Sustainability & Environment

Project LIFE BATTLE CO2. Sustainability in asphalt manufacturing

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Abstract

The Project LIFE BATTLE CO2 “Biomass incorporation in asphalt manufacturing towards less emissions of CO2” represents an innovative effort in the sustainability of the asphalt mixes, focused on the substitution of fossil fuels during the manufacturing process in the asphalt plant. The manufacturing stage of the asphalt mixes represents 50% of the GHG emissions of the asphalt mix considering a cradle to construction approach (including raw materials, raw materials transportation, manufacturing, distribution and construction works). During the manufacturing stage, aggregates heating and bitumen heating are the most energy demanding processes, including the consumption of fossil fuels. Aggregates are usually heated using natural gas or fuel, while bitumen is heated with gasoil. The high dependence on fossil fuels during the manufacturing process is the reason for the CO2 emissions in the asphalt plant, and the project LIFE BATTLE CO2 has been focused on this issue. The Project has developed several prototypes (at semi-industrial scale) specially designed for the aggregate heating and for the bitumen heating using biomass as fuel in both cases for the asphalt manufacturing. The substitution of fuel by biomass in the aggregate heating process has resulted in 75 % decrease in the GHG emissions in the asphalt plant. The substitution of gasoil by biomass in the bitumen heating resulted in 12 % decrease in the asphalt plant. A decrease of 87 % in the GHG emissions in plant was obtained, as well as a reduction of 40% in carbon footprint of the life cycle of the asphalt mix in a “cradle to construction” scope. The project has been also focused on developing the Product Category Rules for the asphalt mixes according to the ISO 14025 Environmental Labels and Declarations – Type III.

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1. INTRODUCTION

Nowadays, most of industrial activities are being analysed under criteria of circular economy and although road infrastructures generate relatively small environmental impacts compared to those of the vehicles rolling on them, this does not prevent trying to reduce the environmental impacts of this type of infrastructure.

From the previous paragraph it could be deduced that the concern for environmental issues in the road sector is small, which is far from the reality. To illustrate this statement let's look at some examples: when the general public is asked which is the most recycled material, the vast majority of responses are directed to plastic packaging, paper or glass. However, few people know that milling from roads made with bituminous mixtures is one of the most reused materials, placing the emphasis on the term reuse since recycling is on a lower step than reuse under sustainability criteria.

Likewise, the asphalt paving sector has been supporting the use of residues in its manufacture for decades, such as crumb rubber. Other by-products that are commonly used in the manufacture of asphalt pavements are steel slag, recycled polymers, etc. In the case of the USA, 76.2 million tons of materials from asphalt pavements were recovered in 2017, of which 99% were reused/recycled in new asphalt mixes [1].

Therefore, the engagement in environmental issues by the road sector is nothing new but it is true that the number of issues to be addressed has increased.

The fight against climate change continues to be at the forefront of the European Union's priorities. Proof of this is the new structure of the LIFE Programmes (LIFE Programme, 2017), the only European funding instrument dedicated exclusively to the environment, where climate change accounts for 25% of the Commission's budget for this type of project.

COP21 in Paris was a cornerstone in which the current state of the fight against climate change was evaluated and the commitments of governments with respect to this environmental problem were updated.

LIFE BattleCO2 is a demonstration project, where the asphalt mix manufacturing sector has proved to be ideal for undertaking the different actions established within the framework of this project. The BattleCO2 project aims to address one of the environmental problems that has traditionally been associated with the asphalt mix sector, which is its high dependence on fossil fuels, and therefore, the CO2 emissions associated with it.

For this purpose, the LIFE financing instrument has been used, which allows the development of demonstrating and innovative projects, with the aim of providing information to all stakeholders in the sector, and the final intention of providing a high potential for replicability in the sector based on the results obtained in the project.

The project is coordinated by CARTIF Foundation, including the participation of the construction company COLLOSA, and the Spanish Road Technological Platform (PTC), as associated beneficiaries.

But to understand how we can still improve the sustainability of asphalt pavements we have to take a look at the whole production process and quantify the impacts of each of the stages. In figure 1 we can see the different stages that ranging from the raw materials to the paving operations, passing through the processes of transport and manufacture of the asphalt mixes themselves and their environmental impact, measured as impact on global warming (kg CO2 eq).

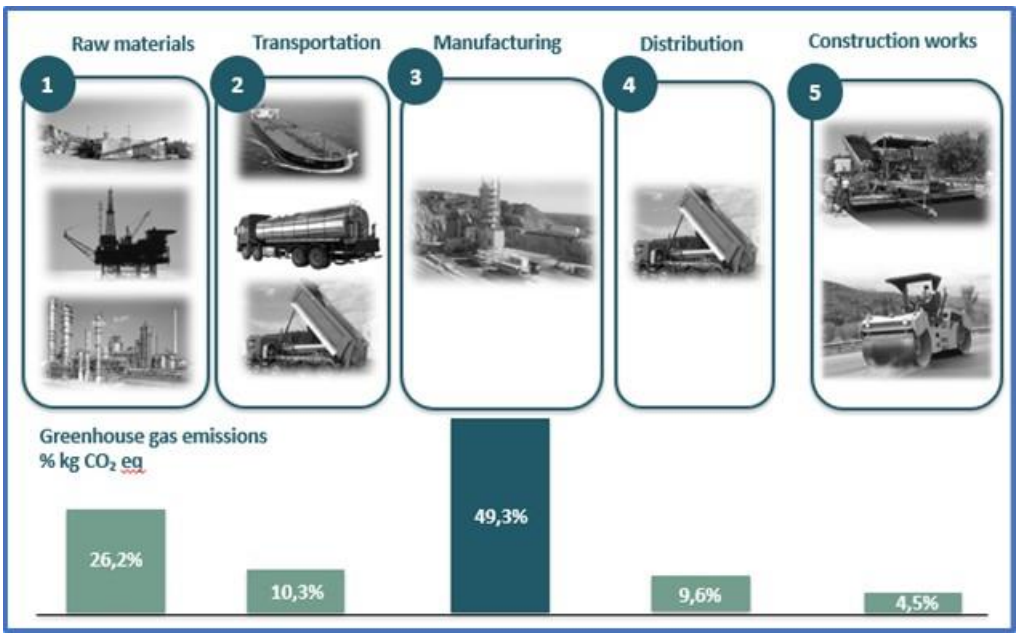

Figure 1: Life Cycle Assessment of bituminous mixes (source COLLOSA)

The data in the graph above show that the manufacturing stage is the one that generates the greatest environmental impact. It should be borne in mind that the vast majority of bituminous mixes manufactured worldwide are hot mixes. Due to the great impact that the manufacturing phase has, for two decades the asphalt paving sector has been working on the development of mixtures that are manufactured at a lower temperature, with warm mixes being the most popular when a significant reduction in the manufacturing temperature is required.

The fuels used to manufacture hot bituminous mixtures have a fossil origin: diesel, fuel oil and natural gas, so their carbon footprint is perfectly defined and they do not have any "bonus" because they are not CO2 sinks.

A different approach to mixtures manufactured at lower temperatures to reduce the carbon footprint of the manufacturing phase of asphalt mixtures is the use of fuels with lower emission values. Two can be included in this category: recycled fuel and biomass. The first of these is not the subject of this article, so we will focus on the use of biomass.

Many sectors, especially those related to energy generation, have been using biomass as an alternative fuel. The burners and auxiliary systems for this type of applications are widely known, however their use for the manufacture of bituminous mixtures adds a series of additional technical requirements that have been developed in the BattleCO2 Project. The following sections will describe these developments and how they have led to an operational pilot plant that allows reductions in CO2 emissions in the manufacturing phase of the order of 80%.

A second group of considerations that have also been dealt within the project focus on finding objective environmental assessment systems that allow for a double aim: to confirm that the technological developments of the pilot plant make it possible to achieve the planned improvements and, furthermore, to provide the market with a tool that can be used in public tenders. We should remember that the asphalt paving sector is almost entirely focused on customers that are public administrations.

The publication in 2014 of directive 24/1024 2 on public procurement included environmental criteria as relevant criteria when making tenders. The inclusion of technical or environmental criteria also requires the existence of objective quantification methods so that the various bids submitted can be analysed and properly assessed.

The Joint Research Center (JRC) in collaboration with the European Commission published two relevant documents to assist in procurement processes that include environmental criteria (known as Green Public Procurement, GPP) [3] [4]. The European Commission also published the document "EU Green Public Procurement Criteria for Road Design, Construction and Maintenance [5] which takes an additional step in defining environmental criteria that may be of high importance in the road construction and maintenance sector.

To close the circle, at the beginning of 2019 the Spanish administration published the National Plan of Green Public Procurement which includes a specific section for the design, construction and maintenance of roads that is in line with the aforementioned European documents.

Although all these documents give legal support to the use of environmental criteria, they do not go into such detail as to provide objective and quantifiable criteria. For this reason, the BattleCO2 project included in its workplan the development of product category rules (PCR) and an environmental product declaration (EPD) for the bituminous mixtures used in the test sections foreseen in the project.

2. DEVELOPMENT OF PROTOTYPES OF BIOMASS BASED HEATING SYSTEMS

Energy consumption of asphalt plants is mainly concentrated in the aggregate drying and heating system as well as in the bitumen heating system. These two elements are the focus of the BattleCO_2 project. The final objective was to have a prototype plant that would demonstrate the readiness of the technology.

Since it was a prototype, the design had to be carried out by coupling a small aggregate and bitumen heating system that could take advantage of other elements of a conventional asphalt plant.

The pilot plant was installed in the town of Cubillas de Santa Marta within the facilities of an asphalt plant of the enterprise COLLOSA.

Figure 2: Top view of the aggregate and bitumen heating systems

In order to carry out the sizing of the pilot plant, a detailed study has been carried out on the calorific capacity of various models of heating systems.

Design of bitumen heating system is simpler than the aggregates heating, but there are some factors that must be taken into account when developing the transition from fossil to biomass:

- Biomass facilities are considerably more bulky than conventional diesel oil boilers commonly used in asphalt plants.
- The handling of solid fuel implies certain peculiarities to which the manufacturers of asphalt mixtures are not used, such as storage silos and feeding equipment, and the correct storage of the biomass to be protected from the rain or humid environment.

The aggregates heating in asphalt mixtures manufacturing process is usually developed using fuel or natural gas. Yield ratios can lead to an interval from low production 80-100 tonnes / hour, to production close to 350 tonnes of heated aggregates per hour. The type of asphalt mix (hot, warm, or half-warm) also has influence in the ratio of production of this heating equipment.

The LIFE BattleCO_2 project is a demonstrator for the use of biomass as a fuel, reaching a production of 30 ton/hour at 160 ºC, but being able to produce higher ratios when manufacturing warm mixtures (manufacturing temperature 110-140 ºC) or half-warm (manufacturing temperature 85-95 ºC). Although the prototype included in the project has an experimental character and the objective is the validation of the technique, this prototype could manufacture

around 30 t/h of hot bituminous mixture, 40 t/h of warm mixture or 90 t/h of half-warm bituminous mixture under real operation conditions.

Moreover, in the project LIFE BattleCO_2, the production of industrial plant of COLLOSA can be increased by almost 20%, without increasing CO2 emissions and achieving this increase using renewable fuel (biomass) instead of fossil fuel.

When addressing the transition from fossil to biomass in the process of aggregates heating, the type of mix to be manufactured, as well as the location and logistics of aggregates must be clearly understood. The most recommendable process involves the increase of the production capacity with the help of biomass, allowing to have a versatile system of aggregate heating according to the specific needs of the company.

The aggregates heating is the most complex element of the whole system when facing the change of fuel. The following critical points must be considered, among others:

- Level of fossil fuel substitution in the process of aggregates heating.
- Level of production to satisfy.
- Assessment of the incorporation of biomass gradually, that is, as a method to increase production capacity, in order not to be 100% biomass-dependent, which could be a risk.
- Equipment to be incorporated into the aggregate heating process to face the fuel change

The process of heating aggregates in the rotary drum according to the new process using biomass presents the same configuration as the conventional process, with direct flame in rotary drum and counter flow. The area of the burner is very close to the exit of hot aggregates, and an incorrect dosage of the biomass in the burner or an excessive flow of air for the combustion can cause that pellets still without finishing burning fall to the rotary drum and contaminate the hot aggregates. Therefore, it is necessary to control the exit of the aggregate of the rotary drum, as well as adjust the parameters of the burner to achieve a good combustion and ensure the permanence of the pellet in the combustion zone the right time.

Figure 3: Installation of the aggregates heating system.

The systems installed in the LIFE BattleCO_2 project have taken into account the fact that biomass fuels generate ash during combustion. The cyclones and bag filters are correctly designed to be in accordance with the normative, so flying ashes and potential particular matter are managed correctly.

The process of heating the aggregates and the exhaust pipes of the combustion gases should be designed to obtain an adequate flow speed to encourage the decantation of particles in the cyclone.

The exhaust gases temperature must be taken into account during the design stage in order to avoid an excess of temperature that may cause damages in the bag filters.

It is important to conduct a research on the availability of local biomass in the area in which the asphalt plant is located, according to the following criteria:

- The area is rich in biomass resources.
- Location of the suppliers, stock of biomass and supply guarantee depending on the manufacturing needs.
- PEFC (Programme for the Endorsement of Forest Certification) certificate that ensures the sustainability of biomass, a forest certification system that guarantees the correct management of natural resources.

Besides, CARTIF has an extensive experience in biomass characterization what allowed the right choice of the biomass supplier and the type of biomass to be used in the pilot plant.

Figure 4: Handling of biomass in the pilot plant

3. MANUFACTURING OF ASPHALT MIXES WITH BIOMASS HEATING SYSTEMS

The objective of this phase of the project was to demonstrate that the pilot plant could be used to obtain the heating temperatures that would allow the production of asphalt mixtures of the appropriate quality. Another element to verify was whether the heated aggregates had been contaminated with ash from the biomass combustion.

At the same time, manufacturing tests with biomass were also used to measure fuel consumption and emissions, which allow data to be provided for the environmental assessment described in the following chapter.

The manufacturing of bituminous mixtures using biomass as alternative fuel has been tested in the project LIFE BattleCO2 working in different mixing typologies:

- Conventional hot mix asphalt
- Warm asphalt with bitumen foam
- Recycled mixtures (cold Reclaimed Asphalt Pavement up to 20%)

In addition to these types of mixtures, biomass use is compatible with other fabrication models, as the hot recycling or half-warm mixtures.

The fabrication of mixtures at lower temperature than the hot mix ones represents a great opportunity to the biomass introduction in the sector.

Both the warm and the half-warm mixes provide an increase in the levels of production that can be reached by the biomass equipment for the asphalt mixes sector. On the other hand, it contributes to the overall energy improvement of the product and the process, since its energy needs are reduced, so it is advisable to consider the possibility of working in this type of mixes when the introduction of the biomass in the manufacturing process. Base, binder and surface course mixes have been studied.

For the manufacture of asphalt mixtures, a complete characterization of the aggregates and the final mixtures was carried out. In the case of aggregates, the existence of unburned ash or biomass was studied, as well as the effect on properties such as Los Angeles abrasion test.

As a conclusion, it can be said that the biomass used as fuel for drying and heating the aggregates passed through the heating drum has no influence on the properties and characteristics of the aggregates since they are not affected by the use of this material as fuel, resulting practically identical to those obtained when the aggregates are dried and heated with fossil fuel.

This phase of the project concluded with the commissioning of two test sections of bituminous mixtures type AC16 50/70 S, one of them on the A-62 dual carriageway and the other on the CL-615 road.

Figure 5: Test site in CL-615 road

4. ENVIRONMENTAL EVALUATION

All the activities indicated in this chapter are based on a detailed life cycle assessment (LCA) of asphalt pavements, which allowed to establish the quantitative objectives of the project: for example, estimating the potential reduction of greenhouse gas emissions. The experience of the project partners on these topics has allowed to confirm at an experimental level the previous estimates.

The functional unit of the study was 1 ton of asphalt mix, including the following stages within the product life cycle:

- - Extraction and acquisition of raw materials,
- - Transport of raw materials,
- - Manufacturing processes,
- - Distribution up to the construction site,
- - Laying

Excluded from the study are the maintenance and end-of-life process, which are normally linked to pavement sections and not to the asphalt mixes themselves.

The environmental indicators that were used in this project were those that appear in the ReCIPE, CML and CED methodologies. The different indicators are listed in table 1.

Table 1. Environmental indicators used to evaluate the impact of the LIFE BattleCO2 project.

Impact category	Indicator	Units	Code	Methodology
climate change	Midpoint	kg CO2 eq	CC	CML
ozone depletion	Midpoint	kg CFC-11 eq	DCO	CML
terrestrial acidification	Midpoint	kg SO2 eq	A	CML
eutrophication	Midpoint	kg PO4-3 eq	E	CML
photochemical oxidation	Midpoint	kg C2H4 eq	OF	CML
Abiotic depletion (resources)	Midpoint	kg Sb eq	AA(E)	CML
Abiotic depletion (fossil fuels)	Midpoint	MJ	AA (CF)	CML

Human toxicity	Midpoint	kg PM 10 eq	TH	CML
Terrestrial ecotoxicity	Midpoint	kg 1-4 DB eq	ET	CML
Particulate matter formation	Midpoint	kg PM 10 eq	FMP	ReciPe
Ionising radiation	Midpoint	kg U235 eq	RI	ReciPe
Water depletion	Midpoint	m3	AA	ReciPe
Cumulative energy demand	Midpoint	MJ	CED	Cumulative energy demand

In addition to these indicators, direct emissions will also be reported according to actual measurements, but also emissions calculated by means of evaluation software. Besides the following primary indicators will be monitored:

- Percentage reduction in fossil fuel use
- Reduction of greenhouse gases
- Reduction of CO
- Reduction of SOx emissions
- Decrease in the manufacturing process in the consumption of fossil fuels in bituminous mix and recycled bituminous mix.

Several types of asphalt mixes were studied in order to decide which one would be used in the test tracks. Table 2 collects the set of asphalt mixes to be evaluated.

Table 2. Type of bituminous mixes included in the evaluation procedure

Layer	Type of bituminous mix
Base	AC22 base 50/70
	AC22 base 50/70 RAP (10 % y 30 %)
Binder	AC 22 bin 50/70 S
	AC22 bin 50/70 S RAP (10 % y 30 %)
	AC 22 bin 50/70 D
	AC22 bin 50/70 D RAP (10 % y 30 %)
Surface	AC 16 surf 50/70 S
	AC 16 surf 50/70 D
	BBTM 11 B surf with PMB
	PA-16 surf with PMB

Life cycle assessment of the various mixtures have been carried out on the basis of data generated in the last 8 years.

At this stage of the project, two differentiated objectives can be distinguished, although with important interactions: the measurement and evaluation of the environmental impacts generated by the production of bituminous mixtures through the use of biomass in comparison with the standard scenario of fossil fuel. A second objective was to make the evaluations traceable and verifiable under an external audit scheme, for which specific product category rules (PCR) have been developed and subsequently an environmental product declaration (EPD) based on these rules was obtained.

Regarding to the first goal, Figure 6 shows the results that the prototype generates in the global warming category. Other impact categories have been measured and evaluated, which are cited in the EPD, but given the importance of greenhouse gas emissions it seems appropriate focusing on this parameter.

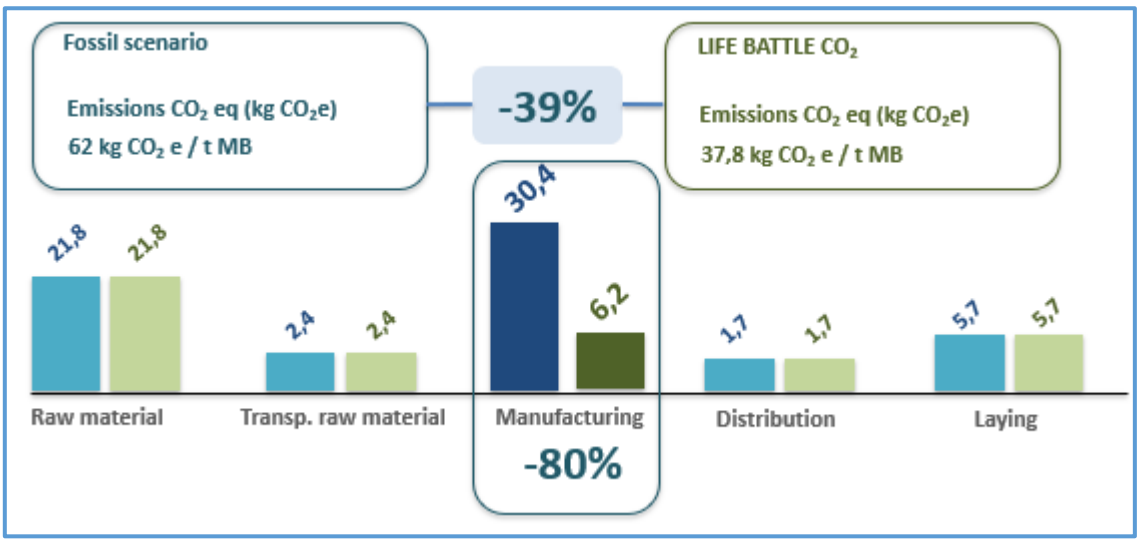

Figure 6: Comparison of carbon footprints of bituminous mixes before and after BattleCO$_2$

In view of the above data, it can be stated that the environmental impact reduction targets for the global warming category have been achieved.

It has already been mentioned that the development of product category rules [6] has also been the goal of the project. When defining system boundaries, the developed PCR scheme may include the following phases.

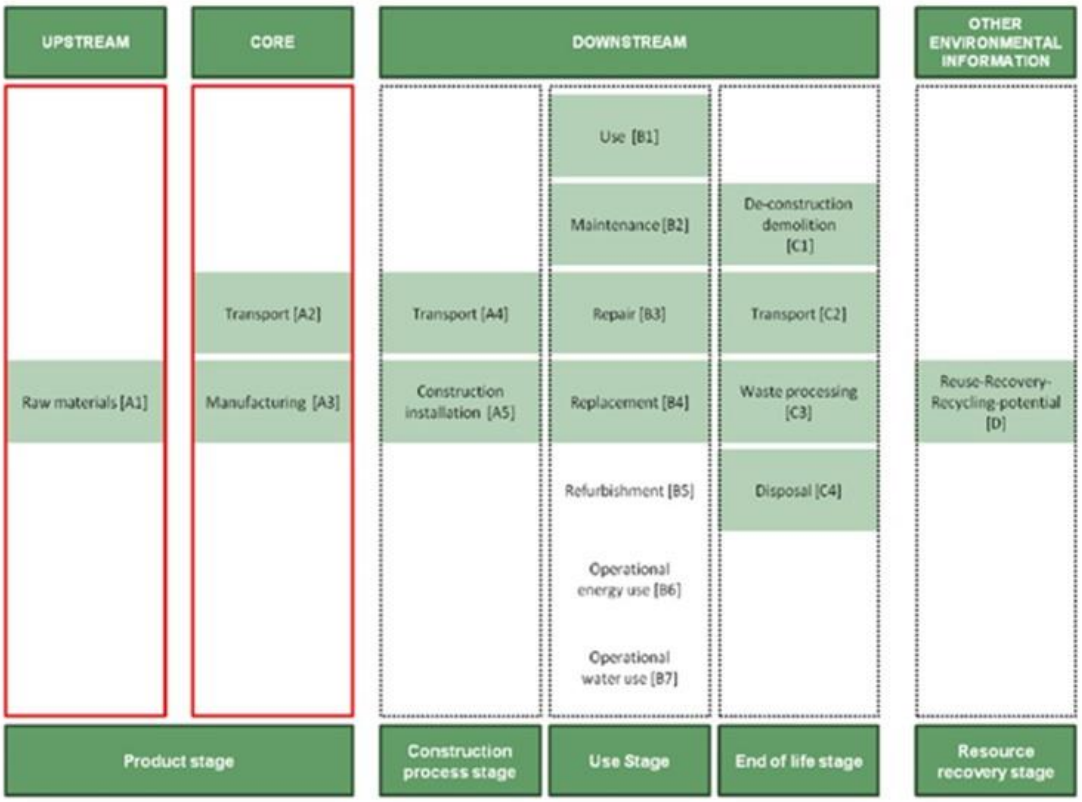

Figure 7: System boundaries for the PCR developed in BattleCO$_2$ project

The environmental product declaration (EPD) generated in this project covers stages A1-A3: raw materials, transport and manufacturing. The details of this EPD are public and can be consulted through the following reference [7]

Figure 8: Cover page of PCR and EPD developed in the project BattleCO_2

5. CONCLUSSIONS

The BattleCO_2 Project, starting from a deep knowledge of the environmental implications underlying the asphalt paving sector, has developed a heating technology based on biomass that allows greenhouse gas reductions close to 80% in the manufacturing stage of bituminous mixes.

The project has demonstrated the technical feasibility of manufacturing bituminous mixtures with biomass obtaining characteristics identical to those obtained with heating systems based on fossil fuels.

The development of Green Public Procurement requires the use of objective and quantifiable criteria to assess the various elements that are included in a paving work. The LIFE BattleCO_2 project has elaborated product category rules and has achieved an environmental product declaration which, in addition to being an element of comparison with current manufacturing technologies, can be used by companies and public administrations due to its free access character. As an example of this open character, the PCR produced has already been incorporated into the EPD system developed by the Australian Asphalt Pavement Association.

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