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LIFE CYCLE MANAGEMENT

Life cycle assessment of nine recovery methods for end-of-life tyres

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Abstract Aliapur was created in 2002 by tyre manufacturers as a means of providing a collective response to the regulatory obligations in force in France on the management of used tyres. Since 2004, Aliapur has implemented a major industrial research programme to support the development and optimisation of long-term, diversified recovery methods. At a time when several used tyre recovery methods have achieved a certain maturity, Aliapur decided to carry out a comparative environmental evaluation of the various recovery alternatives. In addition to comparing the different alternatives, this environmental evaluation aimed at identifying the strengths and weaknesses of each recovery method, and of the management of used tyres as a whole. This evaluation was based on the Life Cycle Assessment approach and conformed to the methodological prescriptions developed in the ISO 14 040 (2006a) and ISO 14 044 (2006b) standards. It was carried out by PricewaterhouseCoopers Ecobilan (2009) a consulting firm specialising in life cycle assessments, and was reviewed by a committee of European LCA experts and interested parties Lecouls and Klöpffer (2010).

Keywords Aliapur · Ecobilan · End-of-life tyres (ELT) · ISO 14 040 · ISO 14 044 · Tyres · Tyre recovery methods · Used tyres

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1 Introduction

Altogether, nine recovery methods for end-of-life tyres (ELT) were studied: four destructive methods (cement works, foundries, steelworks and urban heating) and five non-destructive methods (retention basins, infiltration basins, moulded objects, synthetic turfs and equestrian floors; Table 1).

The environmental assessment of each of these methods was evaluated, taking into account both the direct impacts associated with the recovery method and the impacts avoided through the substitution effect (the recovered used tyres were used as a replacement for "traditional" products such as energy or raw materials).

2 Methodology

2.1 System studied and the functional unit

Figure 1 shows the stages involved in the various ELT recovery methods studied. All these stages were taken into account in the context of this study.

For each recovery method, the environmental impacts were calculated for the same provided service, with the functional unit in the context of this study being "recovering one tonne of used, end-of-life tyres from a collection point".

2.2 Setting the boundaries of the system

2.2.1 Taking into account the avoided impacts and calculating the environmental assessment

The evaluation method was based on the reference methodological principles for studies focusing on the management of household waste.

Table 1 The recovery methods studied—products replaced, type of recovery and quantities involved

Recovery method	Percentage of the ELT arising in France (%)	Type of recovery	"Traditional" method replaced
Retention basins	1–5	Public works recovery	Retention basins made of blocks of concrete and polyethylene blocks
Infiltration basins	1–5		Infiltration basins made from gravel
Steelworks	1–5	Material recycling	Anthracite (+ scrap metal)
Foundries	<1		Foundry coke (+ scrap metal)
Moulded objects	5–20		Anti-vibration mats made of virgin polyurethane
Synthetic turfs	5–20		Synthetic turf made of virgin EPDM and chalk
Equestrian floors	<1		Equestrian floors made of sand
Cement works	>20	Energy recovery	Petroleum coke and coal
Urban heating	1–5		Coal

The environmental assessment for the various recovery methods was thus established by adding:

– the impacts generated by collecting and preparing the ELT,
– the avoided impacts by the fact of replacing "traditional" products with ELT.

As an example, in the case of cement works, using tyres as a replacement for traditional fuels makes it possible to:

– Avoid the extraction and preparation stages needed for these traditional fuels, the supply process for these traditional fuels and the shredding of solid fuels;

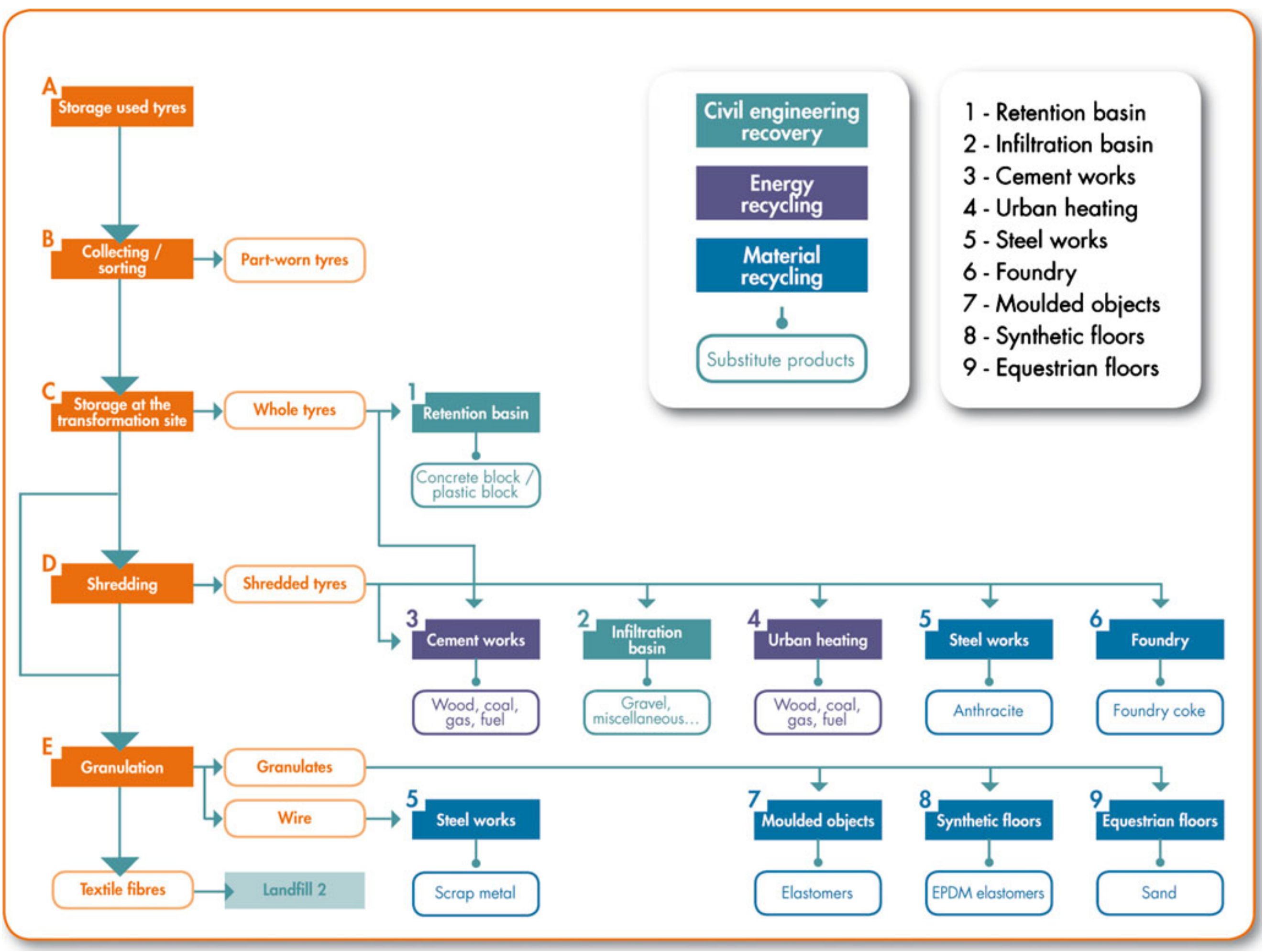

Fig. 1 Stages involved in the various ELT recovery methods

- Replace the fossil origin CO_2 emissions caused by the combustion of the traditional fuels with fossil-origin and biomass CO_2 caused by the combustion of used tyres;
- Recover the steel contained in the ELT.

It should be noted that all the environmental benefits associated with the recovery are attributed to the management of the used tyres, and not, in whole or part, to the downstream life cycles into which the products of the recovery of used tyres are used.

2.2.2 Taking into account the feedstock energy in used tyres

Used tyres contain feedstock energy which is available for use in its thermal form, as expressed through its net calorific value (NCV). As this feedstock energy was initially obtained from the environment, it is necessary to determine to whom this consumption should be allocated.

End-of-life tyres have the status of waste according to the current regulations. In this study, it was considered that the consumption of feedstock energy should be attributed to those who transferred the tyre from a status of product to that of waste.

Used tyres thus have a very real potential—their NCV—which is considered to be free from the point of view of environmental accounting for the stages following this abandonment.

The critical review committee drew attention to the importance of choosing this allocation method, which necessarily had an influence on the results for the "total primary energy consumption" indicator. As a result, a sensitivity analysis was carried out, taking into account the following scenario: 50% of the feedstock energy consumption from the tyres was allocated to those abandoning the tyres, the remaining 50% to the ELT recovery method.

2.2.3 Excluded life cycle stages

As the aim was to compare two solutions, one traditional method and one ELT-based alternative method, none of the stages that were identical for the two solutions being compared were taken into account given that they did not provide any differentiation.

In coherence with current practices in terms of Life Cycle Assessment, but also because of the lack of feedback, the end-of-life step for the non-destructive recovery solutions (e.g. ELT retention basins) was not taken into account in the environmental evaluation.

This methodological point was the subject of discussion with the critical review panel. The content of these exchanges is summarised in Section 2.7 of the present article.

In addition, the studied systems exclude the construction of buildings on the industrial sites, as well as the manufacturing of the machines, tools or transport vehicles.

2.2.4 Other methodological rules

The other methodological rules used for the requirements of the study are summarised below:

- Delimitation rule: the inclusion criterion used by default was mass. The inclusion threshold was set at 5%.
- Allocation for the different products: no allocation issues had to be dealt within the context of this study.
- Time limits: the comparison between the traditional method and the ELT recovery method was made over the same life span, that is, the life span of the work produced from the ELT.
- Interpretation rules: the results of the environmental assessment were judged to be significant when they were greater than the maximum error obtained from the combination of uncertainties from the generated impacts (5%) and avoided impacts (5%).

2.3 Flow and the environmental impacts studied

Eight environmental indicators were taken into consideration in the context of this evaluation. They correspond to the most standard and most recognised indicators in terms of robustness in the field of life cycle assessment:

- Total primary energy consumption
- Consumption of non-renewable resources
- Water consumption
- Contribution to eutrophication
- Emissions of greenhouse gas of fossil origin (direct, 100 years)
- Emissions of acidifying gas
- Creation of tropospheric ozone
- Production of non-dangerous waste

No biodiversity, toxicity or eco-toxicity indicators were calculated because of the lack of solidity in the methods and data, which at present makes it impossible to calculate usable and irrefutable indicators.

However, evaluating the toxic and eco-toxic impacts of the sensitive stages of ELT recovery were carried out upstream of this study, by Aliapur, and several of these studies are available on the website.

The critical review committee esteemed in its report that the eight calculated indicators was a sufficiently complete set of indicators and that it would be possible to attain the aims of the study.

2.4 Modelling the transport stages for used tyres

In-depth modelling work was carried out in order to characterise the transport stages for used tyres. The transportation of ELT from the various storage sites until their recovery is composed of the following stages:

- Collection of used tyres from storage sites and transport to sorting centres: 40,000 collection points, roughly 90 sorting centres;
- Transfer of the ELT from sorting centres to transformation (shredding/granulation) platforms. In most cases, sorting and transformation take place on the same site and this transfer thus does not take place;
  - Transport of the ELT to the recoverers. There are two possible cases:
  - the ELT are transported by road to the recovery sites (France)
  - if the recovery is to take place abroad (cement works, urban heating), the tyres travel first via transit platforms before being sent by sea and then if necessary by road to the recovery site.

The fuel consumption associated with a transport stage was evaluated on the basis of the following formula:

$$\text{Real consumption (in litres)} = \text{Distance} \times \frac{\text{full load consumption}}{100} \times \left[\frac{2}{3} + \frac{1}{3} \times \frac{\text{real load}}{\text{useful load}} + \text{empty return rate} \times \frac{2}{3}\right]$$

With regard to the stage of collection from the storage sites and transfer to the sorting centres, the systematic processing of delivery slips for 2008 made it possible to:

- calculate the transport distance specific to each delivery slip
- constitute homogenous “transport categories” thanks to analysis of distribution of tonnages collected and kilometres travelled
- determine the values for the various modelling parameters

2.5 Main calculation hypotheses and estimations taken into consideration

2.5.1 Impacts associated to the transport of the materials used for the traditional methods

Given the lack of specific data, default values were taken into consideration for the distances and transport parameters for these materials (for example, 100 or 50 km for road transport depending on the case).

2.5.2 Life span of equestrian floors

As there is little feedback on this item, the life span of the ELT equestrian floors was imagined as being the equivalent of that of synthetic ELT sports turf, that is, 10 years.

2.5.3 Retention basins

As there are two traditional techniques that are commonly used, the hypothesis made in this study was that of replacing 50% of concrete blocks and 50% of plastic blocks.

2.5.4 Emissions into the atmosphere from the recovery of ELT in cement works, steelworks and urban heating

Regarding recovery in steelworks, several series of trials carried out since 1997 have made it possible to establish the fact that there is no significant difference in terms of emissions of pollutants between casting with coal and with used tyres.

The emissions associated to the combustion of ELT in cement works and urban heating, however, are relatively poorly known as there are no cases of use of 100% ELT, nor any incremental measurements making it possible to disconnect the fraction of emissions specific to the combustion of used tyres and that of other fuels.

In this context, it was considered that the emissions into the environment caused by the combustion of used tyres were equivalent to those of traditional resources and this, for all the air pollutants with the exception of CO_2.

The emissions of CO_2 caused by the combustion of tyres can be of fossil origin, and be included in the calculation of greenhouse gas emissions, or of biomass origin, and thus not be integrated into the calculations for greenhouse gas. This distinction is consistent with the calculation rules stipulated in the decree dated 31 March 2008 concerning the verification and quantification of the emissions declared in the context of the greenhouse gas emission quota exchange scheme.

The CO_2 of biomass origin from the ELT was evaluated on the basis of the carbon composition of the tyres and their biomass fraction. Combustion was considered to be complete (all the carbon content emitted in the form of CO_2).

2.5.5 Recovery in cement works and urban heating: traditional fuels replaced

It was considered that the tyres were an alternative:

- to the main traditional fuels used in cement works (coal and petroleum coke) and not to other alternative fuels.

Other fossil fuels (fuel oil and natural gas) were not taken into account as these fuels are not used in large quantities;
- to the coal used in urban heating (only fuel used at the present time). A sensitivity analysis comparing the use of ELT with an energy mix representative of the heating networks in France was also carried out.

2.5.6 Recovery of ELT in foundries

The carbon content of used tyres is used to replace the carbon normally provided by coke. Introducing ELT instead of part of the coke leads to modifications in the behaviour of the coke in the cupola (carburation rate).

On this basis, it was decided to model not simply by replacing 0.55 kg of foundry coke with 1 kg of shredded ELT, but also by replacing a system using only foundry coke with another using a mixture of foundry coke and shredded ELT.

This approach made it possible to integrate the change in the coke's carburation rate in the presence of ELT shred and thus the changes in the CO_2 emissions associated to the coke.

In addition, tyres are a source of steel that can be added to the load of scrap metal in the cupola.

2.6 Sources and quality of the data

The data was essentially collected from the contributors using the traditional and alternative fields being studied. They were collected either on site or via a questionnaire (Table 2).

The data on the extraction and production of virgin materials and energy (upstream stages in the life cycle) were obtained from bibliographical sources.

2.7 Critical review

An international committee composed of seven verifiers gave its opinions regarding both methodological decisions and validity of the data used, as well as the results of the study.

- Henri Lecouls (LCA Expert, Coordination of the committee)
- Jacky Bonnemains (CEO of the environmental NGO, Robin des Bois)
- Guy Castelan (technical and regulatory affairs associate at Plastics Europe)
- Walter Klöpffer (senior editor, International Journal of LCA)
- Didier Laffaire (director delegated to the environment, ATILH, association of French cement makers)
- Lars-Gunnar Lindfors (scientific director, Swedish Environmental Research Institute, IVL)
- Jean-Sébastien Thomas (Arcelor Mittal Research, Arcelor Mittal Group)

The comments made during the critical review notably led to:

- better distinguishing the destructive recovery methods from the non-destructive methods in the presentation of the results
- presenting the references to the toxicology studies conducted by Aliapur

Table 2 Contributors approached during the data collection process and evaluation of the quality of the data

Stages/fields	Contributors	Evaluation of the quality of the data
Chemical composition and NCV of the tyres	Aliapur. The values were differentiated depending on the type of ELT and were obtained from reference values and characterisation protocols.	Good reliability, good representativeness
Tyre collection	Aliapur flow monitoring system for 2008. Bilan Carbone™ by the ADEME (correspondence tonnages and GVWR / useful loads of the trucks)	Good reliability, excellent representativeness
Sorting centres	Sorting centre, Megapneus, coherence controls with WISARD	Average reliability and representativeness
Shredding and granulation	Several shredding and/or granulation sites, equipment manufacturers	Good reliability, good representativeness
Retention basins	Brunet Group, LCA carried out by the Ecole Polytechnique Fédérale in Lausanne, EEDEMS platform	Good reliability, average representativeness
Infiltration basins	Quille Group (Bouygues Construction Group), EEDEMS platform	Average reliability and representativeness
Steelworks	LME, Beltrame group (Trith Saint Léger site)	Good reliability, average representativeness
Foundries	Foundry FMGC and the professional trades union, CTIF	Good reliability, average representativeness
Moulded objects	Company RubberGreen, APME	Average Reliability, poor representativeness
Synthetic turfs	Company Eurofield, Cabinet Pierre Robin Labosport	Good reliability, average representativeness
Equestrian floors	CSTB / Ademe / Sportingsols study (on site study for an equestrian centre)	Good reliability, poor representativeness
Cement works	ATIHL, Lafarge site in Port-la-Nouvelle	Good reliability, good representativeness
Urban heating	Hypotheses, lack of available and usable real data	Poor reliability and representativeness

- conducting a sensitivity analysis on the allocation of feedstock energy
- better justifying the life spans of the floors used for sports activities
- clarifying the model of the foundry process

Fundamental discussions also focused on the boundaries between systems, particularly the end-of-life step for non-destructive ELT recovery methods.

The verifiers consider that the end-of-life step for non-destructive recovery should have been taken into account. In addition, they believe that the destructive recovery methods cannot be compared to the non-destructive methods and that they should thus be the subject of separate comparisons.

The authors of the study explained that the decision not to take into account the end-of-life step of the non-destructive methods was based on the fact that:

- the functional unit focused on the recovery of 1 tonne of ELT and not on the destruction of one tonne of ELT;
- the accounting done in the context of the environmental studies on the management of household waste never takes into account the end-of-life step of non-destructive recovery methods. The environmental assessment associated to the recycling of PET bottles in the form of polar fibres does not take into account the end-of-life step of polar fibre products. In this context, the recovery methods using incineration with energy recovery are compared to recycling recovery methods;
- taking into account the end-of-life step, which would combine the dismantling/sorting operations and energy recovery from the tyres, would probably lead to improved results. The accounting option that was calculated thus corresponds to a conservative hypothesis.

The authors of the study agreed with the critical review committee regarding recommendations for a research programme to be initiated on the end-of-life step of non-destructive recovery methods, particularly with regard to retention and infiltration basins for which the risk of "loss of memory" is the greatest.

They would also like the question of whether or not to count the end-of-life step of non-destructive recovery methods to be brought to the awareness of, and discussed by, LCA practitioners so as to make it the subject of a general, consensual position for all the fields concerned.

3 Results

3.1 Life span and substitution rates

The recovery of ELT makes it possible to provide, in an alternative manner, a service that generally requires the consumption of traditional resources. The information collected from the various contributors has thus made it possible to establish substitution rates for each method (Table 3).

3.2 Results for the transport aspect of ELT

3.2.1 Parameters

Modelling tyre collections, from their storage sites to the sorting centres, made it possible to determine and quantify the parameters needed to calculate the fuel consumption associated to this transport stage (Table 4).

The analyses performed made it possible to establish that "skip" and "bulk" collections correspond to different sets of

Table 3 Substitution rates for the various ELT recovery methods

ELT recovery method	Substitution rate for the life span considered on the basis of an equivalent provided service 1 t of ELT replaces	Life span of the ELT-based product and the traditional product
Retention basins	1.95 t of concrete blocks or 0.3 t of polyethylene blocks	Similar life spans (20 years)
Infiltration basins	6 t of gravel	Similar life spans (20 years)
Moulded objects	1 t of virgin polyurethane	Similar life spans
Synthetic turfs	0.5 t of virgin EPDM and 2 t of chalk	ELT: 10 years[a], EPDM: 4 years
Equestrian floors	44 t of sand	ELT: 10 years, sable: 3 years
Cement works	0.7 t of coke and 0.29 t of coal	NA destructive methods
Urban heating	1.15 t of coal	
Steelworks	0.59 t of anthracite and 0.16 t of scrap metal	
Foundry	1,000 t of scrap metal+9.5 t of coke+1 t of ELT replaces 1,002 t of scrap metal+10 t of coke	

[a] Given the lack of feedback regarding the life span of ELT-based equestrian floors, it has been considered as being equivalent to that of a synthetic sports turf made from ELT, that is 10 years

N.B. a football pitch uses roughly 150 t of ELT granulates, a riding school roughly 30 t, and a cement works can use several tens of thousands of tonnes per year

Table 4 Modelling parameters for collections from storage sites to sorting centres

	Skip	Bulk
Total tonnage (t)	142,000	127,000
Distance (km)	77	74
Real load (t)	4	1.4
Useful load (t)	12	3
Consumption for 100 km full (L)	34	15
Empty return (majority hypothesis)	100%	100%
Consumption per tonne (L)	9.5	12

Similarly, these parameters were determined for the other transport stages in the same way

data (tonnage transported, distance covered). On the other hand, the conclusion of the analysis showed that there was no advantage in identifying collections in relation to the category of tyres involved.

3.2.2 Role played by the transport stages in the results

Given the logistic organisation required for the management of used tyres, and the interest shown by many of the parties involved in the environmental impact of transport, and particularly the greenhouse effect, we wanted to evaluate the cumulative role played by all the ELT transport stages for this indicator (Fig. 2).

The transport stages taken into account in the calculations were as follows:

- Road transport for tyres from 40,000 collection points to 90 sorting centres
- Road transport for ELT from sorting centres to the transformation (shredding/granulation) platforms
- Transport from the sorting or transformation centres to recoverers in France (by road) and abroad (by sea and road)

For most recovery methods, the results show that the transport stages play an environmental role (45-84 kg eq. CO_2/tonne of ELT) that is secondary to the impacts generated by the recovery methods, and that the transport impacts are greatly inferior to the benefits generated by using tyres to replace traditional products.

3.3 Environmental assessments per recovery method and for the eight indicators studied

The environmental assessments established in the context of the study show that, regardless of the recovery method studied, and regardless of the impact focused on, the management of end-of-life tyres provides, in most cases, a significant environmental benefit (Table 5).

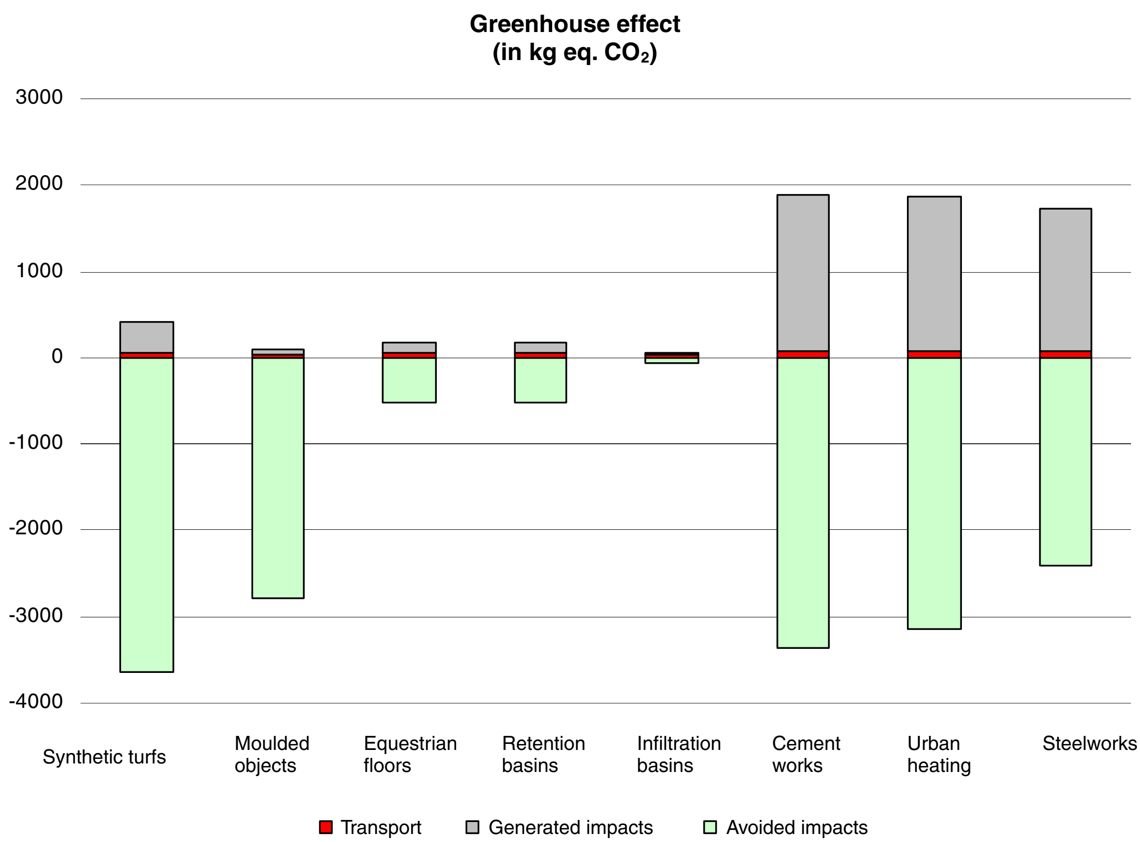

Fig. 2 Greenhouse gas effect indicator - generated impacts, role played by the transport stages and avoided impacts for the various recovery methods studied

Table 5 Environmental assessment of the nine recovery methods studied for 1 t of ELT recovered

Environmental assessment Indicators	Synthetic turf	Moulded objects	Cement works	Steelworks	Urban heating	Equestrian floors	Retention basins	Infiltration basins	Foundries
Total primary energy consumption (in GJ)	–74	–63	–43	–54	–33	–4	–10	0[a]	–29[a]
Emissions of greenhouse gas of fossil origin (direct, 100 years) (in kgeq. CO_2)	–3,217	–2,703	–1,466	–672	–1,275	–342	–448	–11	–1,193[a]
Emissions of acidifying gas (in geq. SO_2)	–10,589	–20,425	–7,031	–2,033	–1,499	–1,557	–1,083	18[a]	–4,115[a]
Emissions of gas playing a role in the creation of tropospheric ozone (in geq. ethylene)	–759	–204	–92	–193	1[a]	–156	–73	0[a]	–301[a]
Consumption of non-renewable resources (in kgeq. antimony)	–33	–26	–21	–26	–17	–3	–4	0	–20[a]
Water consumption (in m^3)	–15	–41	–12	–2	0	–28	–1.3	0	–6[a]
Waste contributing to eutrophication (in geq. PO_4)	–747	–1 838	–327	–77	–27	–270	14[a]	21	–234[a]
Production of waste (in t)	–4	0	0	–1	–1	–29	–	0	–1[a]

[a] Non-significant deviation when the overall result calculated is lower than the greater of the two following values: 10% of the total generated impacts, 10% of the total avoided impacts

Thus, the productions of synthetic, ELT-based turf, the manufacturing of moulded objects from ELT and energy recovery in cement works are shown to be the most beneficial methods.

The recovery in steelworks, urban heating and equestrian floors have intermediate environmental results. Their advantages are more or less marked depending on the indicators taken into consideration.

Retention basins and infiltration basins have the least environmental benefits. There are, however, advantages for these recovery methods in comparison to the traditional solutions that they replace.

Remark Recovery in foundries is an emerging field. The data used in the present study were obtained from industrial trials that need to be confirmed. On the basis of the data currently available, the benefits generated by recovering ELT in foundries have been judged to be non-significant.

3.4 Sensitivity analyses

Various sensitivity analyses were carried out in the context of this study in order to evaluate the incidence of certain technical choices, as well as to verify the solidity of the results.

These analyses thus focused in particular on the following aspects:

- allocation of the feedstock energy of ELT
- the incidence of the choice of granulation technique (techniques currently used in France *versus* cryogenic granulation)
- the energy mix replaced for recovery in urban heating

3.4.1 Sensitivity analysis regarding taking feedstock energy into account

As explained in Section 2, the feedstock energy contained in ELT is counted as being the responsibility of those who transform the tyre from the status of product to that of waste, and not the responsibility of the ELT recovery method.

As shown in Table 6, allocating half the feedstock energy from tyres to the ELT recovery methods produces a notable modification to the results.

This sensitivity analysis consisted in allocating half the feedstock energy from tyres to the ELT recovery method. It made it possible to confirm the solidity of the results obtained for the recovery methods for synthetic turf, moulded objects, cement works, steelworks and urban heating.

It also resulted in us putting into perspective the performances of the other recovery methods for the "primary energy consumption" indicator. This can be explained by the low energy-consuming nature of the traditional solutions being replaced, which use materials with a low, or zero, energy content (sand, gravel, concrete blocks).

3.4.2 Sensitivity analysis on the energy mix replaced for recovery in heating

At the time of the study, there was only one heating installation using ELT as a replacement product. The data concerning this installation were thus used considering that the ELT were used as a replacement for a scenario with 100% coal.

As a complement, a sensitivity analysis was carried out considering that an energy mix of the fossil fuels traditionally used in France (66% natural gas, 18% oil fuel, and 16% coal) was replaced (Table 7).

Table 6 Results of the sensitivity analysis on taking into consideration the feedstock energy of tyres

	Primary energy consumption (GJ/t)	
	0% of the feedstock energy of ELT allocated to the recovery method	50% of the feedstock energy of ELT allocated to the recovery method
Synthetic turf	−74	−60
Moulded objects	−63	−49
Equestrian floors	−4	10
Retention basins	−10	5
Infiltration basins	0	14
Cement works	−43	−28
Urban heating	−33	−18
Steelworks	−54	−40
Foundries	−29	−16

With regard to the emissions of greenhouse gas and acidifying gas, the table above shows that the gains provided by the solution using ELT are lesser when they replace a natural gas/oil fuel/coal energy mix. This is essentially because of the predominance of natural gas in the energy mix replaced, as this fossil fuel has a high NCV and lower combustion emissions than coal.

Thus, while in the main scenario the fuel replaced has combustion emissions of more than 90 t CO_2/TJ, natural gas has, in the case of urban heating, combustion emissions of around 60 t CO_2/TJ, which is of the same order of magnitude as the combustion emissions of ELT taking into account their biomass fraction.

3.4.3 Sensitivity analysis on granulation process

Cryogenic granulation is not used in France: the sites that have this technology are located in Portugal. The Netherlands are also partially implementing this technology (Table 8).

Through this additional analysis, we hoped to highlight the differences at the environmental level between this granulation technique and those used in France (compression granulation and successive shredding granulation).

The results of this analysis are presented for the granulation phase only, with a reference flow of 1 tonne of tyres entering the granulation process. The reference scenario corresponds to the French distribution between the successive shredding and compression granulation techniques.

It should be noted that this comparison does not take into account the difference in quality between the granulates produced.

The increase in impact between the successive shredding or compression granulation techniques on the one hand and cryogenic shredding on the other is significant.

This increase in impact is essentially caused by the considerable energy consumption required at the level of the machines used, plus the production and transport of the liquid nitrogen needed for the cryogenic shredding granulation technique.

4 Interpretation and perspectives

The results of the comparative environmental evaluation conducted by Aliapur show that under the present conditions, the nine ELT recovery methods studied produce

Table 7 Results of the sensitivity analysis on the energy mix replaced (urban heating)

Scenarios Impacts	Reference	Sensitivity analysis
Total primary energy consumption (in GJ)	–33	–31
Emissions of greenhouse gas of fossil origin (direct, 100 years) (in kgeq. CO_2)	–1,275	–323
Emissions of acidifying gas (in geq. SO_2)	–1,499	–555
Emissions of gas playing a role in the creation of tropospheric ozone (in geq. ethylene)	1	–270
Consumption of non-renewable resources (in kgeq. Sb)	–17	–14
Water consumption (in m^3)	0	–1
Waste playing a part in eutrophication (in geq. PO_4)	–27	43
Production of waste (in t)	–1	0

Table 8 Comparison of the environmental generated impacts by different granulation techniques

Scenarios Indicators	Reference scenario	Cryogenics
Total primary energy consumption (in GJ)	3	9
Emissions of greenhouse gas of fossil origin (direct, 100 years) (in kgeq. CO_2)	39	369
Emissions of acidifying gas (in geq. SO_2)	243	2 031
Emissions of gas playing a role in the creation of tropospheric ozone (in geq. ethylene)	5.1	15.7
Consumption of non-renewable resources (in kgeq. Sb)	0.3	2.5
Water consumption (in m^3)	0.66	9.40
Waste playing a part in eutrophication (in geq. PO_4)	23	115
Production of waste (in t)	0.34	0.66

environmental benefits for all the environmental indicators taken into consideration.

The impacts associated to the tyre collection, sorting and shredding/granulation stages were shown to be secondary to the benefits provided by the recovery. This is because of the substitution effect, with the ELT replacing high energy consumption materials, as well as the fact of certain impacts being avoided (the production and transport of certain materials replaced when the life span of the ELT products is greater than that of the products replaced), and the biomass content of the tyres.

These elements confirm the advantages of investing in the collection, sorting and transportation stages for ELT, with the aim of making the most of the potential of ELT.

It is also interesting to note that the environmental assessment of material recycling methods is not systematically better than that of the energy recovery methods. This observation makes it possible to put into perspective the hierarchy of waste quoted in the context of the Directive 2008/98/EC on the subject of waste.

The methodological discussions and sensitivity analyses carried out also highlight the sensitivity of certain results to the hypotheses taken into consideration.

In the particular case of total primary energy consumption, the sensitivity analysis consisted in allocating half the feedstock energy from the tyres to the recovery method. This confirmed the solidity of the results obtained for the recovery methods: synthetic turf, moulded objects, cement works, steelworks and urban heating. On the other hand, it led to us to put into perspective the performances of the other recovery methods with regard to this indicator.

The discussions held in the context of the critical review on the subject of the end-of-life step of the non-destructive recovery methods revealed the importance of increasing knowledge and the methodology for the end-of-life step of this type of recovery.

Aliapur thus intends to play its part by continuing to examine the stakes associated to the end of the second life of tyres and shredded tyres so as to be able to take these products into account right up to their complete elimination.

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