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### ► To cite this version:

Alexandre Mielniczek, Charlotte Roux, Florence Jacquinod, Michel Dauvergne, Adélaïde Feraille.  
LCA model for roads at district scale. SETAC Europe 26th LCA Symposium, Oct 2024, Gothenburg,  
Sweden. , 2024. hal-04753909

**HAL Id: hal-04753909**

**<https://hal.science/hal-04753909v1>**

Submitted on 28 Oct 2024

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# LCA model for roads at district scale

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## Context / Introduction and Objective

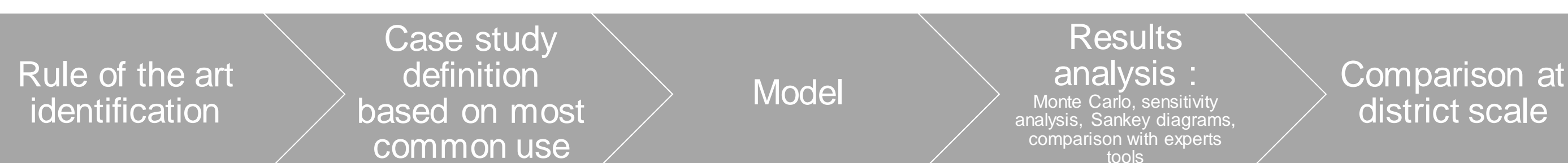
- Urban areas contribute to 75% of global energy use and produce 70% of the planet's carbon dioxide (CO<sub>2</sub>) emissions [i].
- Public spaces are highly artificialized and mainly dedicated to cars (e.g. In Paris, 60% of public space are devoted to cars [ii]).
- Major district-scale environmental impacts come from buildings, mobility, infrastructures (sidewalks and roads), networks and on-site energy production.
- Scientific literature considers that environmental impacts of roads and sidewalks seem to be underestimated [iii].

### Objectives of this study :

Develop a detailed road life-cycle model to estimates impacts from roads construction and maintenance

Verify if roads environmental impacts are underestimated at district scale

## 1. Methodology

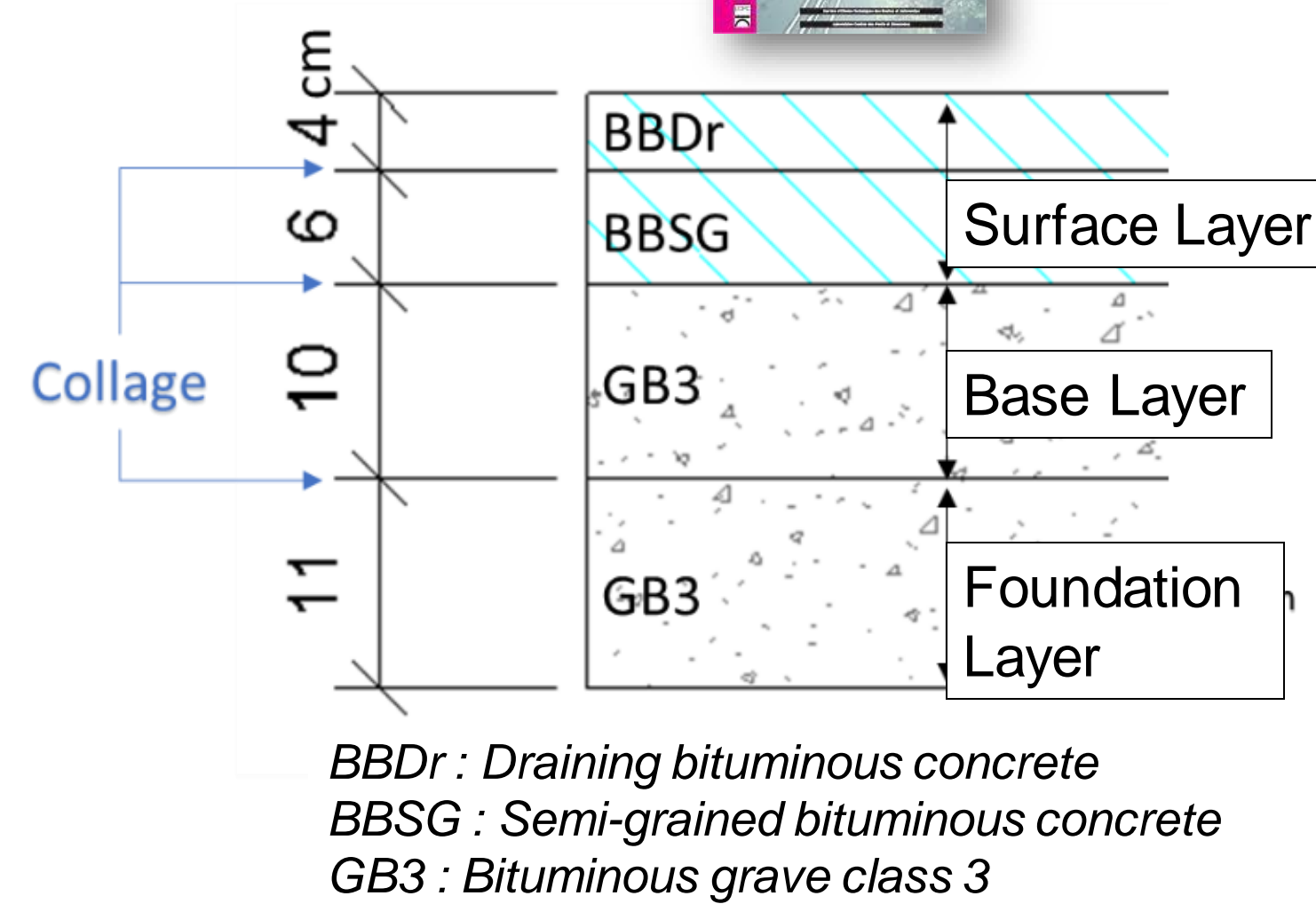


### Rule of the art identification :

- Model based on roads best practices design methodology [iv].

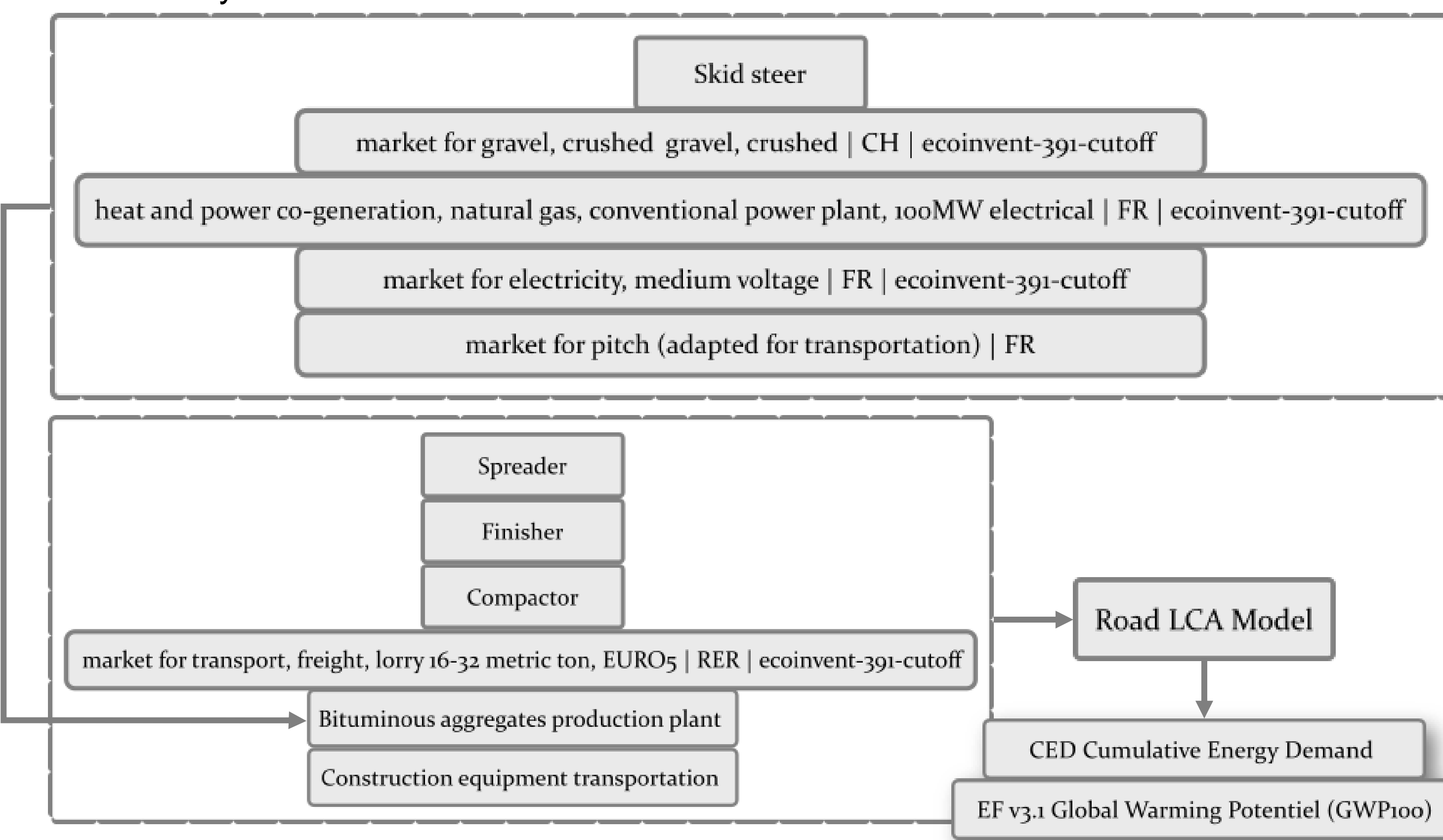
### Standard case of road implementation :

- Road structure consisting mainly of bitumen, supporting up to 6.5 million lorries during 20 years on one lane and one direction. The road is called GB3/GB3 TC5<sub>20</sub>
- Roads are refurbished every 7,5 years as best practices recommends it.



### Model :

- The schema illustrates the different processes used to build the road LCA model. It has been built using the Activity Browser interface relying on the Brighway2 calculation engine. Those tools are open source and widely used by the LCA community.



## 3. Discussion, Conclusion

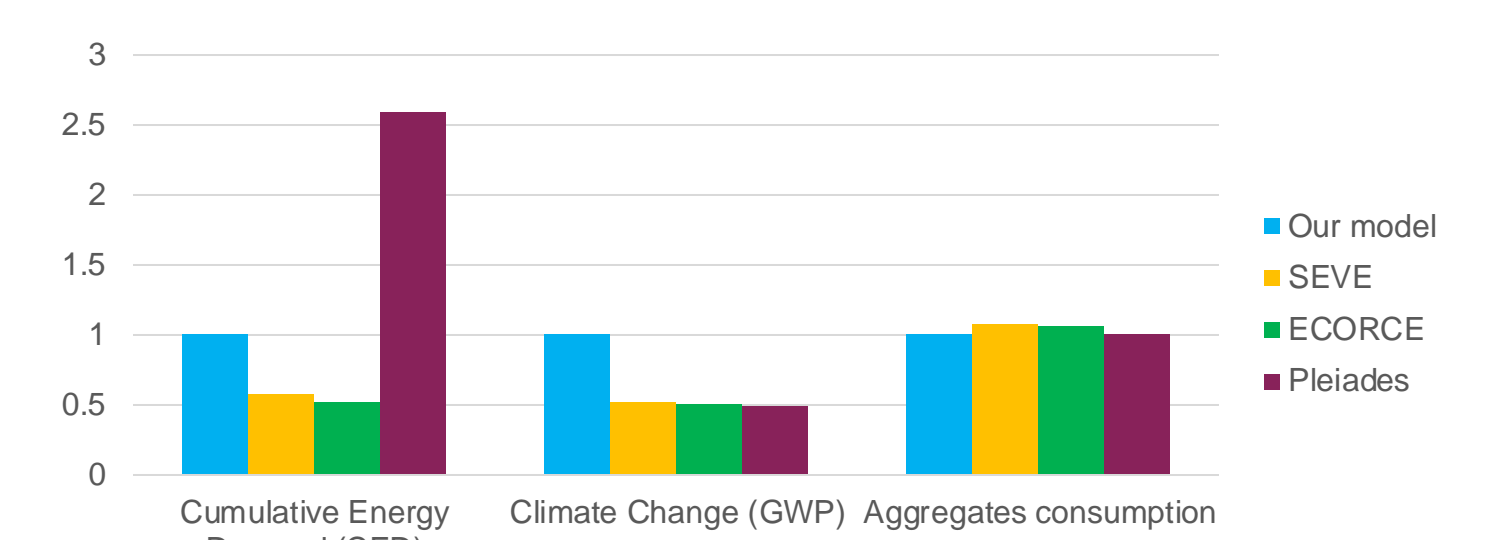
- Bitumen is the main contributor to the CED and GWP impacts, with significant discrepancies in data between Ecolnvent and EUROBITUME, raising concerns about data quality [vi].
- Road maintenance operations weight heavily on the whole road lifecycle, potentially surpassing construction impacts over time.
- Roads relative impacts are greatly neighbourhood density dependent. Proportionally, the denser a neighbourhood is, the lower roads impacts are.
- Results indicate low impacts of roads within neighbourhoods, suggesting a need for more attention to mobility impact allocation [vii].
- Roads could support the creation of green belts when roadside are vegetalized. Thus it could participate in the formation of a green network supporting biodiversity in cities and also participate to urban heat island reduction. Thermal performance of buildings could also be better studied by taking into account road albedo.

## 2. Results

- Calculation has been performed for a 30.000m<sup>2</sup> road with a GB3/GB3 TC5<sub>20</sub> structure as previously described.

- For the construction phase, the results are compared to expert tools dedicated to road LCA (SEVE and ECORCE) and to district LCA tool (Pleiades) :

Comparison is made only on this 3 indicators because it's the only calculated by specialized tools (SEVE and ECORCE).

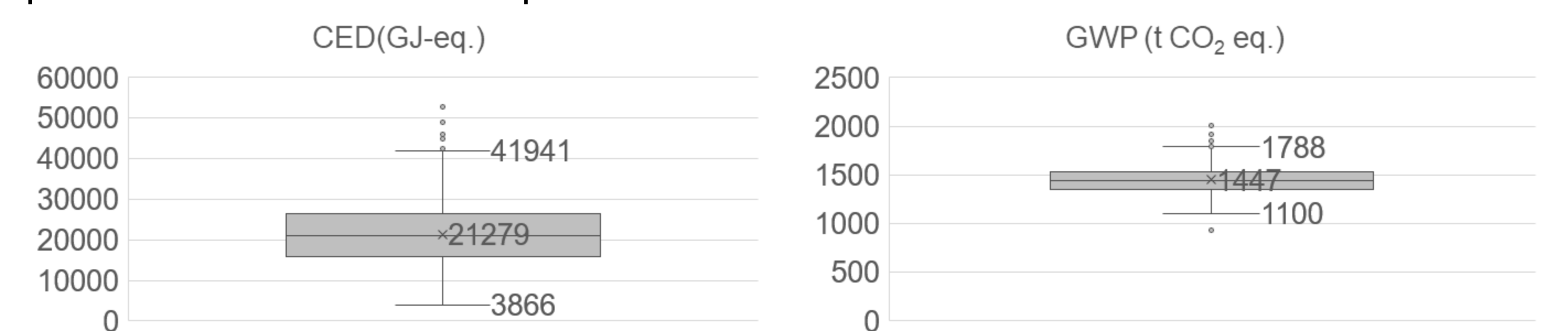


- For the road maintenance phase, calculation is made with 40% recycled aggregates :

Indicator	Value
Cumulative Energy Demand (CED) (GJ)	9 192
Climate Change (GWP) (t CO <sub>2</sub> eq.)	820
Aggregates consumption (t)	13 000

One maintenance operation represents half of the construction impacts when the whole road life cycle needs more than two maintenance operations.

- On our model, for the construction phase, Monte Carlo simulation has been run with 1000 iterations on Cumulative Energy Demand and on Global Warming Potential. The simulations used predefined score indicator in the Ecolnvent processes. The results are presented below :



- Then an uncertainty and global sensitivity analysis (moment-independent method and  $\delta$ -measure) is performed for Cumulative Energy Demand and Global Warming Potential. The tables here after present the results (higher delta value means higher sensitivity). We consider value above 0,07 as sensitive [v].

Sensitivity analysis for Global Warming Potential – Process name		$\delta$ delta
B: Methane, fossil // natural gas venting from petroleum/natural gas production (natural gas, vented) [GLO]		0.306118
T: petroleum FROM market for petroleum [Europe without Switzerland] TO pitch production, petroleum refinery operation (pitch) [Europe without Switzerland]		0.119219
T: natural gas, vented FROM market for natural gas, vented [GLO] TO petroleum and gas production, onshore (petroleum) [RU]		0.079315

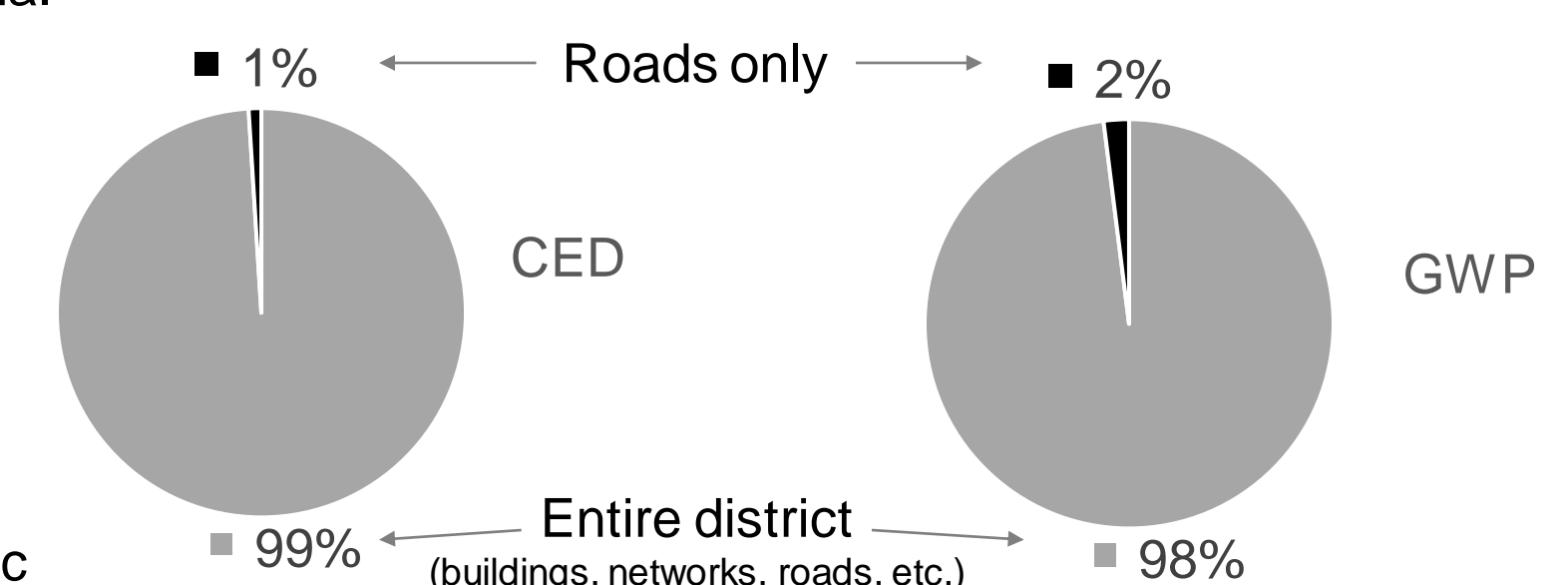
  

Sensitivity analysis for Cumulative Energy Demand – Process name		$\delta$ delta
T: petroleum FROM market for petroleum [Europe without Switzerland] TO pitch production, petroleum refinery operation (pitch) [Europe without Switzerland]		0.191181
B: Oil, crude // petroleum and gas production, onshore (petroleum) [RU]		0.179611
B: Oil, crude // petroleum and gas production, onshore (petroleum) [IQ]		0.092173
B: Oil, crude // petroleum and gas production, offshore (petroleum) [NO]		0.081312
B: Oil, crude // petroleum and gas production, offshore (petroleum) [NG]		0.07894

- We then compare the results with impacts from a dense district (construction and operation phases) based on a real case study. Calculations made by Pleiades tool.

Key data are the following : The district area is 20,6 Ha.

- 152.403m<sup>2</sup> floor area for residential needs, equivalent of 2.225 dwellings,
- 39 500m<sup>2</sup> floor area for offices,
- 15.050m<sup>2</sup> floor area of commercial spaces,
- 3 scholar groups,
- 1 gymnasium,
- 1 urban farm of 1 hectare,
- 1 parking of 450 places,
- 8 hectares of vegetalized spaces private and public combined.



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