Comparative life cycle assessment of two options for waste tyre treatment: material recycling versus civil engineering applications

Executive summary




Comparative life cycle assessment of two options for waste tyre treatment:

material recycling in asphalt and artificial turf vs. civil engineering application for drainage layers in landfills

By FORCE Technology:
Nanja Hedal Kløverpris, Anders Schmidt

By Copenhagen Resource Institute:
Birgitte Jørgensen Kjær

By IFEU - Institut für Energie- und Umweltforschung Heidelberg GmbH
(Institute for Energy and Environmental Research, Germany):
Regine Vogt, Jürgen Giegrich

Add-on report to
Comparative life cycle assessment of two options for waste tyre treatment:
material recycling vs. co-incineration in cement kilns
published by Genan Business & Development A/S in 2009

Executive summary

This life cycle assessment (LCA) study investigates two treatment options for used tyres: material recycling where rubber granulate from tyres is used partly for modification of asphalt and bitumen and partly as infill in artificial turf, and civil engineering where tyres are shredded and used for landfill drainage layers. The study compares nine different environmental impact categories for each treatment option, and it concludes that in all nine impact categories material recycling as an end-of-life treatment option for tyres provides a larger environmental benefit than civil engineering. The difference between the two options is very significant in all impact categories. The results clearly demonstrate that applications of used tyres substituting virgin rubber and using rubber's properties are environmentally superior to civil engineering.

The results as presented in the report refer to one tonne of used tyres as the functional unit. Taking the total amount of waste tyres currently being used for civil engineering purposes in Europe (300,000 tonnes) as an example, 570,000 tonnes of CO_2 emissions (corresponding to annual emissions from more than 50,000 Europeans) could have been saved, if the tyres had been used for material recycling instead. There are also savings in all other environmental impacts categories examined.

The study has been commissioned by the Danish waste tyre handling company of Genan Business & Development A/S and carried out by a team from the Copenhagen Resource Institute, FORCE Technology (Denmark), and the German IFEU Institute in Heidelberg. Tommy Edeskär, SWECO, provided expert knowledge on civil engineering application. The study supplements an LCA carried out in 2009 which showed that material recycling of tyres is environmentally superior to co-incineration in cement kilns.

The study follows the ISO LCA standards 14040 and 14044, and it has been peer reviewed by LCA experts from Gaiker, a Spanish Technology Centre.

Background

The *waste hierarchy* presented in the EU Waste Directive provides a rule of thumb for priority treatment of waste. The hierarchy identifies as a general rule material recycling as being environmentally superior to energy recovery and pinpoints landfilling as the environmentally inferior end-of-life option. A wide array of waste streams such as used tyres, animal fat and meal, textiles, waste from the wood and paper industry, or plastics were landfilled in many EU Member States just a decade ago. An EU ban on the landfill of tyres, which entered into force in 2006, has sparked a debate on which alternative treatment option for used tyres is environmentally most beneficial.

The use of tyres for civil engineering purposes is often presented as a good option for recycling of tyres, but other recycling options may provide larger environmental benefits due to substitution of virgin rubber materials. In the UK, using shredded tyres as a leachate drainage medium is considered as "recovery" rather than "disposal", while Genan's process is generally accepted as material recycling. Both treatment options are classified as "recycling" in most statistics, but it is important that different treatment options within recycling are seen as separate technologies and that their environmental differences are highlighted.

Life cycle assessment method

LCA is a methodology used to identify the environmental impacts related to a product, a service or a system from a holistic point of view that incorporates all known potential environmental impacts and follows the product, service or system from ”cradle to grave”. The life cycle includes all known processes in the stages of extraction of raw materials, production, use, and disposal. This type of holistic analysis has gained increasing interest within the EU and “life cycle thinking” has become an integral part of many strategies and regulations within waste management.

The LCA method is described in the ISO standards 14040 and 14044. An LCA study consists of four phases (Figure A). The main purposes of the goal and scope definition phase are to clarify the purpose of the study, what it can and cannot be used for, the product system studied, and its boundaries. In the inventory analysis phase, data on inputs and outputs of the processes included in the system are collected or calculated. On the basis of this inventory, potential environmental impacts are assessed and finally the results are interpreted. Carrying out an LCA is by definition an iterative process.

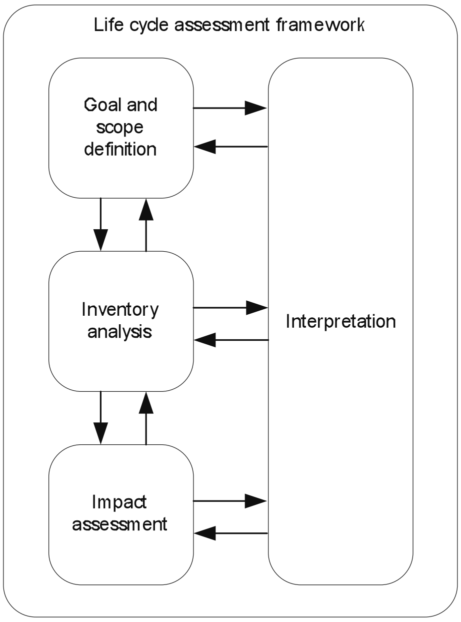

Figure A. Phases of an LCA (ISO, 2006)

LCA is increasingly being used as a decision-support tool, and the application of the method has increasingly focused on examining the consequences of a change. This is also the case in the present study, where the consequences of changing the end-of-life treatment of used tyres from civil engineering applications to material recycling are examined by looking at all processes that are affected by the change.

Scope of the study

This study compares the application of shredded tyres in landfill drainage layers with recycling of tyres for use as an ingredient in rubber asphalt (fine fraction < 1.4 mm) and for use as an infill in artificial turf (> 1.4 mm) (Figure B). In the material recycling process, tyres are shredded and textile and steel fractions are separated. The remaining rubber is granulated before use in modified bitumen for asphalt and as an infill. The textile fraction is incinerated in a cement kiln and the steel fraction is recycled. Through recycling, several processes such as production of synthetic rubber are avoided.

In the civil engineering route, the tyres are shredded and used as a drainage layer in landfills replacing natural aggregates such as gravel, sand, and crushed rock.

A change from civil engineering to recycling implies higher demand for natural aggregates in the civil engineering route, whereas emissions related to transport and shredding of the tyres are avoided.

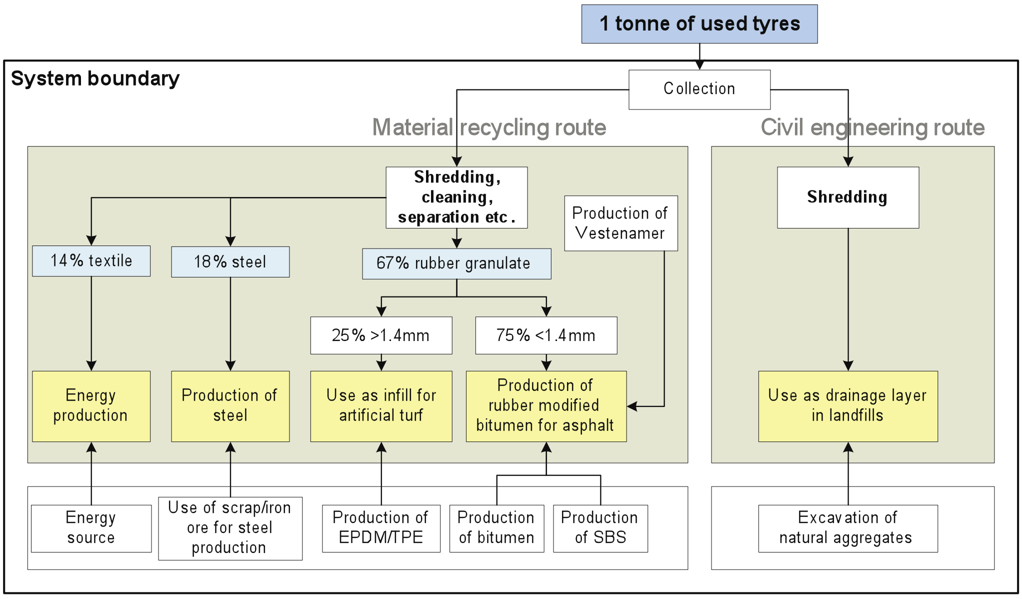

Figure B. The studied system and its boundaries

The civil engineering route is modelled in four scenarios reflecting two geographical situations in terms of transport distances (UK and Sweden) and two types of natural aggregates substituted (gravel/sand and crushed rock). We have chosen use as drainage layers in landfills, but other civil engineering applications may result in similar substitution of natural aggregates.

LCA is a holistic methodology that allows for an investigation of environmental impacts and resource use caused by each of the processes that are part of the two tyre treatment options. The LCA takes into account the substitution of other materials (bitumen, polymer) that would be used in rubber asphalt and as an infill if the tyres were not recycled, and natural aggregates that would be used for drainage layers if tyres were not used.

The environmental impacts identified in an LCA are assessed by calculating the results for a broad range of impact categories. The results are always expressed as potential impacts since the *actual* impact from, for example, emission of CO_2, can only be quantified exactly if and when it actually happens. In this study, the environmental impact categories covered are:

- Global warming potential expressed in kg of CO_2 equivalents. Greenhouse gases such as carbon dioxide and methane can cause climate change.
- Acidification potential expressed as g of SO_2 equivalents. Acids and compounds that can be converted to acids emitted to the atmosphere can cause regional damage to ecosystems as a result of acid rain.

- Nutrification potential in water expressed as g of PO_4 equivalents. Nitrogen and phosphor can lead to nutrient enrichment of ecosystems. In water, this entails increased algae growth which can eventually result in damaged ecosystems.
- Nutrification potential in soil expressed as g of PO_4 equivalents. Nitrogen and phosphor can lead to nutrient enrichment of ecosystems. In soil, this may entail that low-nutrient ecosystems disappear.
- Toxicity potential (carcinogenic risk) expressed as mg of arsenic equivalents. Chemical substances can cause cancer in humans and animals.
- Toxicity potential (acute human toxicity: PM10[1]) expressed as g of PM10 equivalents. Small dust particles can cause respiratory diseases.
- Photochemical ozone creation potential expressed as g of ethylene equivalents. Solvents and other volatile organic compounds react with nitrous oxides and form smog which is detrimental to human health and ecosystems.

Furthermore, two indicators are used to describe the use of resources:

- Cumulative energy demand (balance of fossil fuel use) expressed in GJ.
- Non-energy resource depletion expressed in kg of iron ore (since only iron is of significant relevance in this study).

The impact within each category is calculated for both recycling and civil engineering using data on inputs and outputs of each process included in the analysed system. All impacts are expressed per tonne of tyres.

Results

The results of the study are shown below (Table A). It is noted that the calculation excludes environmental impacts from production and use of tyres, which are equal for both systems. The negative values, found for both treatment routes, thus indicate that impacts are avoided or – in other words – that both treatment options provide benefits for the environment. Hence, larger negative values are better in environmental terms.

It is obvious from Table A that material recycling gives significantly larger benefits for the environment than civil engineering in all examined impact categories. Sensitivity analyses support the results and show that using marine sand excavated from the sea bottom, changing the substitution ratio of shredded tyres to aggregates in drainage layers, or transporting the materials over longer distances does not alter the results. Likewise, changes in the material recycling process with respect to distribution on granulate sizes will not alter the main conclusions.

1 Particulate matter with a diameter of less than 10 micrometers

Table A . Results for material recycling route and four baseline scenarios of the civil engineering route

Impact category (units per tonne of tyres)	**Material recycling**	**Civil engineering**			
		UK gravel/sand	UK crushed rock	SE gravel/sand	SE crushed rock
Global warming potential (kg CO_2 eq.)	-1,922	-24	-28	-77	-82
Fossil fuel (GJ)	-50	-0.3	-0.4	-1.0	-1.1
Iron ore (kg)	-400	0	0	0	0
Acidification potential (g SO_2 eq.)	-6,804	-232	-240	-618	-626
Nutrificiation potential, soil (g PO_4 eq.)	-411	-39	-41	-102	-104
Nutrification potential, water (g PO_4 eq.)	-18	0	0	0	0
Carcinogenic risk potential (mg As eq.)	-1,255	-4.6	-4.7	-13.3	-13.3
PM10 risk (g PM10 eq.)	-5,871	-293	-303	-768	-779
Photochemical ozone creation potential (g ethylene eq.)	-4,737	-41	-42	-109	-110

Figure C graphically summarises the results of the comparison juxtaposed with the results of the LCA study comparing material recycling with co-incineration in cement kilns[2]. The units used are person equivalents, expressing total impact of the treatment of one tonne of tyres relative to the impact caused by one person in one year.

The figure shows that all impact indicators are, to different degrees, in favour of material recycling and the benefits are higher when comparing with civil engineering than with co-incineration. With respect to nutrification potential in water it can be seen that the savings for both treatment options are without any practical importance.

[2] Schmidt A, Kløverpris NH, Bakas I, Kjær BJ, Vogt R, Giegrich J (2009). Comparative life cycle assessment of two options for waste tyre treatment: material recycling vs. co-incineration in cement kilns. Report to Genan.

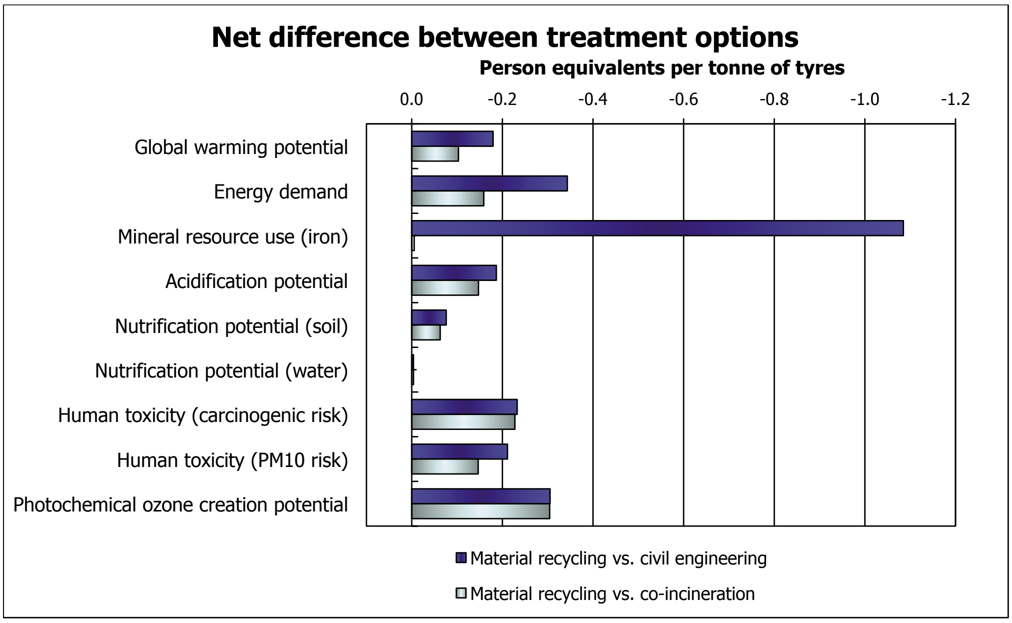

Figure C. Potential environmental savings from material recycling instead of civil engineering (UK gravel/sand scenario) and co-incineration, respectively, in person equivalents per tonne of tyres.

The results indicate the magnitude of savings if tyres are subjected to recycling instead of civil engineering. Disregarding nutrification potential in water, where the difference is negligible, the results show that between 0.08 and 1.08 person equivalents are saved per tonne of tyres being recycled for asphalt and infill material instead of as drainage layers in landfills. If the 300,000 tonnes of waste tyres annually recycled for civil engineering applications in Europe were subjected to recycling instead, it would result in annual potential savings of between 20,000 and 325,000 person equivalents, again depending on impact category. The most prominent example is savings in emission of greenhouse gases, where a change to material recycling would save about 570,000 tonnes of CO_2 equivalents, or more than the annual emissions of 50,000 Europeans.

The results thus clearly show that the environmental benefits of using waste tyres for material recycling are much higher than the benefits from using them for civil engineering in terms of landfill drainage layers. Other civil engineering applications, where the shredded tyres could substitute natural aggregates would most probably show a similar trend. This has, however, not been examined.

Main assumptions

As in any LCA, the quantification of environmental impacts is only possible by making a series of qualified assumptions. This is an inherent part of an LCA, and it is common that conclusions are highly dependent on some of those assumptions. In order to check the robustness of the conclusions to the assumptions made, the assumptions are presented transparently and the most important ones have been tested in a sensitivity analysis.

A sensitivity analysis in the study comparing recycling with co-incineration showed that the overall benefits from material recycling only depend on the size of the granulate fractions to a limited extent. Thus, benefits in global warming potential vary from 1,684 to 2,034 kg of CO_2 equivalents per tonne of tyres, if the fine fraction is between 25%

and 100% of the output. Most of the other environmental impacts examined in the study show a similar picture. The main reason that the fine fraction gives relatively higher benefit is that more virgin rubber is substituted when the granulate is used in asphalt than as an infill.

This study is largely based on data for German, Danish, UK and Swedish conditions, but sensitivity analyses have proved that the results can be considered robust and valid also at a European level.

IB&C°