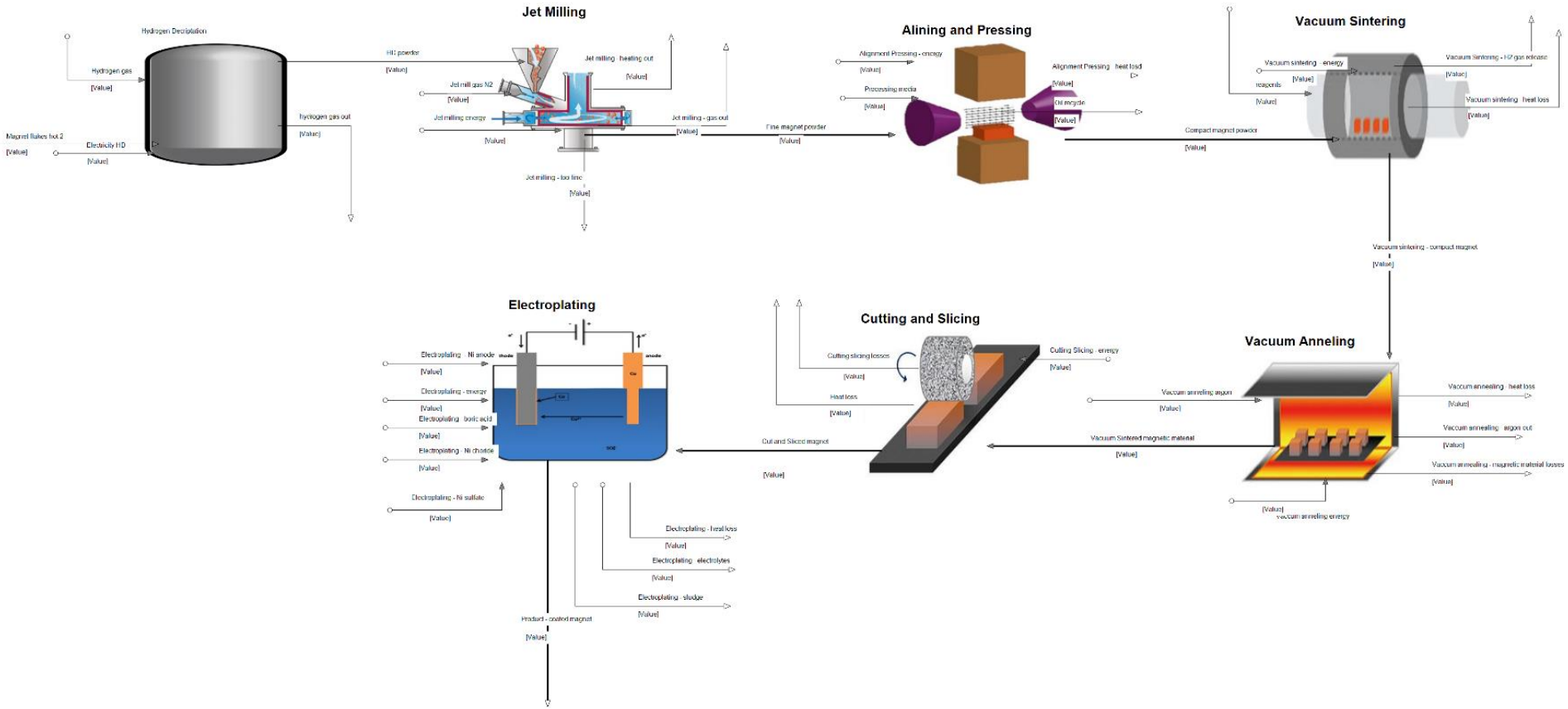
Sintered magnet production

STRIP CASTING FOR MAGNET MANUFACTURING

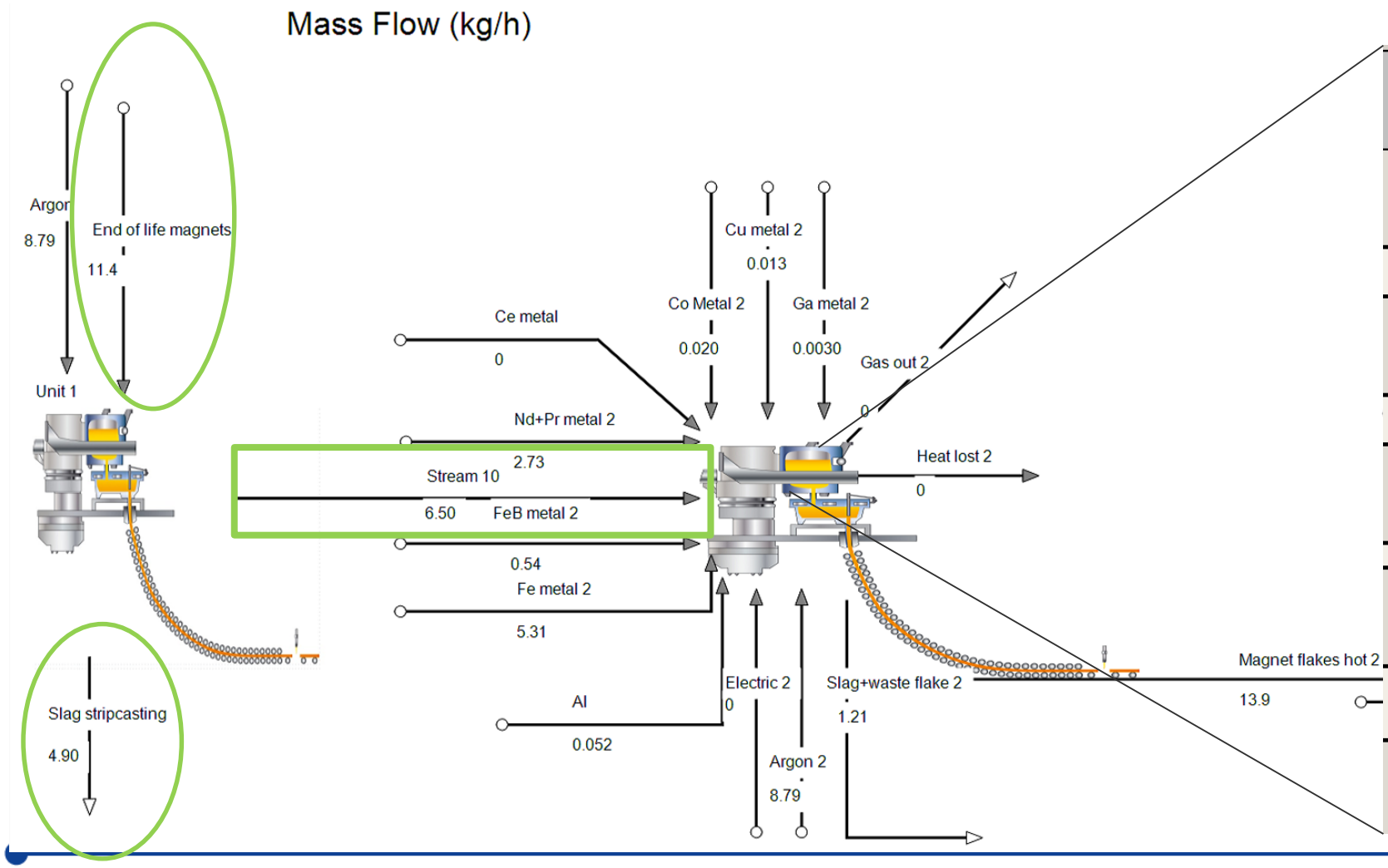


2 strip casting units

Hydrogen Decriptation



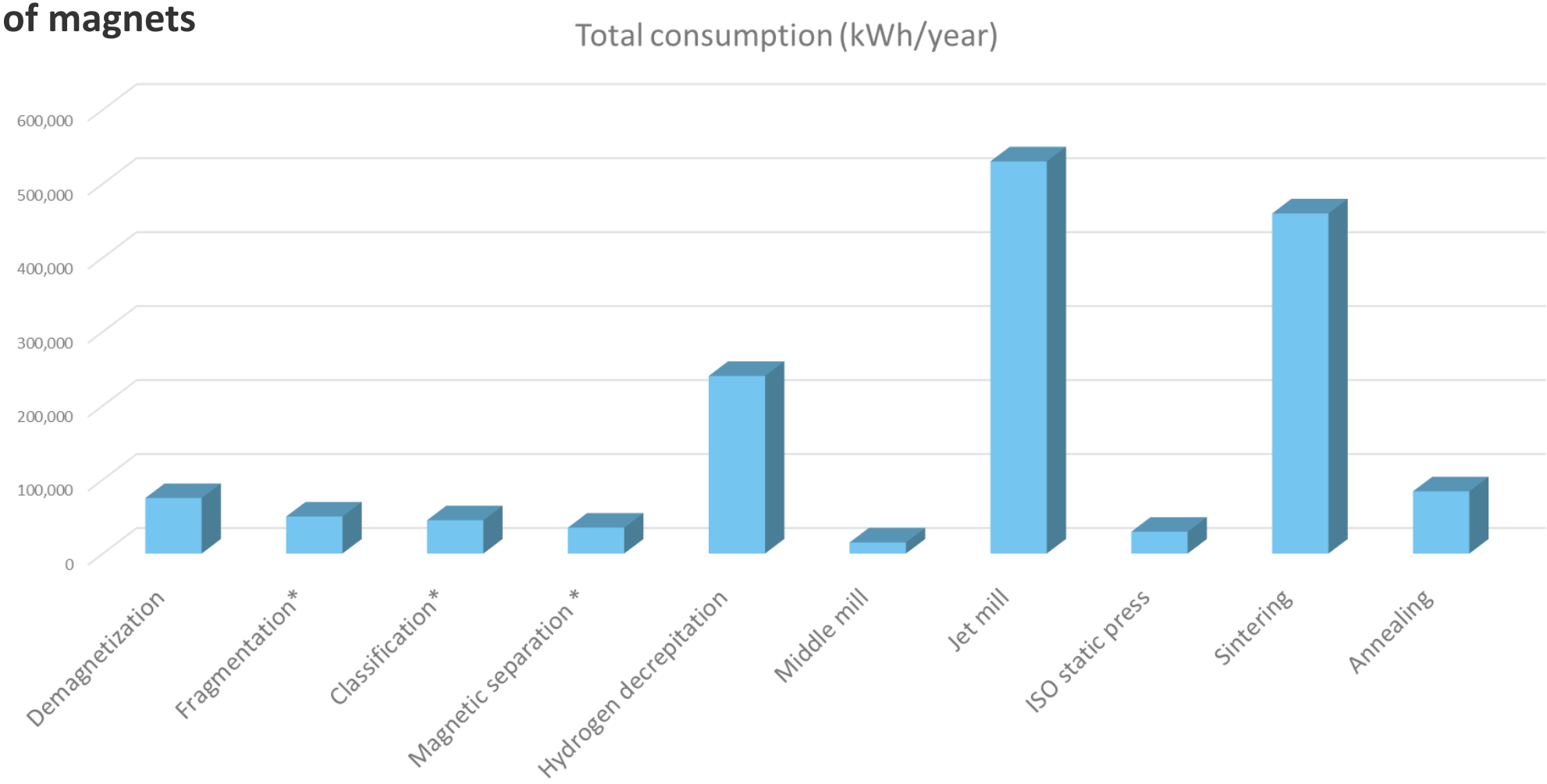
STRIP CASTING FOR MAGNET MANUFACTURING



Input streams	Value	Units	Flow Rates kg/h	Nm³/h	kmol/h	The kW
Total Gas Flow	5.00	Nm3/h				
Total Condensed Flow	0.02	t/h	23.96	5.00	0.50	
FeB metal 2	0.54	kg/h	Flow Rates			The
Temperature	25.00	°C	kg/h	Nm³/h	kmol/h	kW
Pressure	1.00	bar				
Total	100.00	wt-%	0.54	0.00	0.05	
B	100.00		0.54	0.00	0.05	
Fe metal 2	5.31	kg/h	Flow Rates			The
Temperature	25.00	°C	kg/h	Nm³/h	kmol/h	kW
Pressure	1.00	bar				
Total	100.00	wt-%	5.31	0.00	0.10	
Fe	100.00		5.31	0.00	0.10	
Ce metal	0.11	kg/h	Flow Rates			The
Temperature	25.00	°C	kg/h	Nm³/h	kmol/h	kW
Pressure	1.00	bar				
Total	0.00	wt-%	0.00	0.00	0.00	
Nd+Pr metal 2	2.73	kg/h	Flow Rates			The
Temperature	25.00	°C	kg/h	Nm³/h	kmol/h	kW
Pressure	1.00	bar				
Total	100.00	wt-%	2.73	0.00	0.02	
Nd	75.00		2.04	0.00	0.01	
Pr	25.00		0.68	0.00	0.00	
Cu metal 2	0.01	kg/h	Flow Rates			The
Temperature	25.00	°C	kg/h	Nm³/h	kmol/h	kW
Pressure	1.00	bar				
Total	100.00	wt-%	0.01	0.00	0.00	

ESTIMATED ENERGY CONSUMPTION - UPSCALE PROCESS

1000 ton of magnets



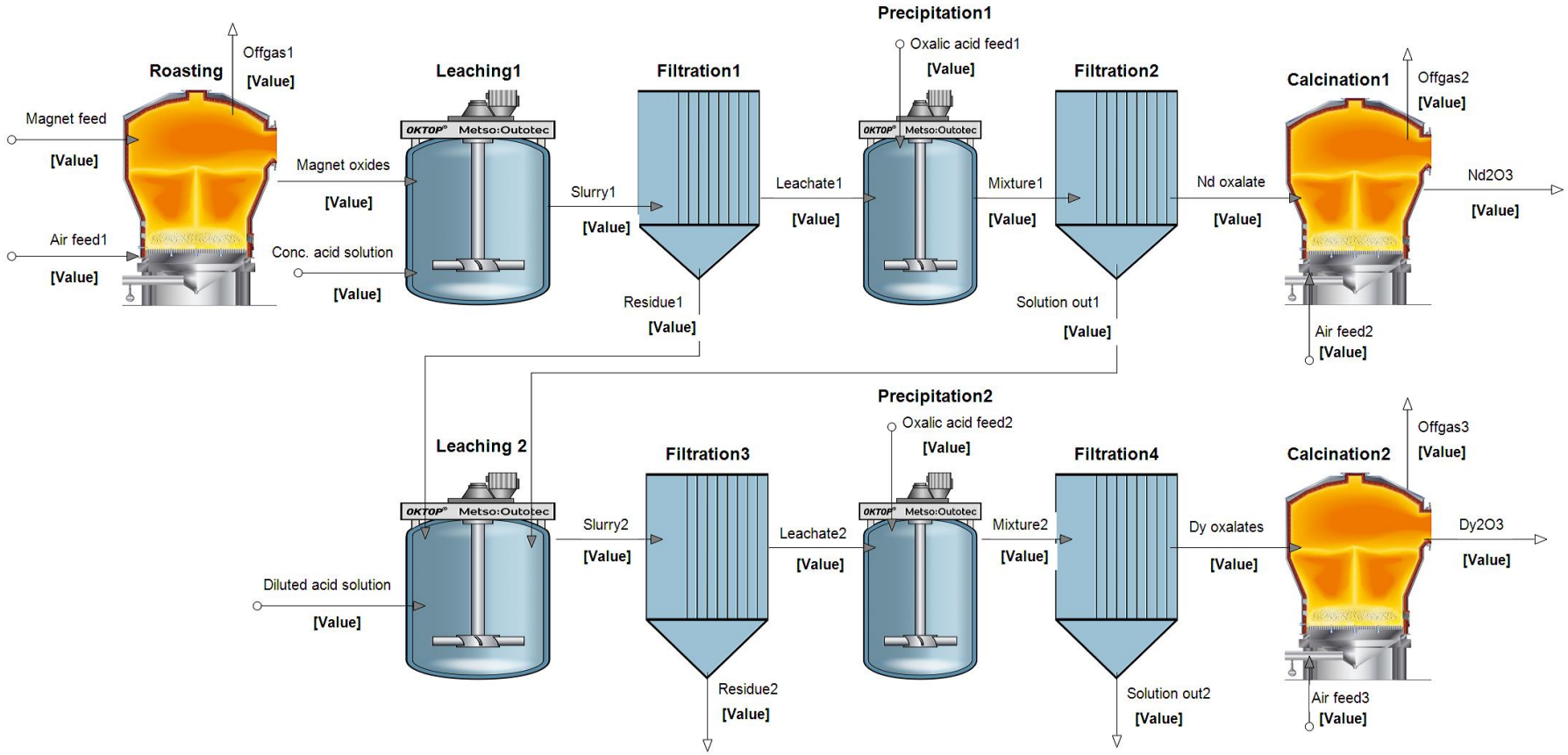
HYDROMETALLURGICAL ROUTE - GENERAL FLOWSHEET

Process' highlights

- Roasting of magnet powder
- Leaching with organic acid
  - Concentrated solution
  - Diluted solution
- Neodymium oxides
- Dysprosium oxides

- **Input parameters from BRGM**
  - Initial concentration
  - pH
  - Leaching temperature

Simplified BRGM flowsheet

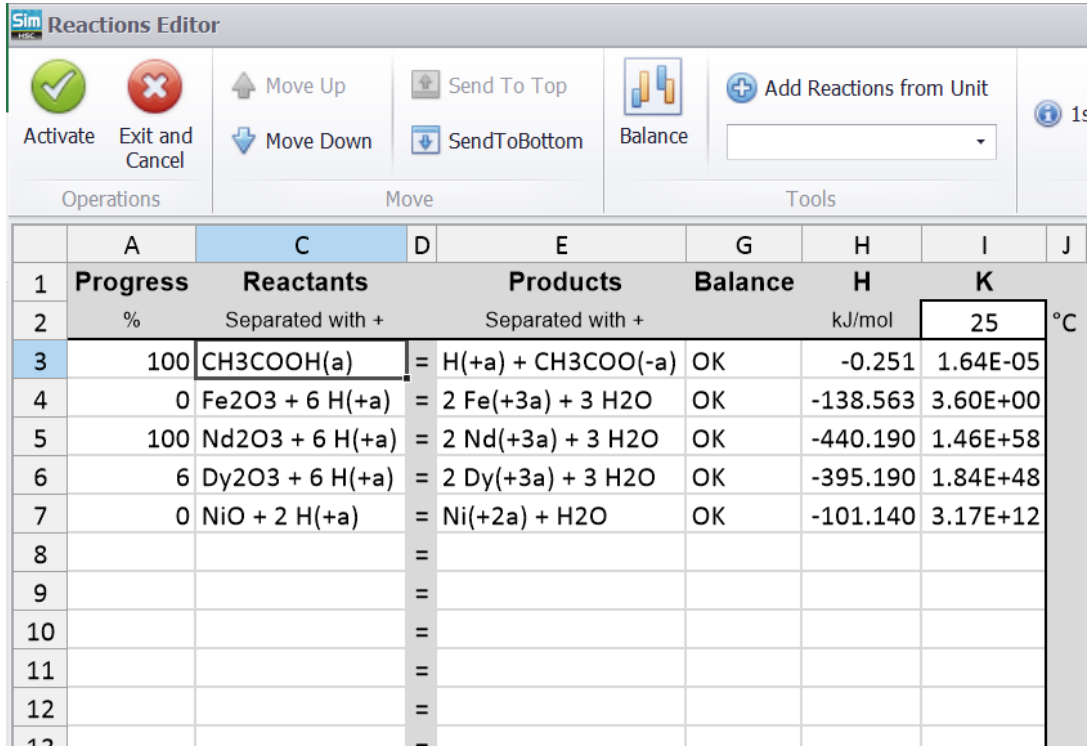


HYDROMETALLURGICAL ROUTE

Challenges on simulation

- Leaching behaviour of each element must be known
  - Assume all possible reactions
  - Determine the leaching efficiency
- Nd presents a high dissolution rate in concentrated acetic acid
- Dy shows a low leaching efficiency in high concentrated solution
- Fe and Ni do not dissolve in acetic acid

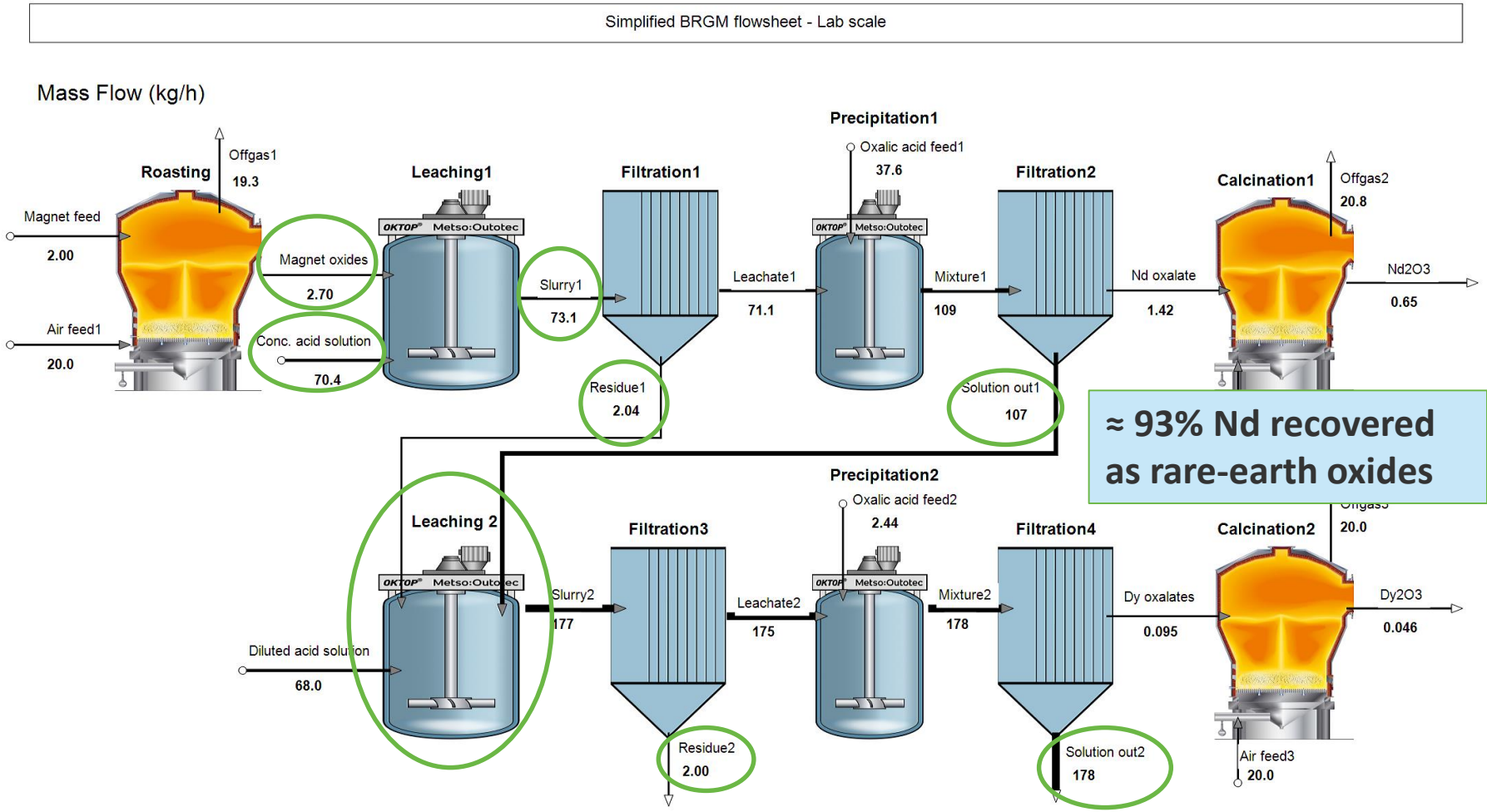
Example of HSC reactions interface



	A	C	D	E	G	H	I	J
1	**Progress**	**Reactants**		**Products**	**Balance**	**H**	**K**	
2	%	Separated with +		Separated with +		kJ/mol	25	°C
3	100	CH3COOH(a)	=	H(+a) + CH3COO(-a)	OK	-0.251	1.64E-05	
4	0	Fe2O3 + 6 H(+a)	=	2 Fe(+3a) + 3 H2O	OK	-138.563	3.60E+00	
5	100	Nd2O3 + 6 H(+a)	=	2 Nd(+3a) + 3 H2O	OK	-440.190	1.46E+58	
6	6	Dy2O3 + 6 H(+a)	=	2 Dy(+3a) + 3 H2O	OK	-395.190	1.84E+48	
7	0	NiO + 2 H(+a)	=	Ni(+2a) + H2O	OK	-101.140	3.17E+12	
8			=					
9			=					
10			=					
11			=					
12			=					

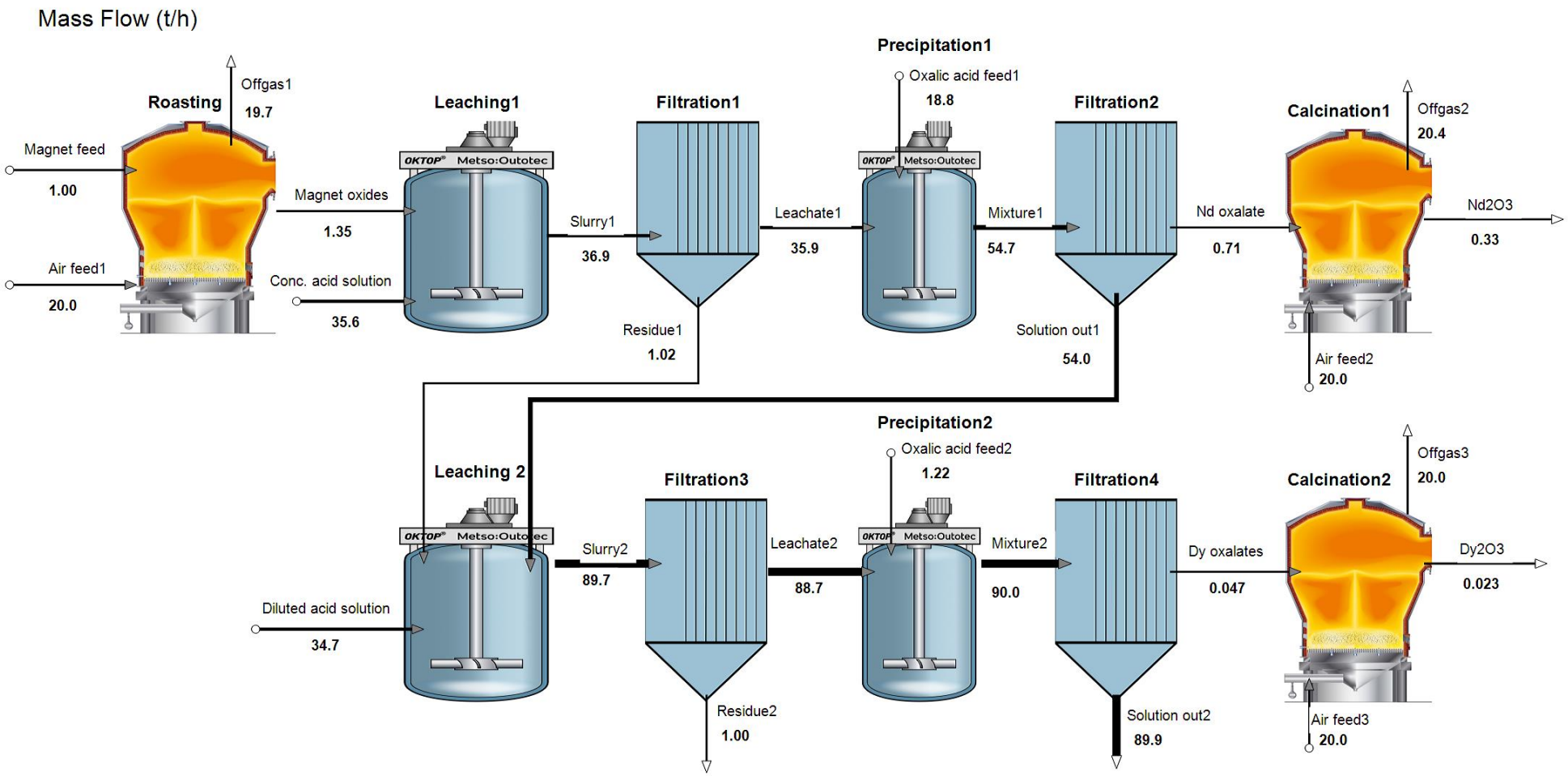
HYDROMETALLURGICAL ROUTE – MASS FLOW SIMULATION (KG/H)

- Mass increment after roasting
- Conc. acid solution: water and acid to reach the concentration of 16 M
- Slurry 1: Nd+3. Non-dissolved Dy, Fe and Ni.
- Residue 1: Non-dissolved compounds in leaching 1 go to the leaching 2
- Solution out 1: goes to leaching 2
- Leaching 2: dissolution of Dy. The solution needs to be diluted to reach concentration of 1.6 M
- Residue 2: Non-dissolved compounds in leaching steps (Fe and Ni)
- Solution 2: can be recycled



HYDROMETALLURGICAL ROUTE – SCALING UP THE PROCESS

Simplified BRGM flowsheet - scaled up



HYDROMETALLURGICAL ROUTE - ENTHALPY FLOW (KW)

The easiest way to reach enthalpy balance is controlling either input or output temperature of each unit

Unit Editor - Prcipitation1

Variable list
- Variable List Editor

Wizards
- Chemical Reactions Wizard
- Enable Gibbs Wizard

Tools
- Insert Sheet
- Number Format

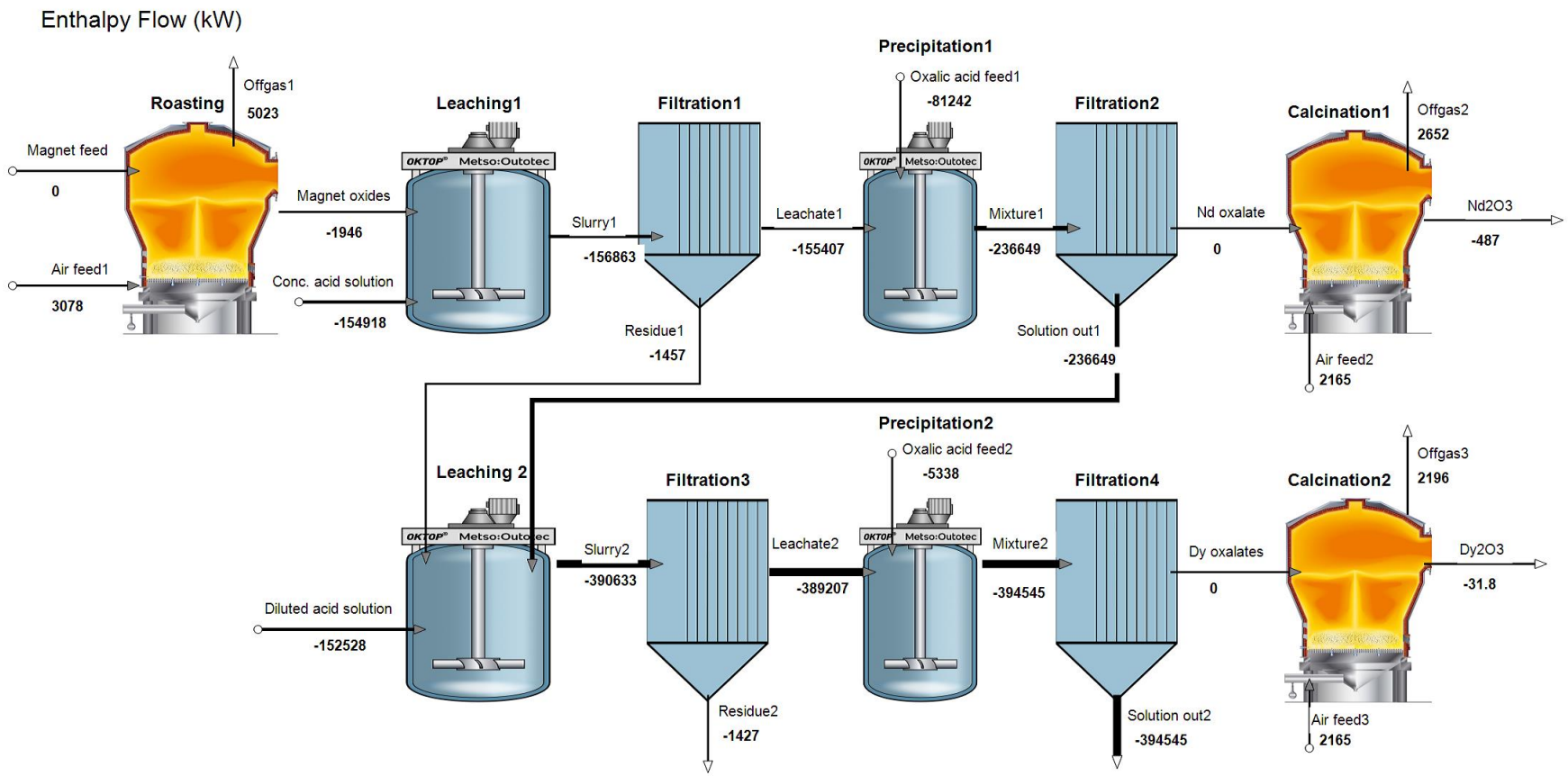
Controls
- Add New Control
- Remove Control
- Move Control Left
- Add Schema

Help
- Help

D14 =Input!F8

	B	C	D
2			
4	**CONTROL TARGET**	**Acid oxalic conc.**	**Enthalpy control**
5	Process unit	Prcipitation1	Prcipitation1
6	Measurement Unit	g/L	kW
7	**Set Point**	**13.6**	**0**
8	**Measured**	**13.591**	**0.000**
9	Tolerance +/-	0.01	0.01
10			
11	**CONTROL VARIABLE**	**water feed**	**Input temp**
12	Process Unit	Prcipitation1	Prcipitation1
13	Measurement Unit	kg/h	C
14	**Control Variable**	**37.05181719**	**76.04715513**
15	Min Limit	0	0
16	Max Limit	20000	100
17	X Max Step		
20			
21	**CONTROL MODE**	**Static**	**Static**
22	Active	ON	ON
23	Iterations Max Limit	15	15
24	X Max Step Method		
25	Type	Internal	Internal
26	Method	Tangential (fast)	Tangential (fast)
28			
56			
57			

Simplified BRGM flowsheet - scaled up



CONCLUSION

- Flowsheet simulation enables the integration of the whole process, from collecting to recovery steps
- It is an useful tool to analyse mass and energy flow of each step, in order to identify hot spots (LCA) and improving the process efficiency
- Simulation can indicate the most suitable recycling route of EoL permanent magnets, based on material lost and energy consumption
- Mass flow analysis of hydrometallurgical process indicated the recovery of Nd 93% as rare earth oxides

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