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How can process simulation be used to get more reliable data for LCA of mining emerging technologies?

S. Muller[1], J. Bodin[1], J. Segura Salazar[2], J. Villeneuve[1]

SETAC Europe 29th annual meeting
29th May 2019
Session: Improving decision for support for sustainability going beyond standard LCA

1: BRGM 2: Imperial College London

INSTITUT CARNOT brgm

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Context and objectives

Raw materials, a concern within the European context

In 2017: 88,6 billions tons of raw materials used

+ 100% from 2017 to 2050 (IRP, 2017)





Different issues:

- **Environmental consequences**
- **Sustainability**
- **Circular economy**
- **Criticality** (supply risks,...)

Resource access: a **strategic interest for nations**



In 2008, « Raw materials initiative »

- Ensuring access to raw materials
- Fostering a sustainable supply of raw materials from European sources

Context and objectives

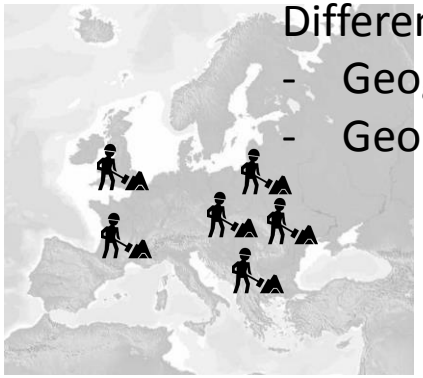
IMP@CT project: Unlock the access to small complex mineral deposits in a more sustainable way

- Overall goal of the project:
  - Propose a new mining paradigm: the SOSO concept to improve the viability of small complex deposits





€ viable

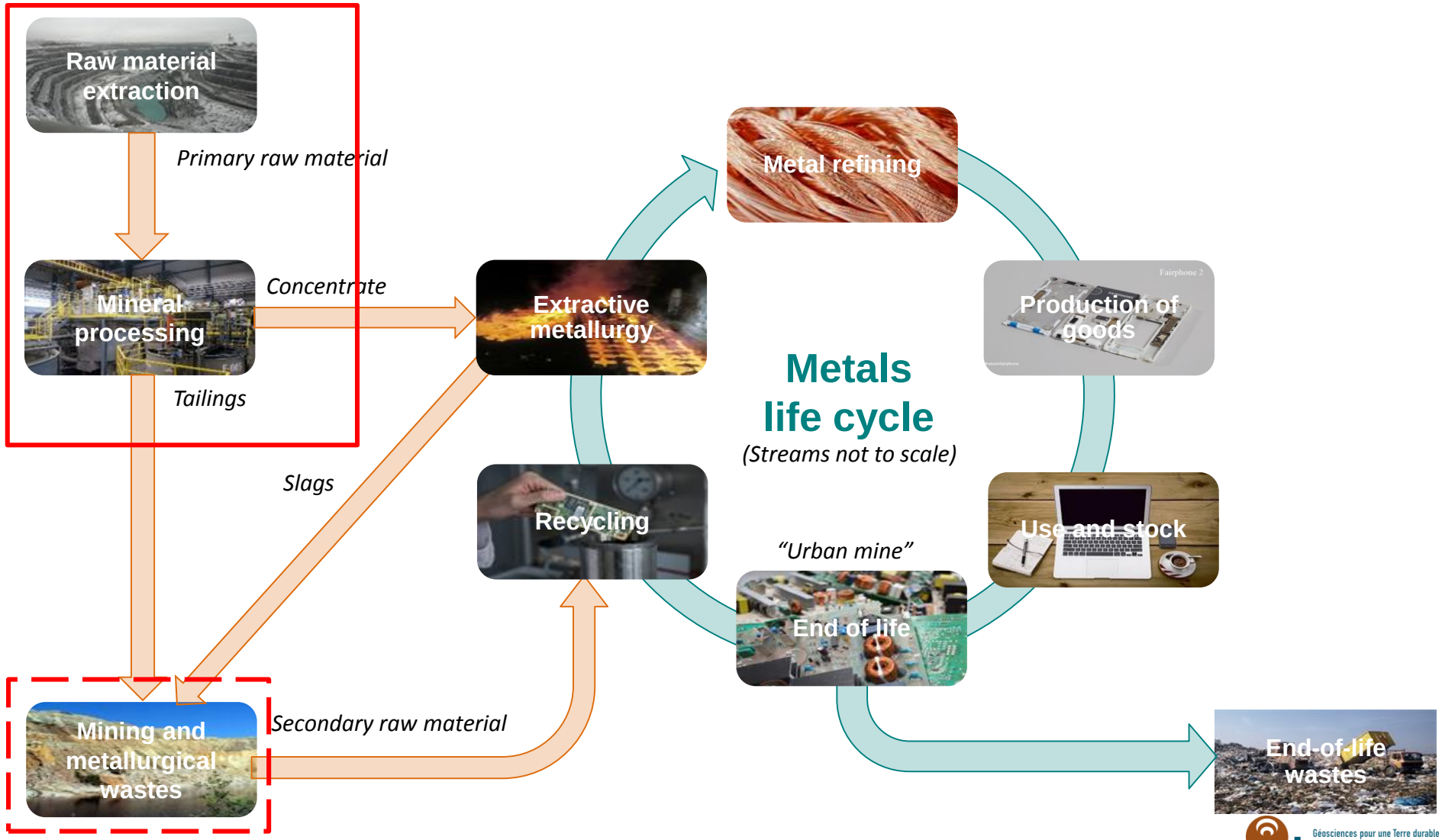


Different contexts
- Geographical
- Geological

H2020 project : Started in January 2017, will end in May 2020 - Grant no 730411

Context and objectives

IMP@CT focus on the firt phases of the metal life cycle



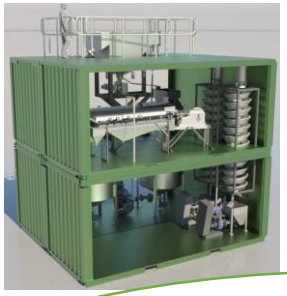
Context and objectives

Applying LCA in the framework of IMP@CT

OVERALL GOAL

- Address the environmental sustainability of the newly developed modularized mobile plant (MMP) solutions for small-scale mining operations through life cycle assessment

How to assess the potential environmental benefits against BAU of the newly developed MMP?



HAVING IN MIND MMP CHARACTERISITICS

- Should be mobile / flexible / modular
- Developed at a pilot scale

Validated in the mining and processing of small scale Pb and Sb deposits in the Balkans

Associated challenges

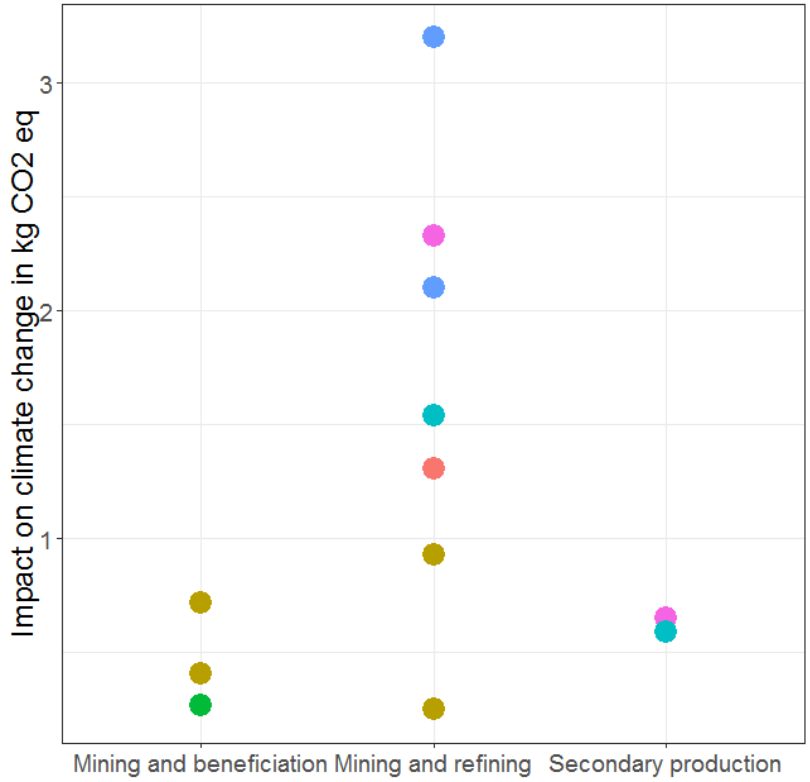
- Upscaling effect
- Contextual assessment

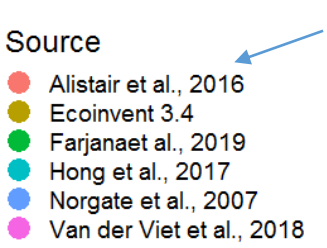
Answer

Use mineral process simulation **coupled** with LCA

First, what are the impacts of the BAU?

Assessing the climate change impacts of 1 kg of lead in different forms





International Lead association

What lead to results variability

GEOLOGY CONTEXT

TECHNOLOGY

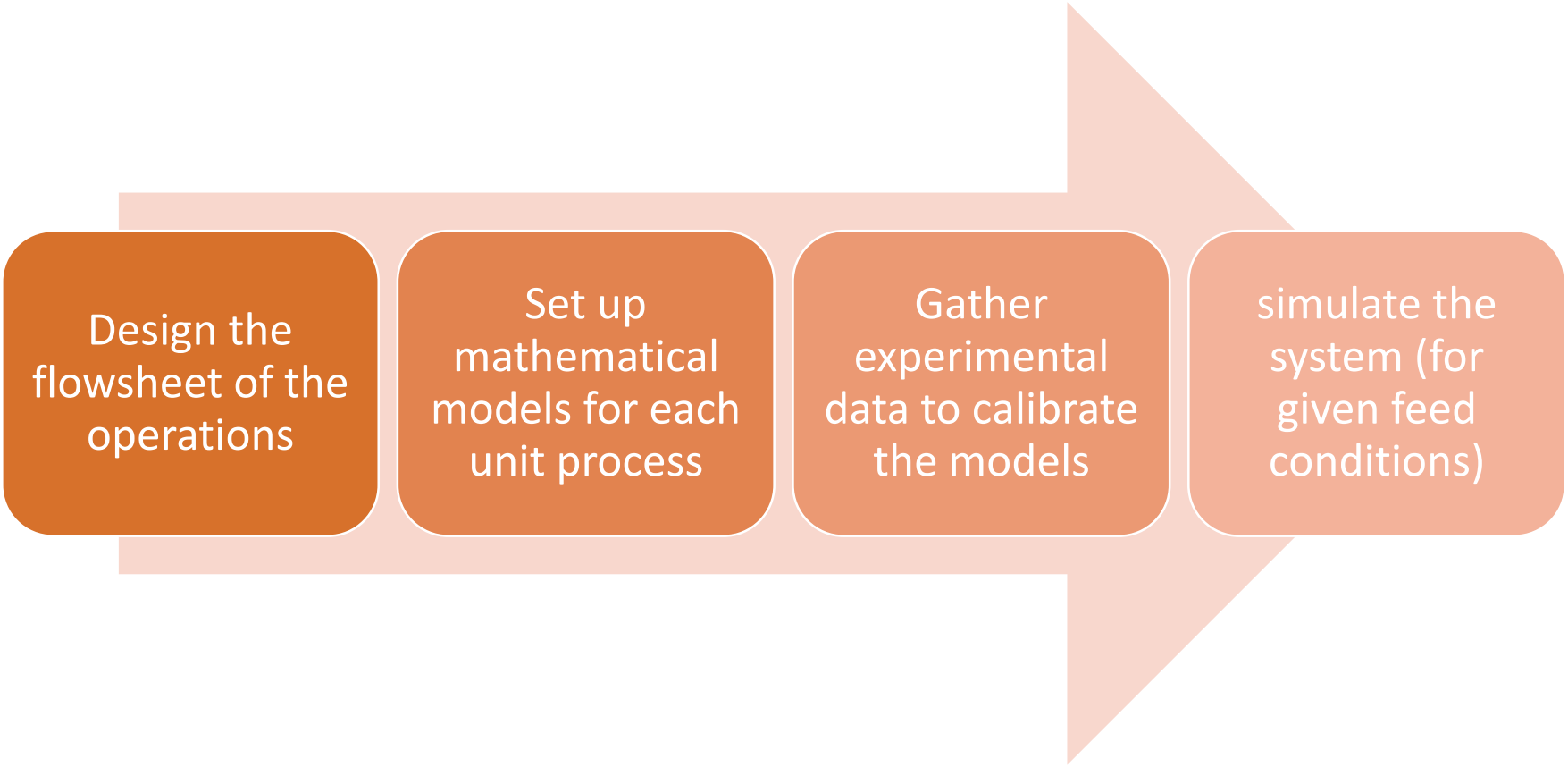
GEOGRAPHICAL CONTEXT

LCA METHODOLOGI-CAL CHOICES

Get rid of the upscaling effect

Concept of process simulation

- Development starts in the 1960s
- Used to predict the performances of an industrial mineral processing plant
- Based on lab/pilot scale experimental data



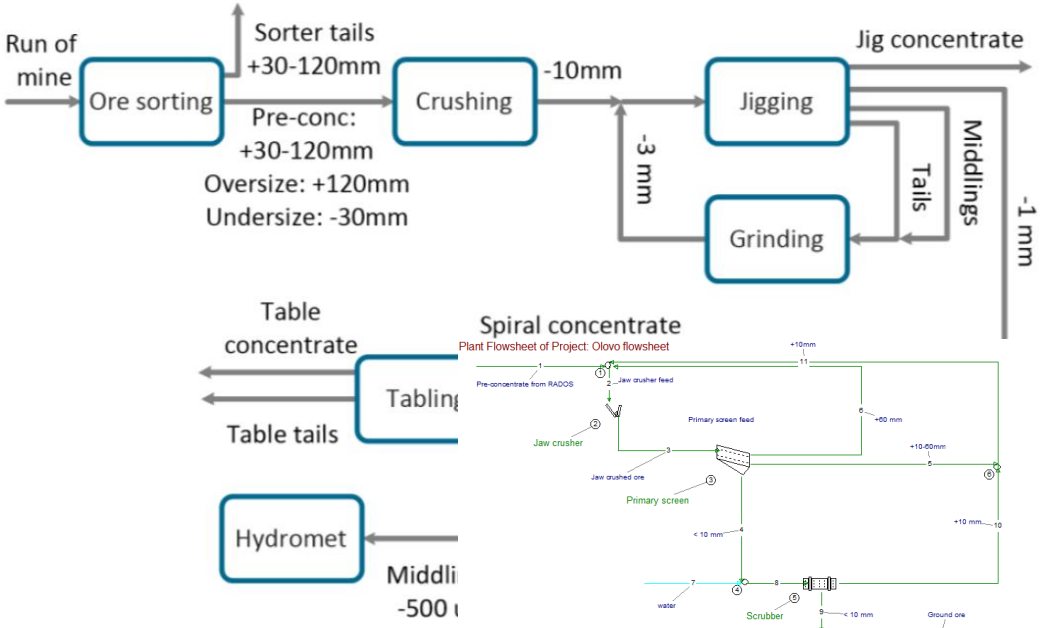
Get rid of the upscaling effect

Design the flowsheet of the operations

Set up mathematical models for each unit process

Gather experimental data to calibrate the models

simulate the system (for given feed conditions)



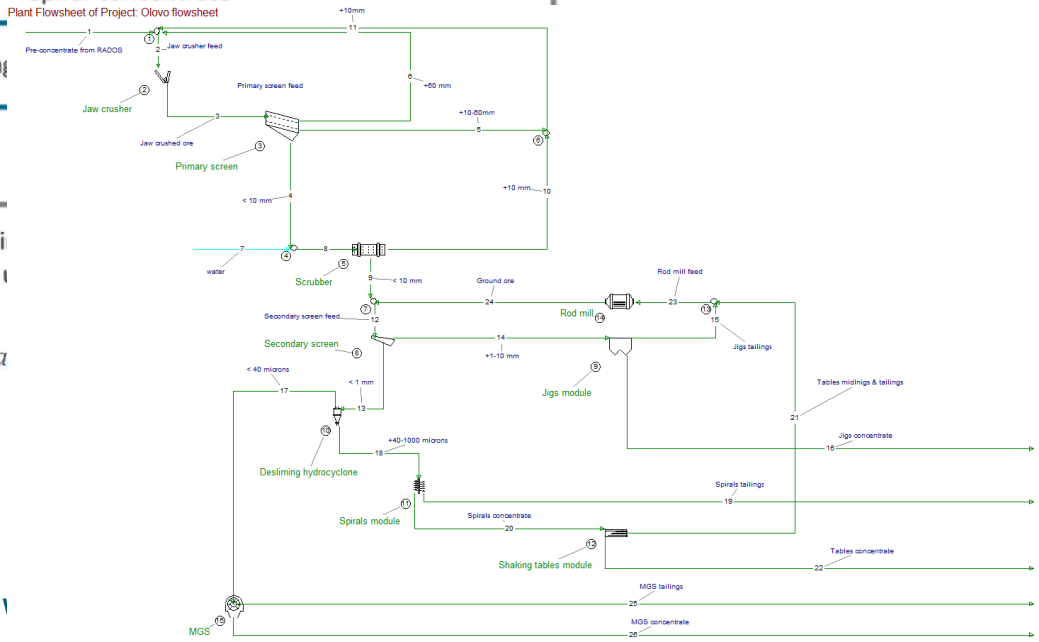


Figure 1. The block flow diagra

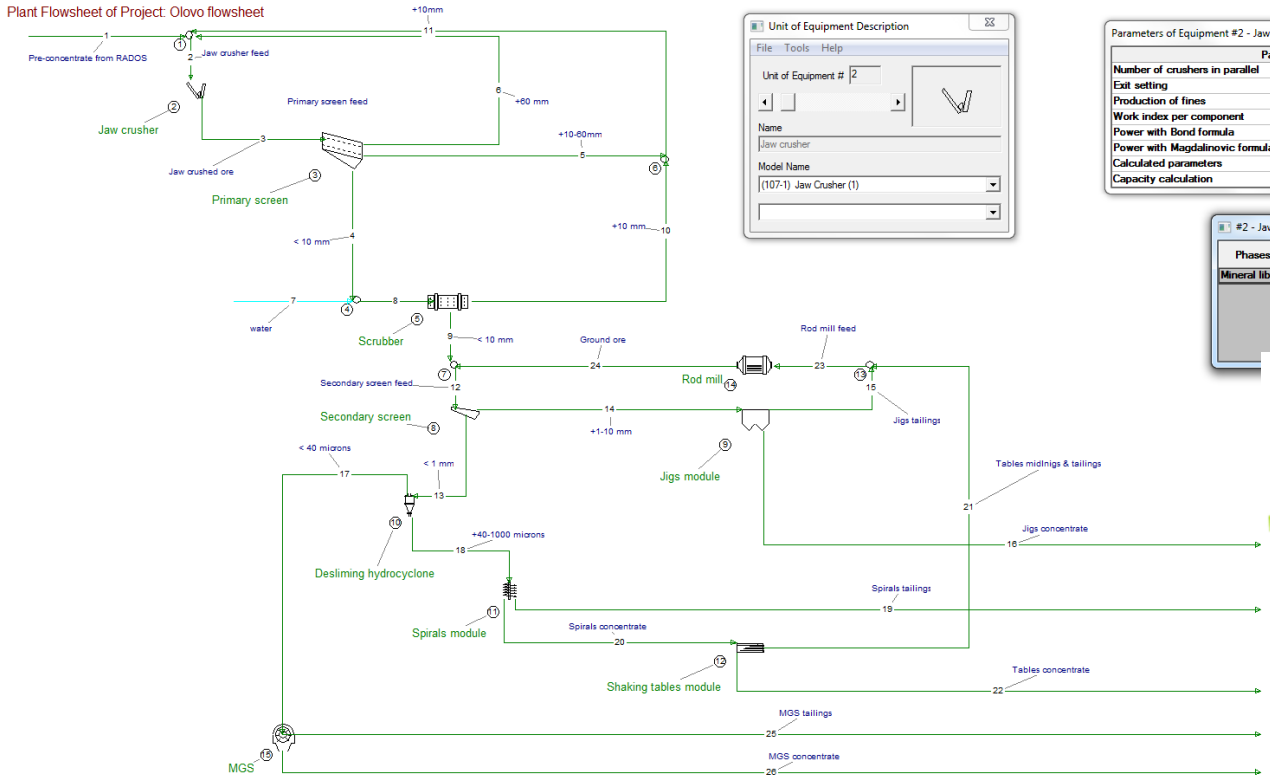
Get rid of the upscaling effect

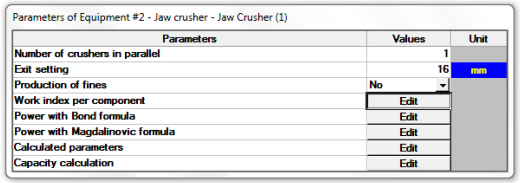
Design the flowsheet of the operations

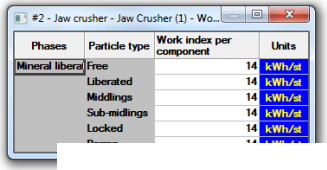
Set up mathematical models for each unit process

Gather experimental data to calibrate the models

simulate the system (for given feed conditions)







USIM PAC

Example: Bond work index

$$W = \frac{\sqrt{100} \cdot Wi}{\sqrt{P}} - \frac{\sqrt{100} \cdot Wi}{\sqrt{F}}$$

where

W = predicted mill energy consumption, in kWh/st
Wi = Work Index, in kWh/st
100 = 100 µm, which is the product size in the definition of Work Index
P, F = 80% passing sizes, in µm of the feed (F) and product (P)

This equation is also commonly written as

$$W = 10 \cdot Wi\left(\frac{1}{\sqrt{P}} - \frac{1}{\sqrt{F}}\right)$$

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Get rid of the upscaling effect

Design the flowsheet of the operations

Set up mathematical models for each unit process

Gather experimental data to calibrate the models

simulate the system (for given feed conditions)

SOLID PHASE MODEL			Particle types distribution							Contact person
			Free	Liberated	Middlings	Sub-midlings	Locked	Barren	Total	
Particle size distribution	Size classes	units	%	%	%	%	%	%	%	
	20 mm	%ind							100	
	10 mm	%ind							100	
	5 mm	%ind							100	
	2 mm	%ind							100	
	1 mm	%ind							100	
	0,5 mm	%ind							100	
	Pan	%ind							100	
	total	100								

Particle types definition		unit	Particle types					
			Free	Liberated	Middlings	Sub-midlings	Locked	Barren
Grades	Cerrusite (PbCO3)	%	80-100	60-80	40-60	20-40	0-20	0
	Carbonates (CaCO3	%	0-20	20-40	40-60	60-80	80-100	100
Density	min	-	5.78	5.01	4.24	3.47	2.7	2.7
	max	-	6.55	5.78	5.01	4.24	3.47	2.7

USIM PAC

Mineral liberation/Variable composition

Mass flowrate	5	t/h
Volumetric flowrate	1,59299	m3/h
Density	3,13875	kg/dm3

Particle type grade per size

Size distribution

Size classes	% Individual	% Passing	% Retained
150 mm	0	100	0
25 mm	27	73	27
12,5 mm	8	65	35
6 mm	13	52	48
2 mm	20	32	68
500 µm	15	17	83
100 µm	10	7	93
Pan	7	0	100

Particle types

Free	Liberated	Middlings	Sub-midlings	Locked	Barren
%	%	%	%	%	%
0	0	0	0	0	100
0	0	5	10	15	70
0	0	5	10	15	70
25	5	5	5	5	55
25	5	5	5	5	55
26,5	4,8	4,2	5	5,7	53,8
31,5	3,4	3	2,4	4,7	55
46,6	3,8	3,5	3,2	5	37,9
18,637	2,976	4,575	6,364	8,575	58,873

Means

Composition

PbCO3	CaCO3
%	%
0	100
7	93
7	93
30,5	69,5
30,5	69,5
31,38	68,62
33,42	66,58
47,81	52,19
23,9107	76,0893

Composition of particle types

Particle types	Grades	Units	Grades PbCO3	Grades CaCO3
Particle types			%	%
Free	18,637	%	90	10
Liberated	2,976	%	70	30
Middlings	4,575	%	50	50
Sub-midlings	6,364	%	30	70
Locked	8,575	%	10	90
Barren	58,873	%	0	100
		Means	23,9107	76,0893

Mineral liberation/Variable composition / Water & reagents

Mass flowrate	5	t/h
Volumetric flowrate	1,59299	m3/h
Solid percent	100	%
Density	3,13875	kg/dm3

Get rid of the upscaling effect

Outputs of process simulation and link with LCI

Process simulation with algorithms including:



- Mass balance calculations
- Data reconciliation

Operating variables

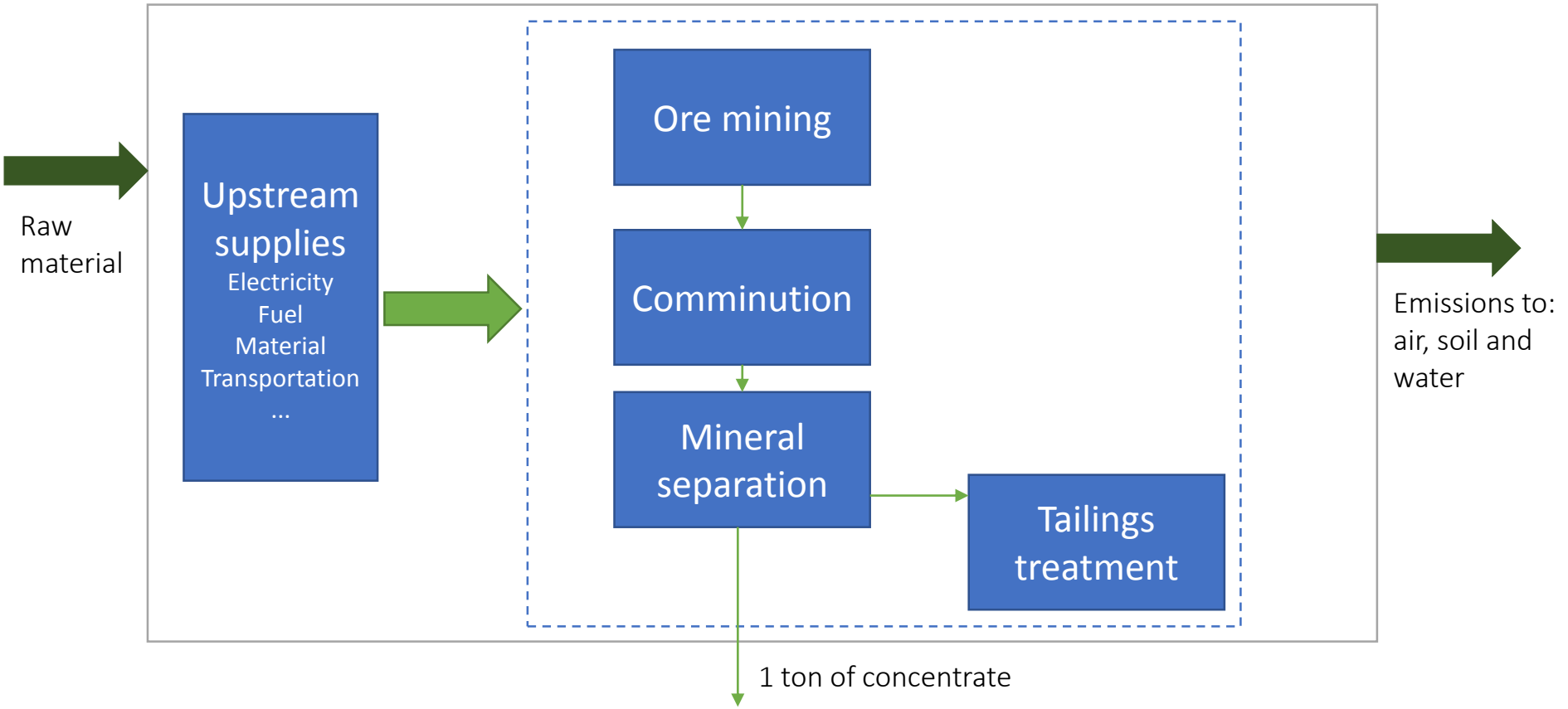
- Flow rates (liquids and solids)
- Energy and reagents consumption
- Mine wastes

Direct inputs for the LCI phase

Performing a contextual assessment



Generic functional unit for metal mining in the context of IMP@CT: "The production of 1 ton of concentrate containing x% of metal using the IMP@CT developed technologies"



Performing a contextual assessment



Build a parametrized Excel tool that can be used whatever the context

USIM PAC

Process simulation

Experimental data

Literature data

Energy, reagents, flows (S + L)

Energy, transport, dust ...

Specific emissions

EXCEL WORKBOOK

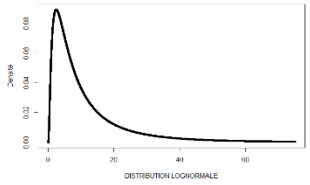
Foreground modelling for the assessed functional unit

ecoinvent Centre

SimaPro

Life cycle inventory and life cycle impact assessment calculations

Taking into account ore and process variability



Process simulation

Monte Carlo

$N(\mu;\sigma)$

Experimental data

$LN(\mu_g;\sigma_g)$

Literature data

$LN(\mu_g;\sigma_g)$

EXCEL WORKBOOK

Foreground modelling for the assessed functional unit

with uncertainty information – using ecoinvent uncertainty approach

Life cycle inventory and life cycle impact assessment calculations

Monte Carlo

Foreground modelling with information on uncertainty

Resulting uncertain potential environmental impacts

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Conclusions and perspectives

- Process simulation can enhance LCI data reliability
  - A way to model specific unit process inputs needed for LCI
  - Uncertainty can be quantified on these inputs

- Process simulation can specially be used on earlier process development stages
  - Coupling process simulation and LCA → a tool for ecodesign (see for example Reuter et al.)

- This coupling is not new in LCA
  - HSC can be linked to GaBi and there is discussions going on to link HSC to OpenLCA

- Specific ongoing work for IMPACT
  - Data collection
  - On field sampling
  - Couple results environmental LCA results to sLCA results

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Thank you for your attention

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