Benchmarking of materials composition and transportation influences on Life Cycle Assessment of Recycled Aggregate Concrete

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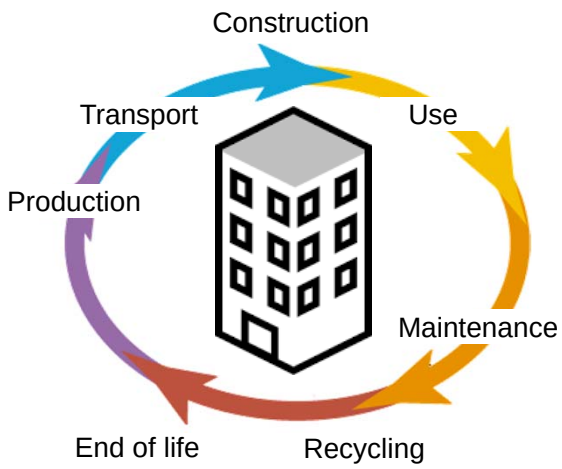
LCA METHODOLOGY

Life cycle → Quantitative inventory → Indicators



	Flow	Quantity
Input	Coal	500 mg
	Limestone	45 g
	Water	0.03 L
	Etc.	…
Output	CO_2 (air)	3 g
	Hydrocarbons (air)	12 mg
	Mercury (water)	5 µg
	Nitrates (water)	78 mg
	Plutonium (soil)	145 kBq
	Wastes	100 kg
	Etc.	…

- Resource depletion
- Energy consumption
- Climate change
- Atmospheric acidification
- Ozone layer depletion
- Wastes
- …

Allows to quantify the damage of a product or a structure on the environment

The EN 15804 Building Product LCA Standard

Environmental impacts	
Impact indicator	Unit
Abiotic depletion	kg Sb eq
Consumption of energetic resources	MJ
Acidification of soils and water	kg SO_2 eq
Ozone layer depletion	kg CFC-11 eq
Global warming	kg CO_2 eq
Eutrophication	kg PO_4^{3-} eq
Photochemical oxidation	kg C_2H_4 eq

Waste categories	
Parameter	Unit
Hazardous waste disposed	kg
Non-hazardous waste disposed	kg
Radioactive waste disposed	kg

Resource use	
Parameter	Unit
Total use of renewable primary energy resources	MJ
Total use of non-renewable primary energy resources	MJ

BETie
Béton et Impacts Environnementaux

French National Union Concrete Ready for Employment (SNBPE)

SimaPro

GaBi
Product Sustainability Performance

openLCa

Aim of the study

<u>LCA comparison of 1 m³ of concrete</u> produced from natural or recycled aggregates (RA).

These concretes make it possible to ensure the same function, the compositions are variable

Cement dosage: 270 – 326 kg/m³
Limestone filler
Admixtures

Recycled sand
0% *(mass)* of sand is recycled

C25/30-0R-30R

Strength class

Recycled gravel
30% of aggregates are recycled

<u>Sensitivity to the transport</u> of concretes of equal volume composition (1 m³)

Influence of substitution rate in RA

	0% RA	10% RA	30% RA	100% RA
Water (kg)	182	192	213	284
Cement (kg) (CEM I)	260	260	260	260
Natural aggregate (NA) (kg)	1906	1715	1334	-
Recycled aggregate (RA) (kg)	-	153	458	1527
Superplasticizer (kg)	1.92	1.95	2.08	2.34

<u>Study of experimental construction sites</u>

Inventory data

- Cement: ATILH data
- Aggregates: UNPG data
  - Solid rock (gravel)
  - Loose rock (sand)
  - Recycled (gravel + sand)
- Admixtures: SYNAD data
  - Plasticizer
  - Air entrainment agent
- Data used to create the "Mix" process
  - Mixer capacity: 2 m^3
  - Mixing time: 55 s
  - Power: 220 kW
  - Energy consumed: 14.4 MJ/m^3
- Transport
  - European emission standards EURO 4

ATILH

Industries Technical Association of Hydraulic binders

UNPG

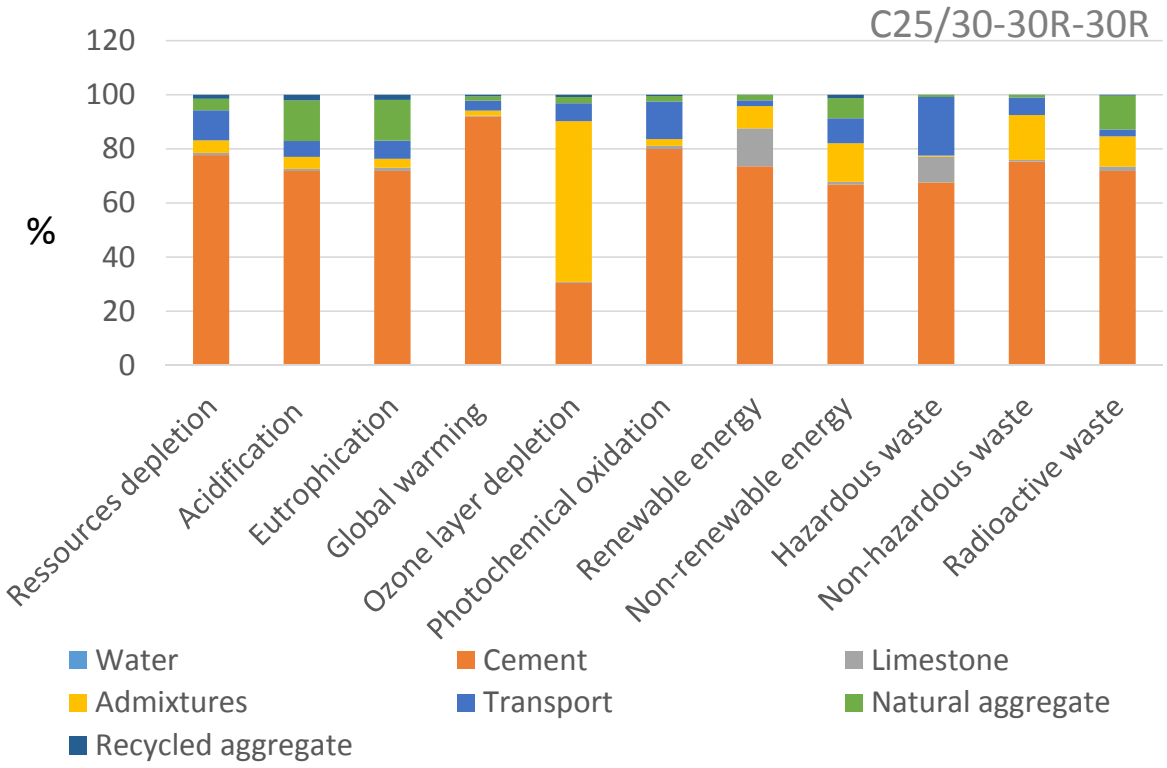
French Aggregates Association

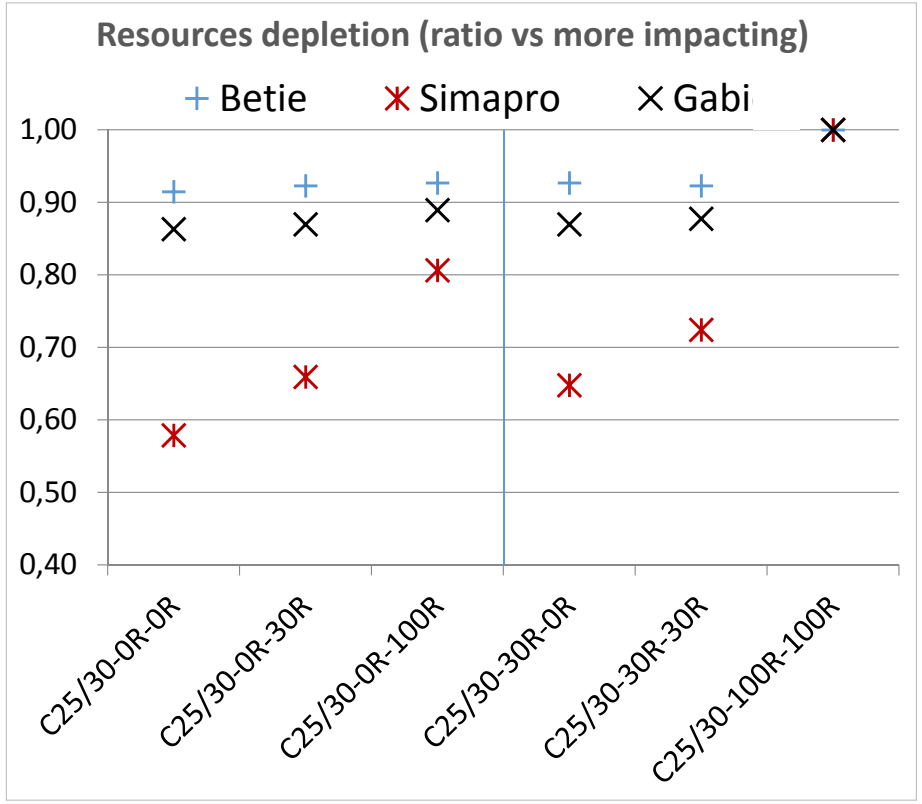
SYNAD

French National Union of Admixtures for Concrete and Mortar

Environment assessment of recycled aggregate concretes

- Concrete containing RA globally more impacting than sample with NA because the formulations are made with increasing cement rate as a function of the percentage of RA.
- The magnitude of the deviations depends on the software: methods and associated databases.

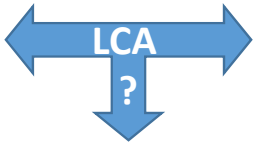




Need for transport sensitivity study

Environment assessment of recycled aggregate concretes

- Study of the sensitivity to transport of LCA



- LCA study on experimental construction site

Eco-friendly nature of recycled aggregate concrete:

Non-storage of waste

+ Non-depletion of natural aggregate resources

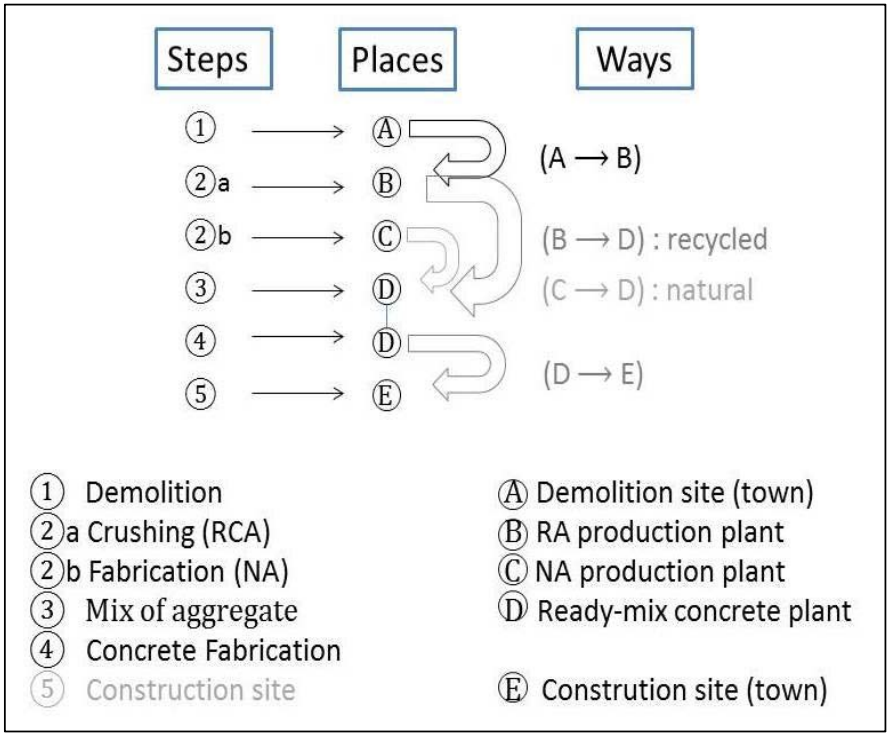
Sensitivity/transport

Routing Circuits

- Current Practice

Distances between places (km)

- Average / 3 more close
- As the crow flies



Different possibilities of conveying aggregates

Sensitivity study of transport

- Parametrical study

2 factors:

- RA % (quantitative) : 0, 10, 30 and 100
- City (qualitative) : Lille, Lyon, Strasbourg and Bordeaux

⇒ Control values for each RA %: without circuit & not including city

Selected concrete compositions: at constant volume of constituents

Same dosage for cement, efficient water, aggregate volumes.

- Same strength class thanks to admixtures

  Rc28 = 32.3 ± 2.5 MPa

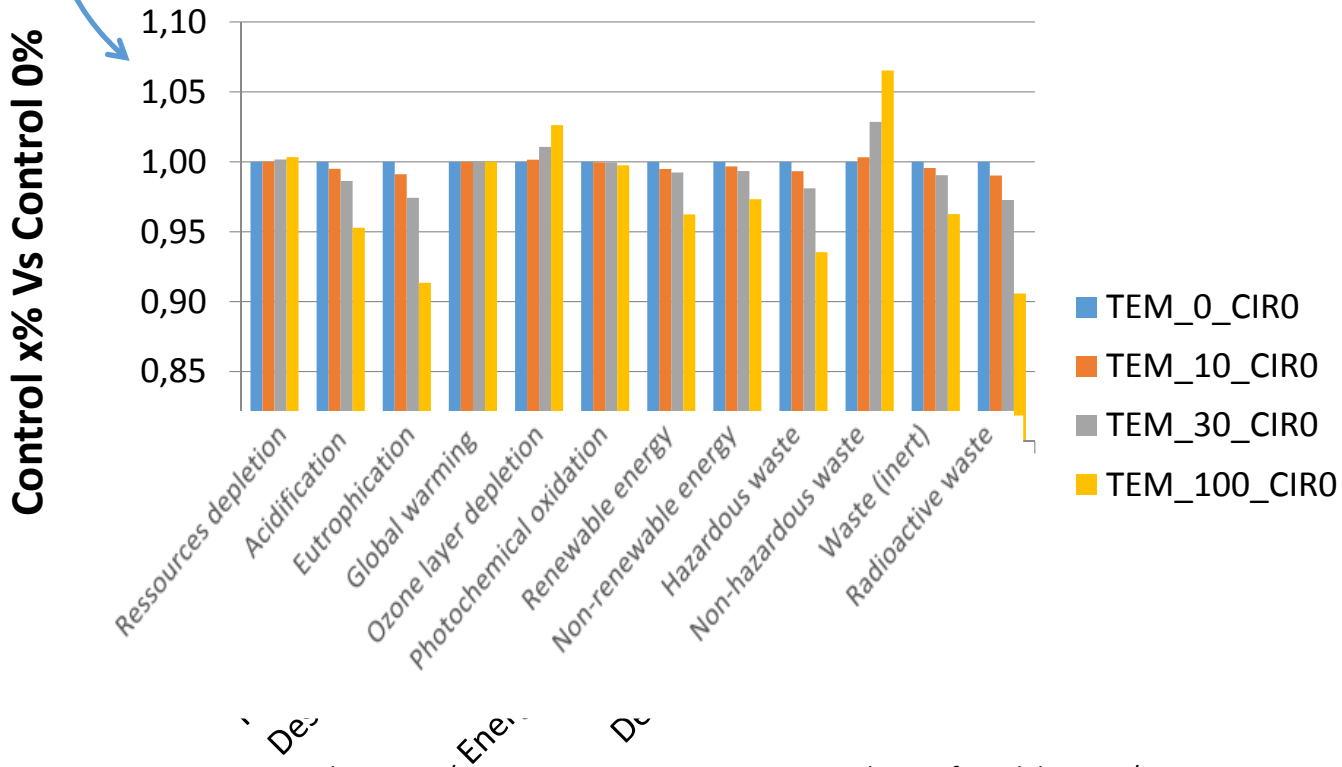
- Differences between compositions: admixture %, total water, aggregate mass (ρ)

- Preliminary analyse in t.km
  - Sensitivity to transport

$$\text{t.Km} = M_{RA} \times D_{RA} + M_{NA} \times D_{NA} + M_{concrete} \times D_{concrete}$$

Control concrete LCA

- Moderate deviation: ± 10%
- Impact Indicator gap between aggregates is moderate and the impact of cement remains predominant

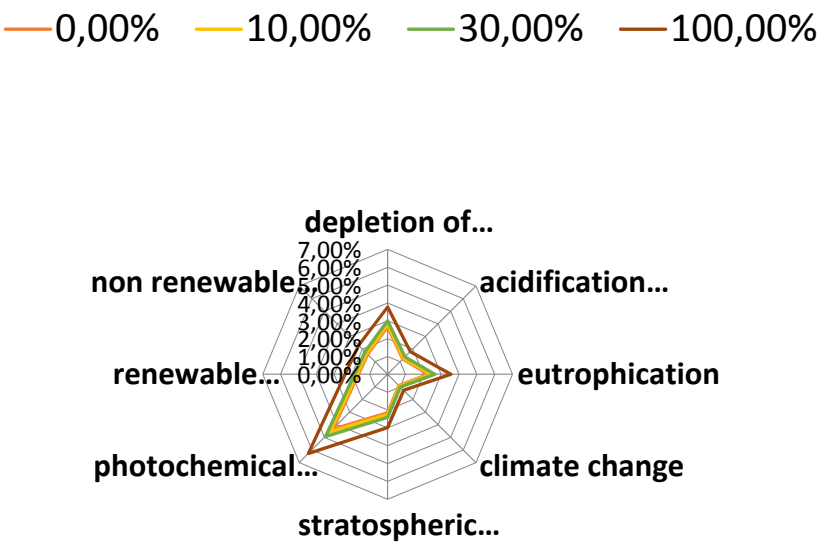


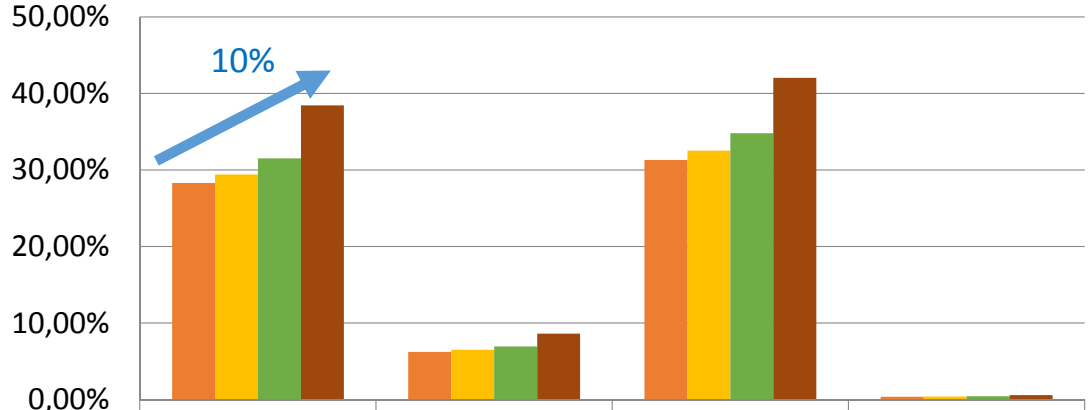
LCA sensitivity study

To what extent are the differences in t.km influencing the environmental impact indicators?

Share of aggregate and concrete transport on penalizing circuit

Strasbourg circuit





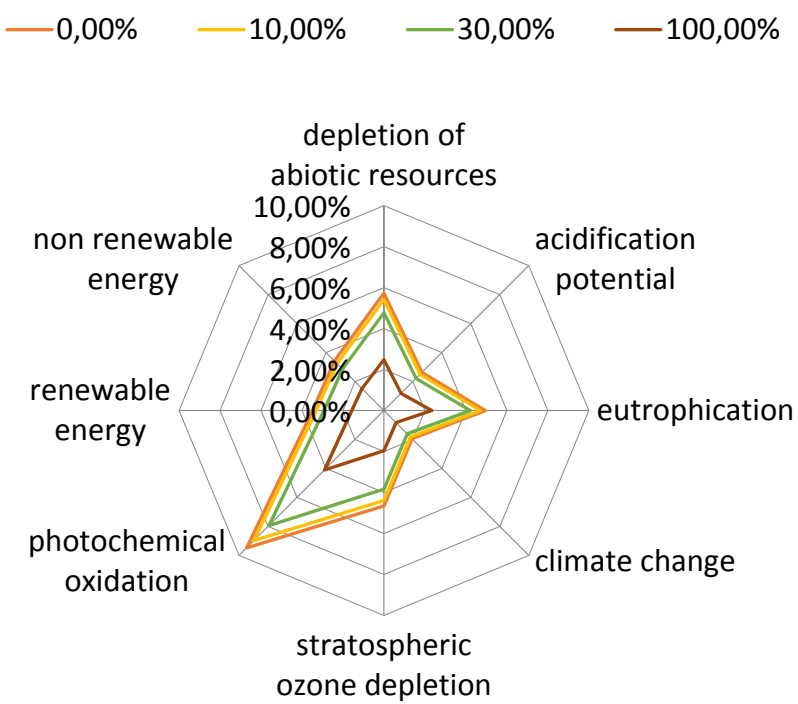
	Hazardous waste	Non-hazardous waste	Inert waste	Radioactive waste
0,00%	28,31%	6,24%	31%	0,38%
10,00%	29,41%	6,52%	33%	0,40%
30,00%	31,53%	6,94%	35%	0,44%
100,00%	38,46%	8,63%	42%	0,59%

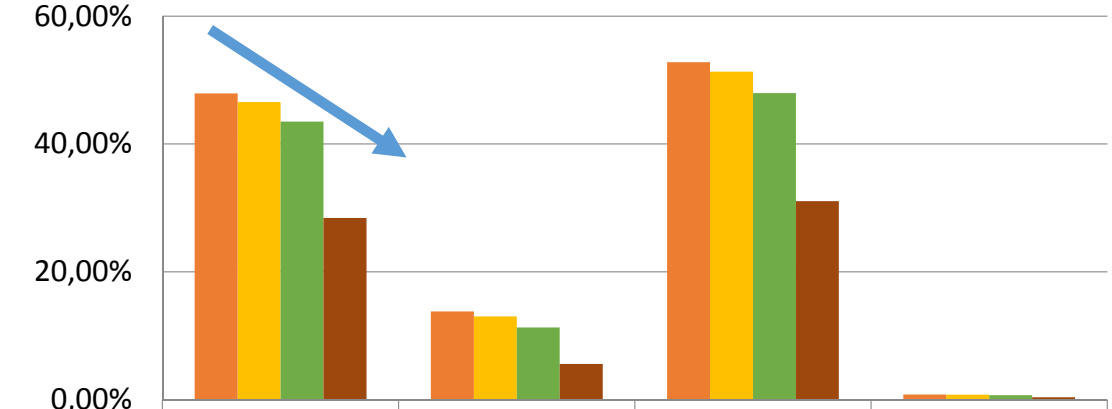
LCA sensitivity study

To what extent are the differences in t.km influencing the environmental impact indicators?

Share of aggregate and concrete transport on penalizing circuit

Lille circuit

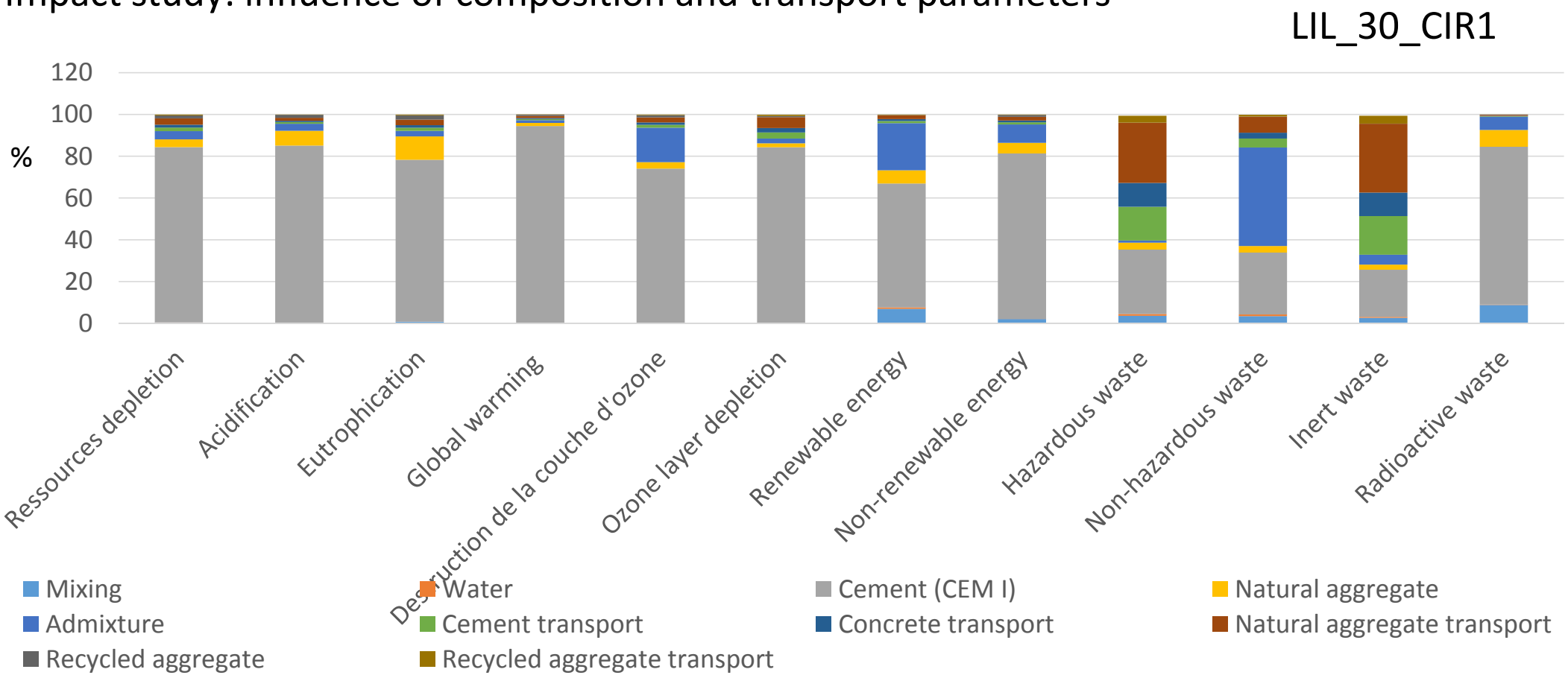




	Hazardous waste	Non-hazardous waste	Inert waste	Radioactive waste
0,00%	47,92%	13,79%	53%	0,81%
10,00%	46,55%	13,02%	51%	0,77%
30,00%	43,51%	11,29%	48%	0,69%
100,00%	28,43%	5,59%	31%	0,39%

LCA sensitivity study

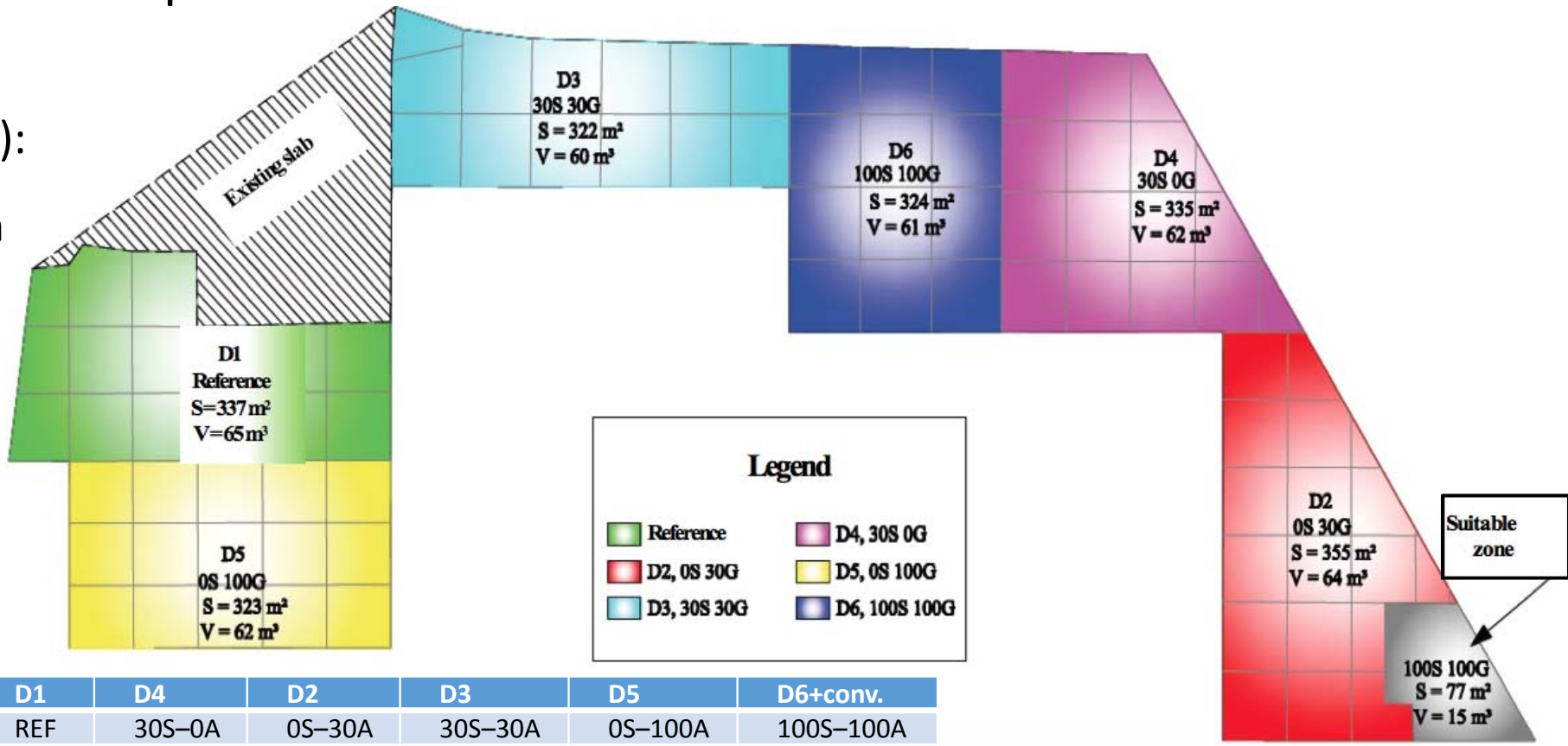
Impact study: influence of composition and transport parameters



Experimental construction sites

Chaponost (slab):

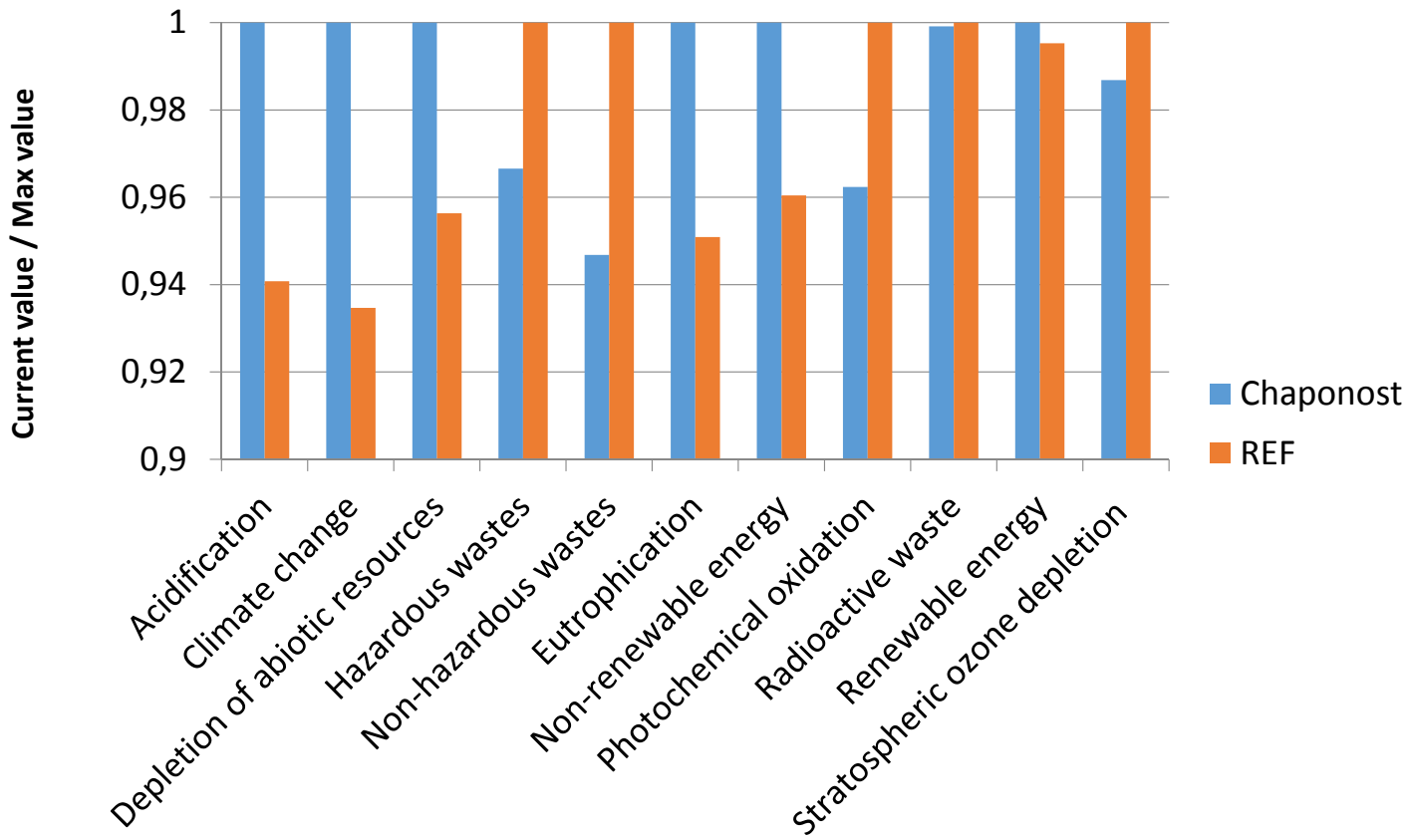
Site ground plan



	D1	D4	D2	D3	D5	D6+conv.
Components (kg/m³)	REF	30S–0A	0S–30A	30S–30A	0S–100A	100S–100A
Natural aggregate	1796	1467	1437	1151	772	
Recycled aggregate		235	282	514	778	1379
Cement	302	306	305	308	346	390
Plasticizer	2.57	3.65	2.60	2.62	2.94	3.32
Retarder		1.54	0.88	1.54	1.04	1.95
Water	173	188	178	205	205	260

Experimental construction sites

Comparison of experimental site and simulated construction site (100% natural aggregates)



Conclusion: environmental performances

How to measure them?

How to compare them?

How?

Standardized framework
(**LCA**)
or
Targeted impact study
+ Avoidance study

Ex: depletion of aggregates and waste storage

On what?

Reference materials
(for a defined function)
Or
Comparison
(influence of a substitution NA/RA)

BUT

Dilution effects if different compositions

Functional unit and reference flows

How far?

What transport
1 study →
1 circuit

Several circuits →
Study of sensitivity, influence of territorialisation

System boundaries

Thank you for your attention

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