Life Cycle Assessment methodology (LCA) applied to the case study of a pyrolysis process performed on End-of-Life Tires

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This work proposes an assessment of the environmental impacts of the **pyrolysis process of End of Life Tires (ELT)**, performed by a company (“Curti s.p.a.”), and to compare it with alternative scenarios of valorisation and/or disposal.

**LCA (life cycle assessment)** methodology in order to determine the **most critical stages of the process investigated**, the **environmental benefits arising from the recovery of materials and energy** and the **greater or lesser impact comparing the technology with others recovering material or energy**, already present on the market.
In Italy, 248000 t End of Life Tires (ELT) have been collected in 2015

Overall recovery

Nominal recovery

(Source: Ecopneus Report 2015)
Description of the context

Material recovery
(source: Ecopneus Report 2015)

ELT generation
Collection
Storage
Grinding / Crushing / Pulverisation

Uses of grinded material
Electric Energy
Cement factories
Road paving

Uses of granulated material
Synthetic pitches
Athletic flooring
Acoustic insulation

Uses of pulverised material
Asphalt
Sealant
Rubber goods
LCA approach

**LIFE CYCLE OF A SYSTEM**

- DESIGN
- EXTRACTION OF RAW MATERIALS AND ENERGY SOURCES
- MANUFACTURING TECHNOLOGIES, MATERIALS, PROCEDURES
- ENERGY
- TRANSPORTATION
- DISTRIBUTION
- USE
- END OF LIFE: CYCLE CLOSURE (RECYCLING AND RECOVERY)
ISO 14040 and 14044 (2006)

Goal & Scope Definition:
- Determine the scope and system boundaries

Life Cycle Inventory:
- Data collection, modeling & analysis

Impact Assessment:
- Analysis of inputs/outputs using category indicators
- Group, normalize, weight results

Interpretation:
- Draw conclusions
- Checks for completeness, contribution, sensitivity analysis, consistency w/goal and scope, analysis, etc.

Life cycle assessment framework:
- Goal and Scope Definition
- Inventory Analysis
- Impact Assessment
- Interpretation
ISO 14040 and 14044 (2006)

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LCA approach

LCA applied to a product

- Raw material extraction
- Production
- Distribution
- Use
- End of life

System boundaries
LCA approach

LCA applied to waste management

- Raw material extraction
- Production
- Distribution
- Use
- End of life

System boundaries

Scenarios

A B C D
Goal & Scope Definition

Life Cycle phases considered:

- *Treatment process* (including all input and output flows for the supply and distribution of material and energy);

- *Material recovery* (to recycling facilities);

- *Disposal of waste/residues*

**Functional Unit**

It is the physical quantity to which all streams and impacts are reported (in input and output): *1 ton of End of Life Tires* has been chosen. In the case of the pyrolysis plant, rated at 4 t/h has been considered.
The case study

- Pyrolysis chamber
- Demister
- H$_2$S scrubber
- Fan
- Burners

Collection point of solid residues (char)
Collection point of pyrolysis oil
Energy recovery
Life Cycle Inventory

- ELT: 4000 kg/h
- Water: 94 kg/h
- Gases & vapours: 2314 kg/h
- Carbon black: 1260 kg/h
- Metals: 520 kg/h
- Reactor
- Treatment
- Energy recovery
  - Syngas: 1137 kg/h
  - Sludge: 54 kg/h
  - Pyrolysis oil: 1028 kg/h
- Storage
Life Cycle Impact Assessment: Scenario Pyrolysis “Curti”

The avoided impact due to the recovery of carbon black, steel and oil exceeds (more than one order of magnitude) the impact generated by the process (on which energy consumption affects the results of about 10%).
Life Cycle Impact Assessment: Pre-treatment impacts comparison

Cumulative Energy Demand (CED) method

- “Curti” (Single cut)
- Grinding (for energy recovery processes)
- Crushing (for energy/material recovery processes)
- Pulverization (for material recovery processes)

As for the pre-treatment, “Curti” process results in an energy demand equal to 1/3, 1/10, 1/20 compared to the alternative ones
Life Cycle Impact Assessment: Comparison with energy recovery scenarios

ReCiPe analysis method-endpoint

- “Curti” pyrolysis process
- Cement plant
- Waste to Energy (WtE) process

Compared to other energy recovery scenarios, the balance is largely favourable.
Life Cycle Impact Assessment: Comparison with material recovery scenarios

ReCiPe analysis method-endpoint

- “Curti” pyrolysis process
- CASE 1: full recovery of metals and synthetic rubber
- CASE 2: intermediate option with recovery of metal, synthetic rubber, sand and bitumen

In the comparison with other recovery scenarios, a great influence is given by the different options of granules recovery, considering which materials should actually be replaced: a complete recovery of metals and synthetic rubber (CASE1) would bring to a greater advantage; intermediate options (CASE 2) would make “Curti” process preferable.
Conclusions

• A pyrolysis process, implying a chemical transformation of a waste into valuable materials and energy, was investigated from a life cycle perspective.

• The process was found to be favourable in terms of energy consumption, due to the very low requirements in the pre-treatment step, compared to the alternatives.

• However, the greatest impacts were not those associated to the direct emissions of the process, but the benefits coming from the recovery of materials and energy (avoided fossil and mineral depletion).

• According to the different fate of the recycled materials in alternative scenarios, the greater or lower benefits coming from pyrolysis could be questionable.

• Other recovery scenarios could be investigated in the future.

• Furthermore, by applying a sensitivity analysis (e.g., Monte Carlo method), the robustness of the model in function of the uncertainty of the data used could better be checked (especially the secondary ones collected from the literature).
Main references


Thanks for your attention!!

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