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How cold-*in situ*-recycling pavement rehabilitation processes could improve circular economy results: Case study of a Spanish road

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Introduction & Background

Roads' main objective is to provide a high quality service to users in order to meet their mobility needs. The average road surface's life-time is between 20 and 30 years due to the fact that its initial characteristics are degraded over time. This deterioration period depends on several key factors:

- Those directly related to the structural design. the construction process or the number of planned rehabilitation and maintenance operations during its useful life.
- Those linked to the traffic (intensity. type. loads. speed. etc.) or to different environmental aspects (temperature variations. rain. snow. frost. salt. solar radiation. oxidation processes of binders. etc.).

Therefore. the main objectives of the rehabilitation and maintenance operations are twofold:

- To preserve the asphalt road in optimum conditions in order to guarantee a safe circulation of road users.
- To avoid the costs that a total road reconstruction may entail.

Several techniques for repairing roads are used to extend their life-spans. from traditional asphalt overlays or reconstruction to more updated methods which use recycled materials either cold or hot. either in-plant or in-place (*in-situ*). The choice of the appropriate technique can have important environmental sustainability implications.

The objective of this study is to present the preliminary results of an environmental assessment of a modern pavement rehabilitation technique (cold – *in situ*) located in Huelva (Spain). in a section of 400 metres of A-672 road. by means of a life cycle approach.

Materials & Methods

The environmental assessment has been done by means of the calculation of the Environmental Footprint (EF).

The unit of analysis has been referred to the total rehabilitated area. So, if a width of 4.1 metres is considered. the total rehabilitated area is 1640 square metres.

Regarding the system boundaries. the following main processes have been included:

- Extraction and analysis of pavement samples.
- Raw materials extraction.
- Transport of these materials to the construction site or the materials' production plants.
- Bitumen. water and asphalt mixtures manufacturing and their distribution to the construction site.
- Infrastructures (except asphalt plant).
- Rehabilitation stage.

Air.e ® Software has been used in order to obtain the results. Figure 1 shows a general flow chart of the process as shown in the software.

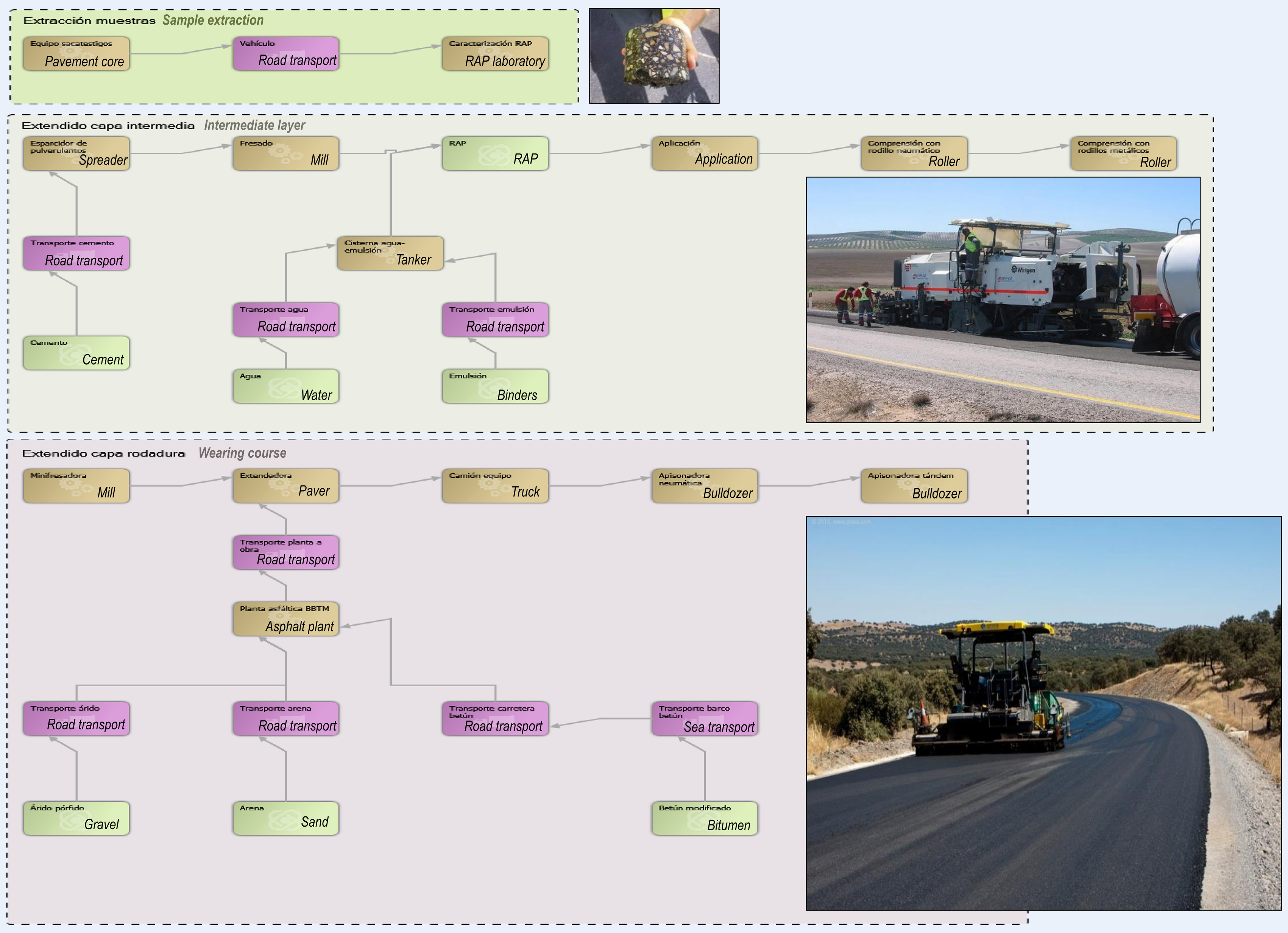

Figure 1. Flow chart of the system boundaries considered in the rehabilitation technique (Air.e screenshot).

Results

Table and Figure 2 show the results of the EF considering the main life cycle stages.

Impact categories	Sample	Raw Materials	Transports	Manufacturing	Placing	Total	Total (by m²)
Acidification (mol H⁺)	3.76E+01	3.46E+01	3.13E+01	4.18E+01	6.21E-01	**1.46E+02**	**8.90E-02**
Water Depletion (l SWU)	1.66E+06	2.83E+06	1.97E+07	1.88E+05	1.07E+04	**2.44E+07**	**1.49E+04**
Mineral Depletion (kg Sb eq)	2.39E-01	1.67E-01	6.79E-01	1.38E-02	4.99E-03	**1.10E+00**	**6.73E-04**
Ozone Depletion (kg CFC-11 eq)	9.19E-03	6.79E-04	7.01E-04	7.10E-04	1.65E-05	**1.13E-02**	**6.89E-06**
Global Warming (kg CO_2 eq)	4.07E+03	3.76E+03	6.96E+03	3.95E+03	9.80E+01	**1.88E+04**	**1.15E+01**
Fresh Ecotoxicity (CTU_e)	2.31E+06	2.23E+05	2.23E+05	3.60E+05	1.92E+03	**3.12E+06**	**1.90E+03**
Human Toxicity (cancer) (CTU_h)	2.08E-04	1.04E-04	1.62E-04	1.05E-04	5.44E-06	**5.85E-04**	**3.57E-07**
Human Toxicity (non-cancer) (CTU_h)	5.46E-04	6.52E-04	3.75E-04	1.43E-04	3.59E-05	**1.75E-03**	**1.07E-06**
Particle Material (kg $PM_{2.5}$ eq)	2.82E+00	2.58E+00	3.75E+00	5.08E+00	7.34E-02	**1.43E+01**	**8.72E-03**
Fresh Eutrophication (kg P eq)	1.20E-01	4.90E-02	2.04E-01	2.85E-02	4.29E-03	**4.05E-01**	**2.47E-04**
Marine Eutrophication (kg N eq)	6.86E+00	6.79E+00	4.35E+00	1.77E+01	1.88E-01	**3.59E+01**	**2.19E-02**
Terrestrial Eutrophication (mol N eq)	7.56E+01	7.47E+01	4.82E+01	1.94E+02	2.05E+00	**3.95E+02**	**2.41E-01**
Photochemical Ozone (kg NMVOC eq)	2.98E+01	2.21E+01	1.79E+01	5.34E+01	6.43E-01	**1.24E+02**	**7.55E-02**
Ionizing Radiation (kg U^{235} eq)	3.35E+03	3.21E+02	2.93E+02	2.67E+02	7.86E+00	**4.24E+03**	**2.58E+00**
Land Use (kg C def)	7.97E+04	1.52E+04	7.22E+03	9.83E+03	2.95E+02	**1.12E+05**	**6.84E+01**

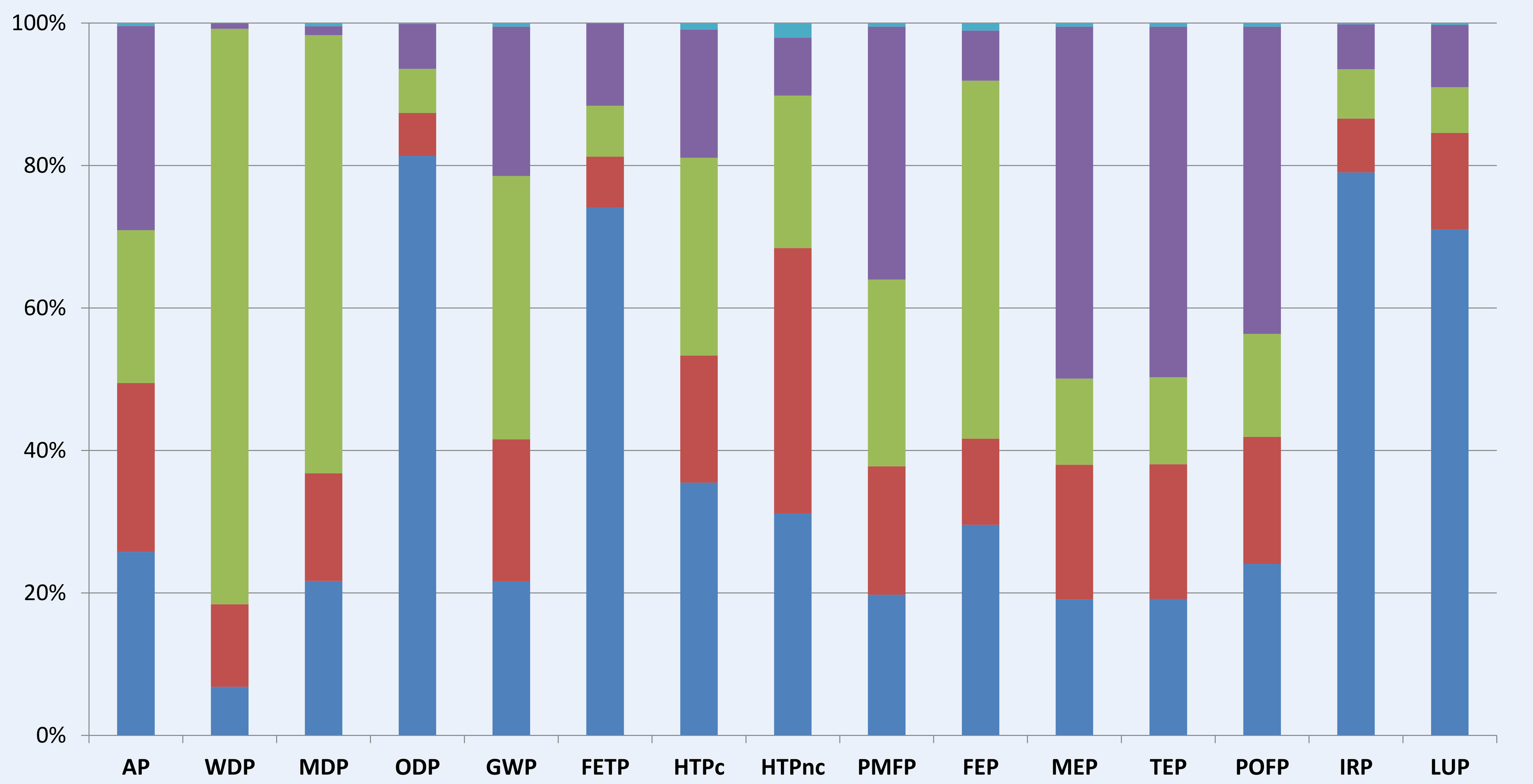

Figure 2. Percentage of contribution of each stage.

Discussion & Conclusions

Results could be used as a basis for comparison with both newer restoration techniques in the country and the use of advanced materials.

Global results allowed the identification of 'hotspots' in order to consider future actions for reducing the environmental impact, such as the processes of raw materials mining and certain processes of manufacturing materials. Therefore, the cold-in situ and the use of RAP are advisable to achieve it.

PROYECTO REPARA 2.0
Desarrollo de nuevas técnicas y sistemas de información para la REhabilitación sostenible de PAvimentos y carreteRAs

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