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

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

S. Muller<sup>1</sup>, J. Bodin<sup>1</sup>, J. Segura Salazar<sup>2</sup>, J. Villeneuve<sup>1</sup>

SETAC Europe 29<sup>th</sup> annual meeting

29<sup>th</sup> May 2019

Session: Improving decision for support for sustainability going beyond standard LCA

1: BRGM 2: Imperial College London



Géosciences pour une Terre durable

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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 »

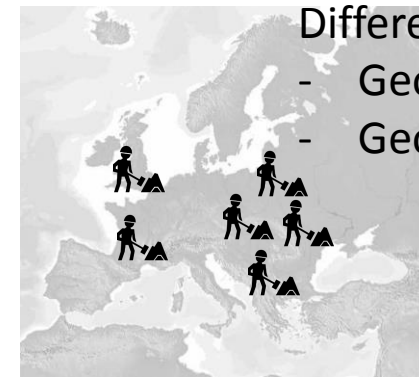
- Ensuring access to raw materials
- Fostering a sustainable supply of raw materials from European sources

### 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



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EPSE



UNIVERSITY OF EASTERN FINLAND

MINECO



Imperial College London

Extractive PROCESS DESIGNERS



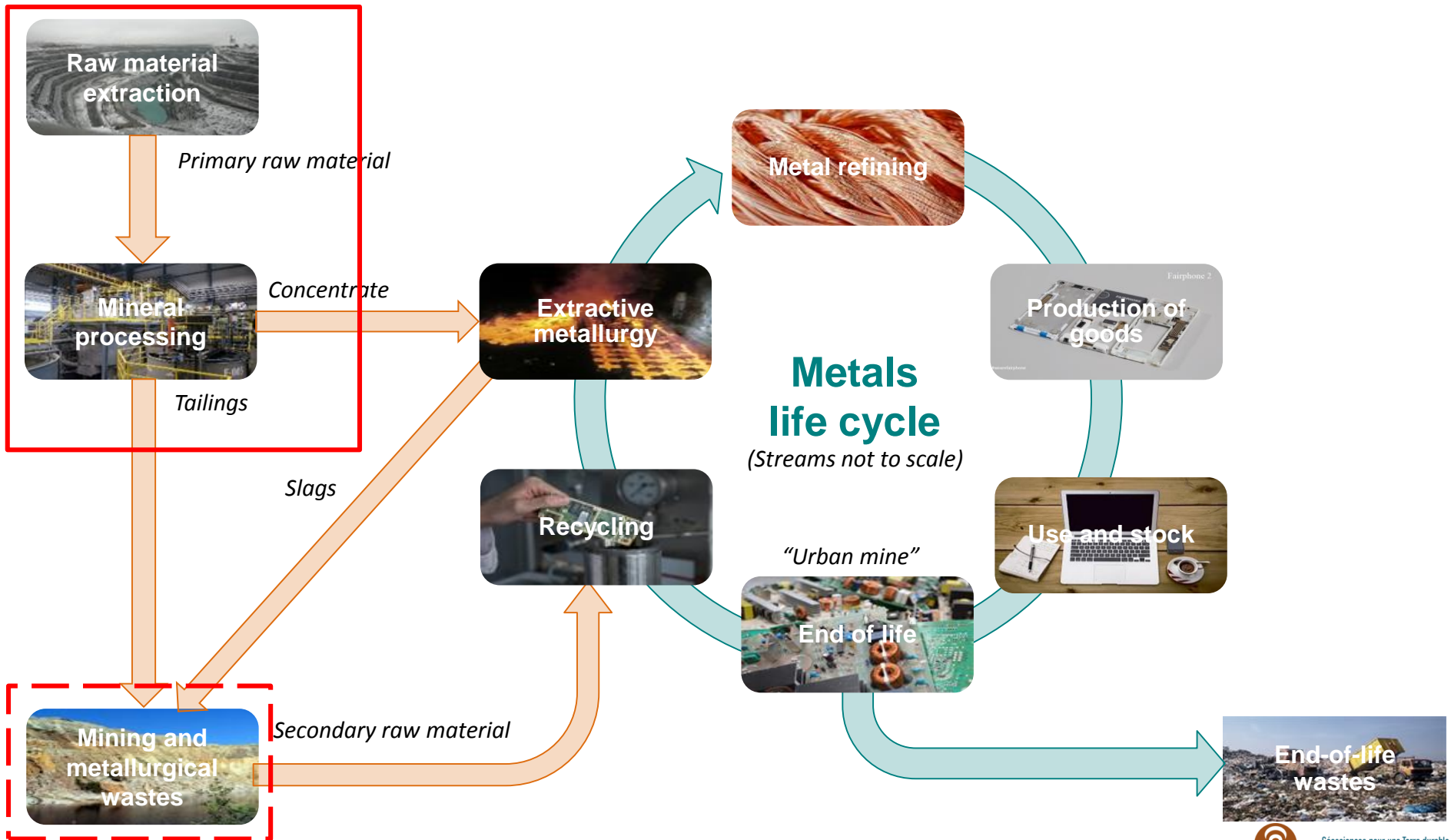
RWTH AACHEN UNIVERSITY



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

# Context and objectives

## IMP@CT focus on the first 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 CHARACTERISTICS

- 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

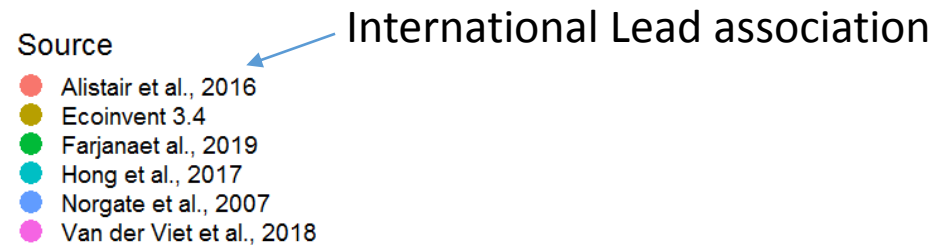
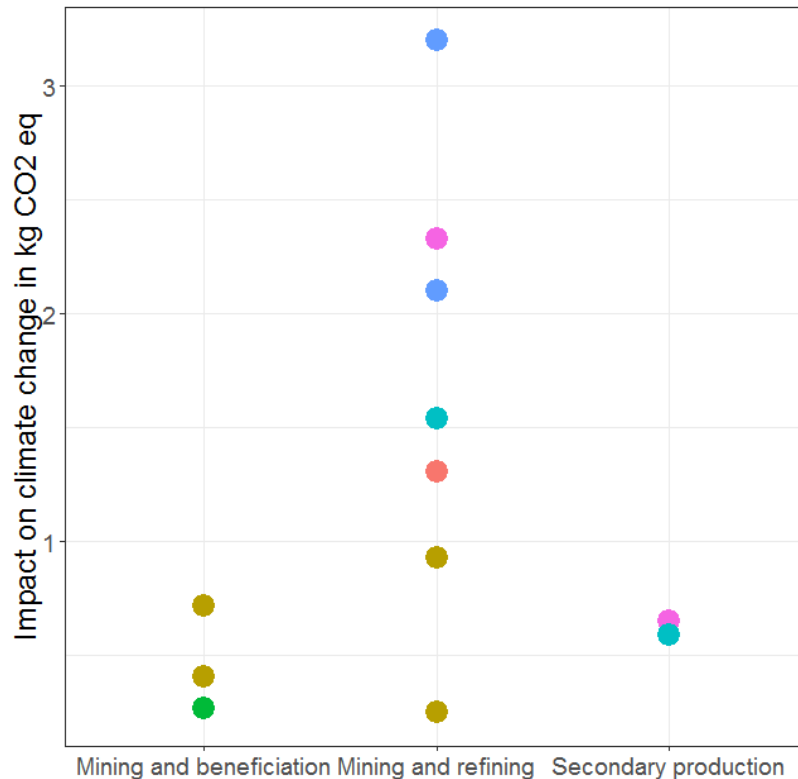


Answer

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



What lead to results variability

GEOLOGY  
CONTEXT

TECHNOLOGY

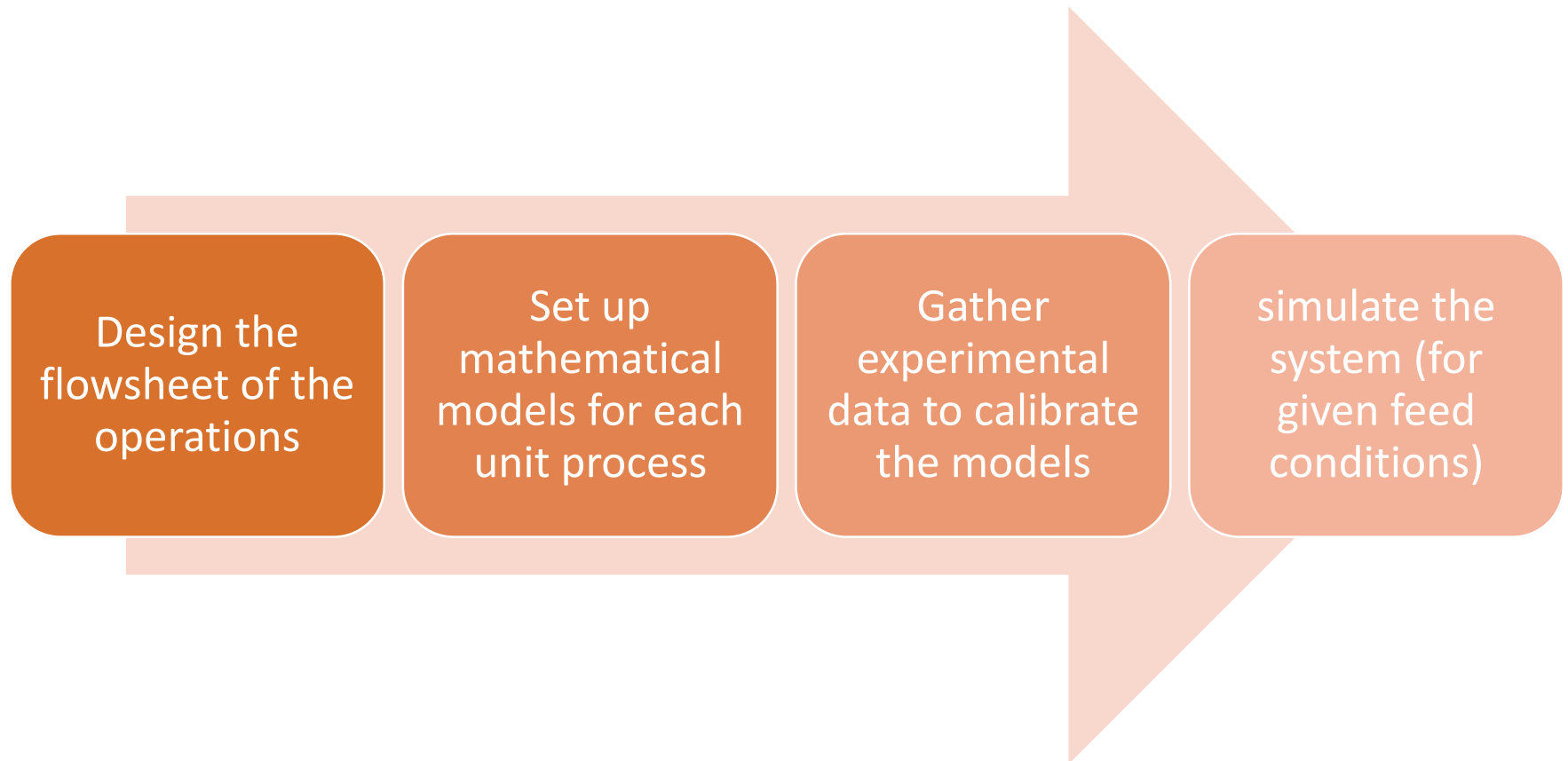
GEOGRAPHICAL  
CONTEXT

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)

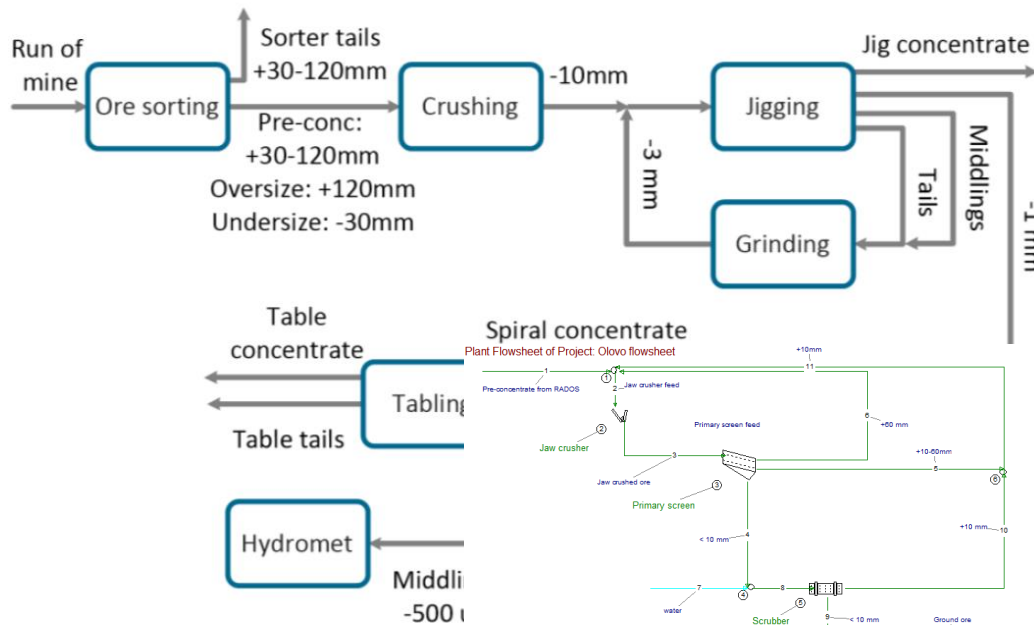
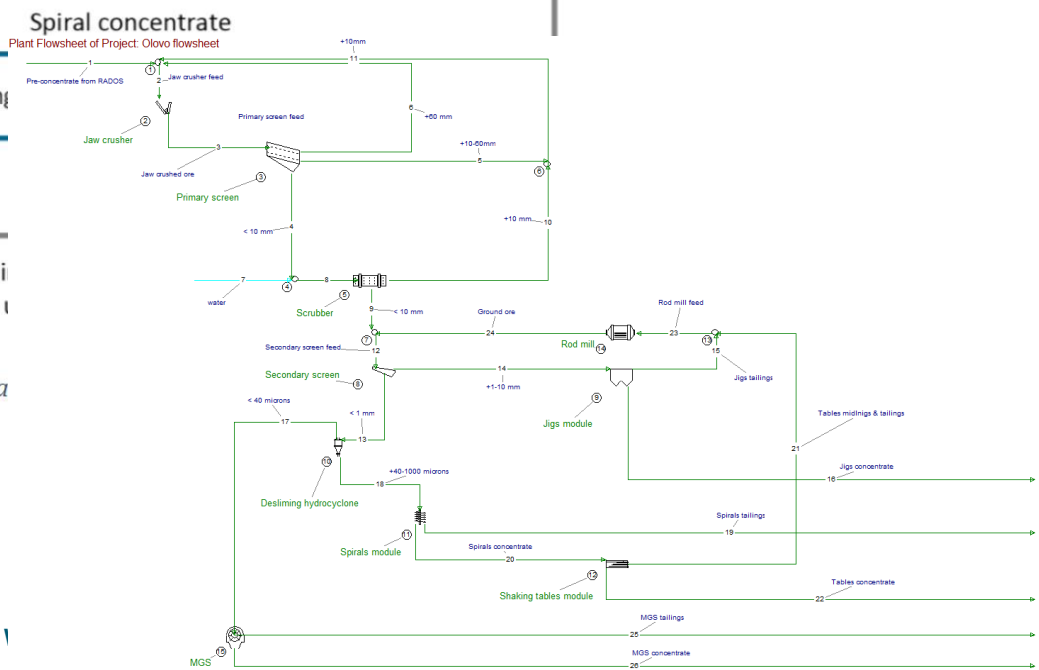


Figure 1. The block flow diagram



# Get rid of the upscaling effect

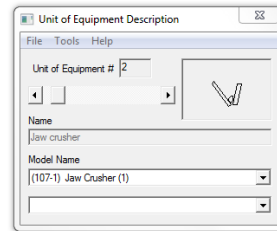
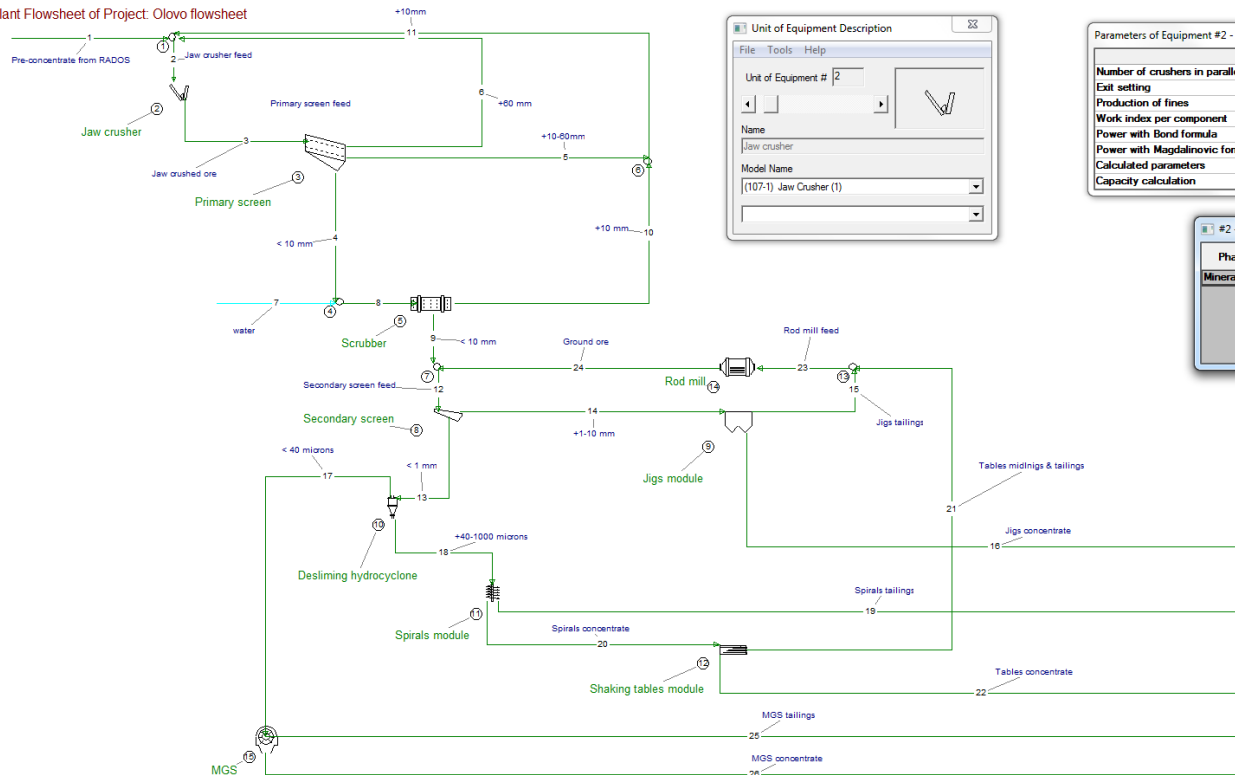
Design the flowsheet of the operations

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Plant Flowsheet of Project: Olovo flowsheet



Parameters of Equipment #2 - Jaw crusher - Jaw Crusher (1)

Parameters	Values	Unit
Number of crushers in parallel	1	
Exit setting	16	mm
Production of fines	No	
Work index per component		Edit
Power with Bond formula		Edit
Power with Magdalinovic formula		Edit
Calculated parameters		Edit
Capacity calculation		Edit

#2 - Jaw crusher - Jaw Crusher (1) - Wo...

Phases	Particle type	Work index per component	Units
Mineral libera	Free	14	kWh/t
	Liberated	14	kWh/t
	Middlings	14	kWh/t
	Sub-middlings	14	kWh/t
	Locked	14	kWh/t

USIM PAC

Example: Bond work index

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

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

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

# 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
Size classes	units		Free %	Liberated %	Middlings %	Sub-middlings %	Locked %	Barren %	Total %	
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					
Grades	Cerrusite (PbCO <sub>3</sub> )	%	Free 80-100	Liberated 60-80	Middlings 40-60	Sub-middlings 20-40	Locked 0-20	Barren 0
	Carbonates (CaCO <sub>3</sub> )	%	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	th	
Volumetric flowrate	1.59299	m <sup>3</sup> /h	
Density	3.13672	kg/dm <sup>3</sup>	

Particle type grade per size				Particle types							Composition	
Size classes	% Individual	% Passing	% Retained	Free %	Liberated %	Middlings %	Sub-middlings %	Locked %	Barren %	PbCO <sub>3</sub> %	CaCO <sub>3</sub> %	
150 mm	0	100	0	0	0	0	0	0	100	0	100	
25 mm	27	73	27	0	0	5	10	15	70	7	93	
12,5 mm	8	65	35	0	0	5	10	15	70	7	93	
6 mm	13	52	48	25	5	5	5	5	55	30,5	69,5	
2 mm	20	32	68	25	5	5	5	5	55	30,5	69,5	
100 µm	15	17	83	25,5	4,9	4,2	5	5,7	53,8	31,38	68,62	
100 µm	10	7	93	31,5	3,4	3	2,4	4,7	55	33,42	66,58	
Pan	7	0	100	46,6	3,8	3,5	3,2	5	37,9	47,81	52,19	
				Means	18,637	2,976	4,575	6,364	8,576	58,873		

Composition of particle types			
Particle types	Grades	Grades	
		PbCO <sub>3</sub> %	CaCO <sub>3</sub> %
Free	18.637	90	10
Liberated	2.976	70	30
Middlings	4.575	50	50
Sub-middlings	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	th	
Volumetric flowrate	1.59299	m <sup>3</sup> /h	
Solid percent	100	%	
Density	3.13672	kg/dm <sup>3</sup>	

## 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

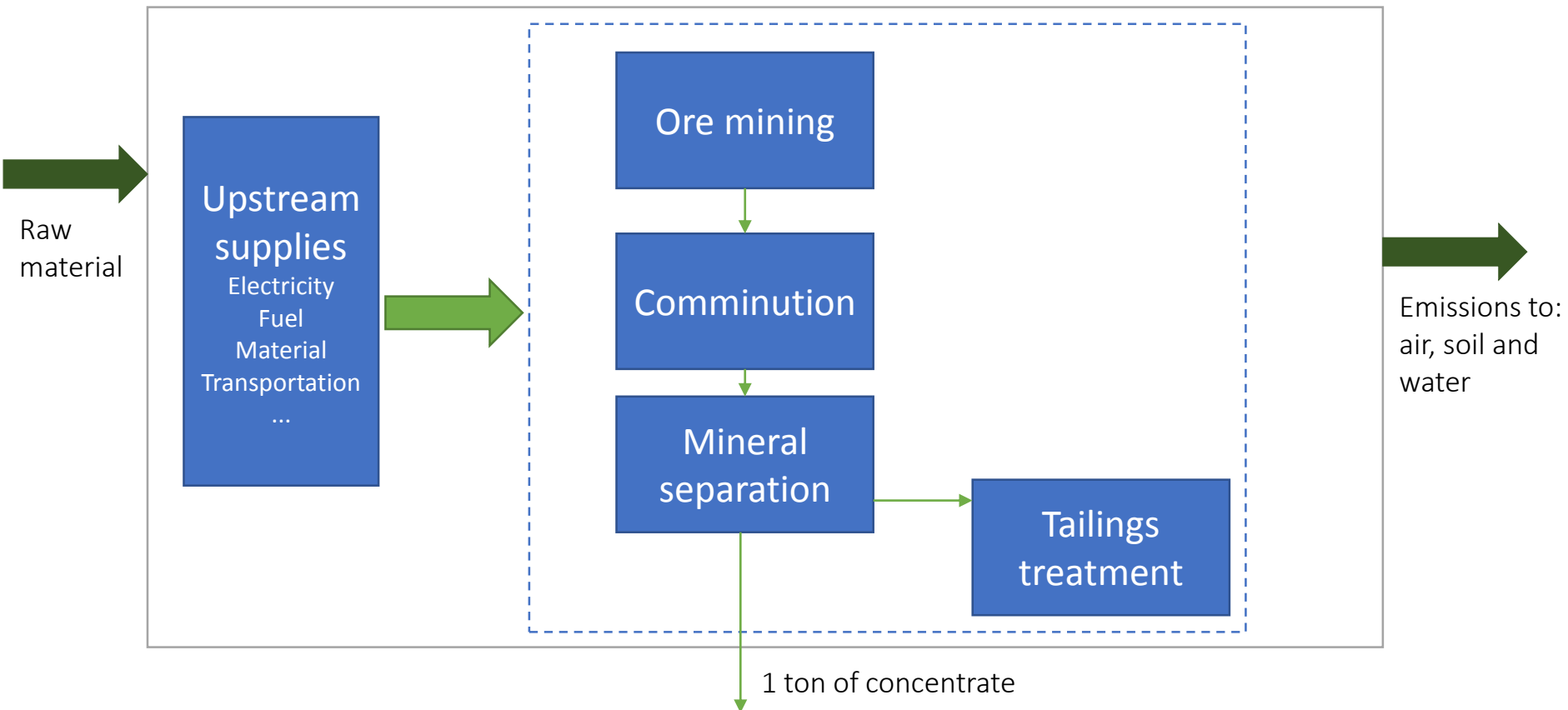
- Flow rates (liquids and solids )
- Energy and reagents consumption
- Mine wastes

} Direct inputs for the  
LCI phase

# Performing a contextual assessment



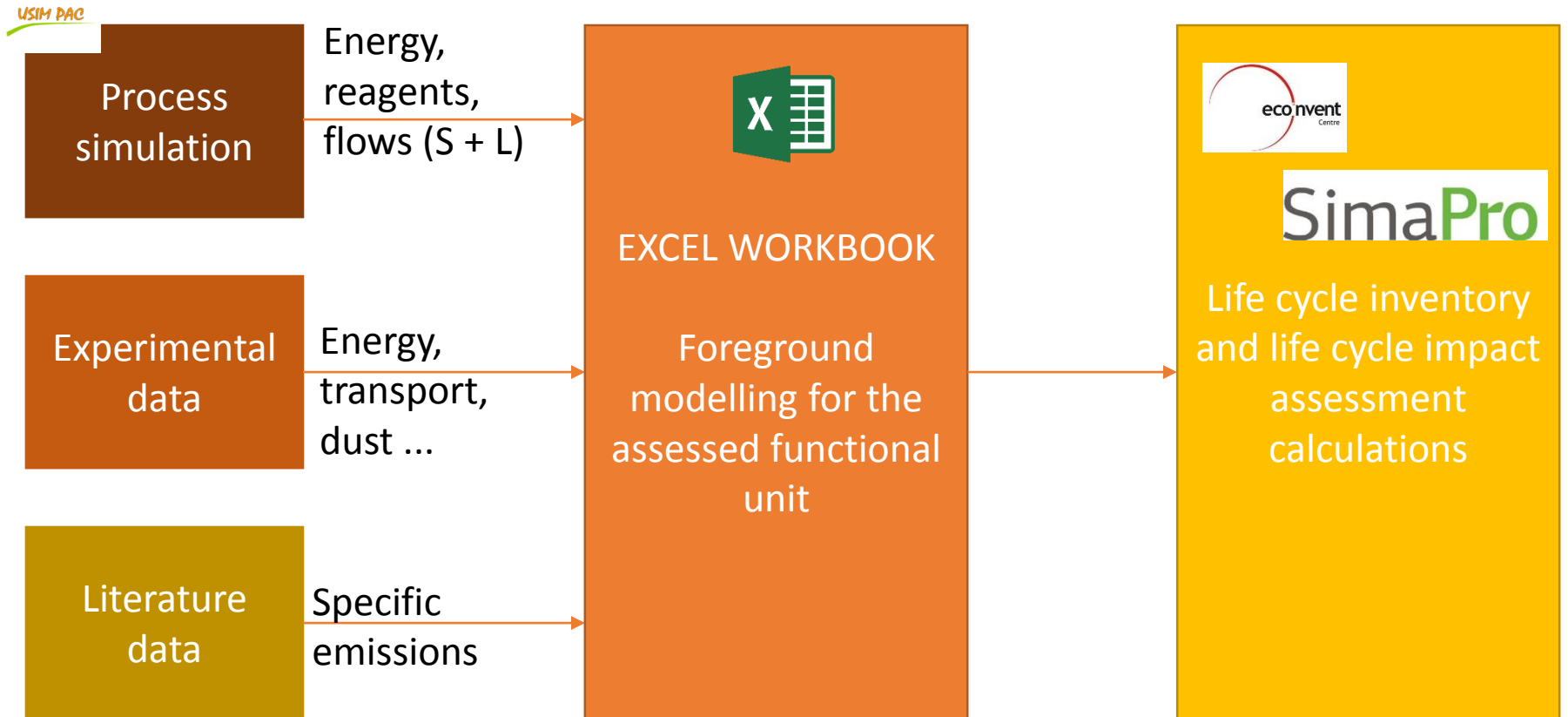
**Generic functional unit for metal mining in the context of IMP@CT:** “The production of 1 ton of concentrate containing x% of metal using the IMP@CT developed technologies”



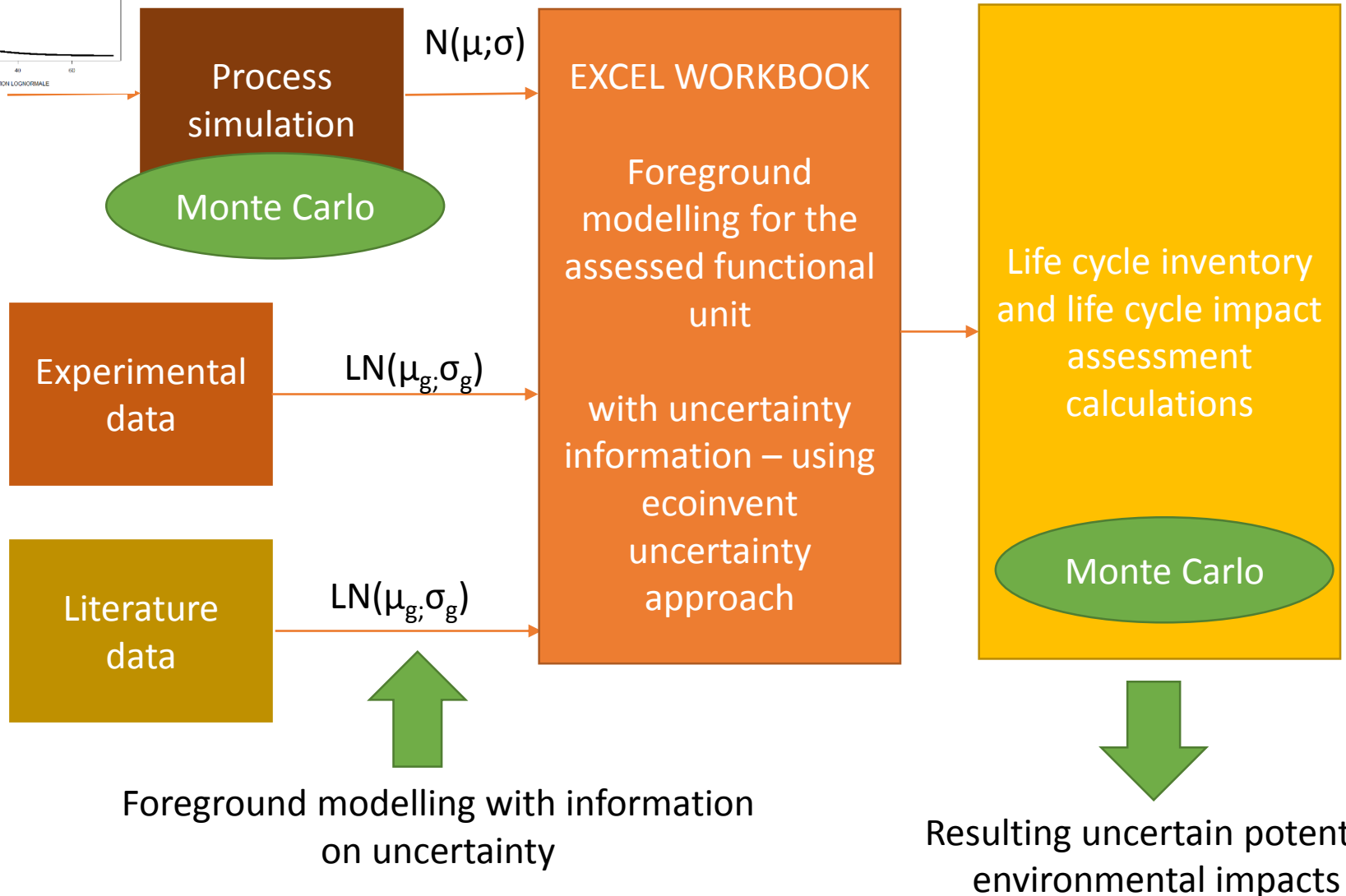
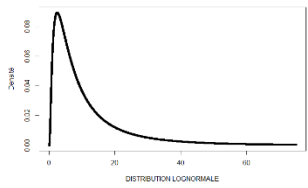
# Performing a contextual assessment



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



# Taking into account ore and process variability



Foreground modelling with information on uncertainty

Resulting uncertain potential environmental impacts

## 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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