Post-consumer textile waste re-use: main steps of a sustainable process

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Abstract: The European Directive 2008/98/EC on Waste provides guidelines for ensuring sustainable waste management. Specifically, a hierarchy for ranking the available management options is established. Highest priority is given to waste prevention, followed by re-use and, only after that, recycling and recovery of materials, energy recovery through incineration and finally, disposal in landfills. However, even the second highest priority, reuse, is often overlooked in favor of recycling, given the existence of well-established technologies. In this paper, re-use of post-consumer textile waste is studied, by specifying the main steps supporting such a sustainable process and by outlining the magnitude of the expected impact. Finally, a case study is presented.

Keywords: re-use, recovery, recycling, post-consumer textile waste, directive 2008/98/EC, Italian legislation, hygenization

1. INTRODUCTION

In recent years, the problem of waste management has increasingly come to the attention of both practitioners and researchers, given its impact on a wide range of fields (economic, social, environmental). Moreover, waste flow is growing year by year. As reported in the Eurostat database, 2,505,660,000 tonnes were produced in Europe in 2010, in comparison with the 2,498,360,000 tonnes produced in 2008. The same trend can be traced in Italy, where 32,478,921 and 32,471,571 tonnes were produced in 2010 and 2008, respectively, by households (higher values were registered if both manufacturing activities and households were considered). This included some 100,000 tonnes of textile waste (ISPRA 2013). This component of municipal solid waste is rapidly increasing (Morgan et al. 2009), given the growth of fashion retailers offering cheap clothes, often substituting old ones even though they are still in good condition.

It follows from this that re-use could represent an efficient option within the management of textile waste.

In the following, a framework supporting the implementation of the re-use process is outlined.

2. DIRECTIVE 2008/98/EC

The European Community has defined directives with the aim of homogenizing the behaviour of its member states in a wide range of market segments. Waste is a crucial aspect. Directive 2008/98/EC lays down measures to protect the environment and human health by preventing or reducing the adverse impacts of the generation and management of waste and by reducing overall adverse impact on natural resources. In any case, it is always desirable to achieve efficiency improvements.

In article 4, Directive 2008/98/EC establishes a priority order for waste management options:
- prevention;
- preparing for reuse;
- recycling;
- other recovery (including energy recovery);
- safe disposal.

Hence, the first priority is to reduce the volume of waste generated and sent to incineration or landfill. After that comes re-use, and only then should recycling be pursued.

Directive 2008/98/EC also includes a set of definitions, emanating from a long debate. Waste is “any substance or object which the holder discards or intends or is required to discard”. Thus, the definition of waste has a direct link with the action of discarding. No difference is made depending on whether the discarded substance or object has a potential for re-use or a value for an industrial process or a person. A substance or an object ceases to be classified as waste only when it meets End-Of-Waste (EOW) criteria as defined in article 6:
- the substance or object is commonly used for specific purposes;
- a market or demand exists;
- the substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products;
- the use of the substance or object will not lead to overall adverse environmental or human health impacts.
Figure 1: a) Re-use as a prevention action, executed before products and substances become waste; b) Re-use following preparation for re-use activities that meet EOW criteria

“Re-use” means any operation by which products or components that are not waste are used again for the same purpose for which they were conceived.

“Preparing for re-use” means checking, cleaning or repair operations, by which products or components of products that have become waste are prepared so that they can be re-used without any other pre-processing.

“Recovery” means any operation, the principal result of which is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfil a particular function, or waste being prepared to fulfil that function, in the plant or in the wider economy.

“Recycling” means any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for back-filling operations.

As a consequence, re-use could be implemented both as a prevention action or an action following a preparation for re-use activity, implemented after a substance or a product has become “waste”. Obviously, in the latter case, preparation for re-use should enable waste products and substances subsequently to satisfy EOW criteria and consequently accompany their re-introduction into the market. Fig. 1 illustrates these concepts. In the first section (a) used products or substances are not discarded. They are donated to charity and non-profit associations that may accept or reject them after a check of their operative condition and an evaluation of the existence of potential buyers. Charity and non-profit associations do not give guarantees regarding the safe use or quality of donated items. Alternatively, the used substances or products can be discarded and left to local waste managers (by following collection procedures that vary from country to country). They will accept all discarded substances or products and then apply treatment procedures considered the most suitable for each lot (either collected separately or self-selected in ad-hoc plants). Re-usable products could immediately be diverted to preparation for re-use and consequently put back on the market.

In the following, re-use will be analysed in depth, by describing the main steps required for its implementation, in particular in the Italian context and in the sector where post-consumer textile waste is managed.

3. A FRAMEWORK SUPPORTING RE-USE OF POST-CONSUMER TEXTILE WASTE

Given the aforementioned crucial distinction between used products and substances classified as waste or not, the way to re-use used clothing, which is the focus of this section, starts with a similar crossroads. Used clothes can be managed as waste or non-waste.

Similarly to what occurs in the general case of portion a) of Fig. 1, used clothes can be channelled to charity and non-profit organizations that will check them and decide to accept the donation or not. In such a case, used clothes are not considered waste and can be re-inserted into the market (see Fig. 2).

Fig. 2: Flow chart of operations ensuring re-use of used clothes in good condition and not classified as waste.
Or, as depicted in section b) of Fig. 1, the final user of a used garment can decide to deposit it in one of the bulk bins located along streets or in dedicated waste collection areas (either municipal or private). Now, recovery measures are required in order to obtain EOW status. While considered as waste, strict legislative requirements must be followed for transportation, treatment, storage and selling.

There is an initial sorting stage for separating re-usable clothes from those channelled to recovery options (i.e. textile cutting for producing paddings for sofas and chairs, for making industrial wiping cloths, or for incineration to recover energy). If they are not eligible for any of these options, landfill will be the final destination. Eventually, before dismantling the non-re-usable portion of a garment, various spare parts (“accessories”) might be salvaged (i.e. buttons, buckles, zips ...).

In a next step, items of identical nature and/or made of the same material are grouped together, with the aim of facilitating or homogenizing the operative conditions for downstream activities. Moreover, a quality examination (grading) will occur, for diverting re-usable clothes to appropriate recovery treatments and ultimately channel them to final markets.

As depicted in Fig. 3, after collection and selection, valorization will be implemented to imbue new life into used items, by means of all or some of the following procedures:

- cleaning or hygenization. For safe further use, used clothes should be cleaned or at least hygenized. The Italian legislative reference is DM 5th February 1998, that traces conditions for EOW of used clothes and accessories: a) aerobic mesophilic lower than $10^6$/g, b) streptococcus faecalis lower than $10^2$/g, c) no salmonella in 20 g. However, technical indications concerning the design and implementation of procedures and plants assuring such performance indicators are not yet in place. A first tracking will be the object of experiments that will be carried out by the authors. The same experiment will analyse the link between hygenization and preceding operations, i.e. collection and separation. At the time of writing, no answers are available to the following questions: Are there more accurate sorting mechanisms that, implemented during collection and/or selection, could improve the performance of the hygenization process? Or that would reduce the quantity of products destined to be made into wiping cloths, furniture padding or incineration? Or, alternatively, that could augment the price of re-usable clothes?
- refurbishing, during which repair operations occur.
- redesign, for meeting new customers’ needs and wishes (e.g. a renewal/re-valorization with personalized colours or applications).

Finally, valorised clothes are ready for selling, in foreign or domestic markets. This is crucial, given that the existence of a market interest is a qualifying condition for EOW status. Specifically, high-quality used clothes, or those refurbished or redesigned, will be channelled to vintage shops and often sold in the domestic market. Alternatively, re-usable clothes of lower grade can be channelled to foreign markets (especially Africa), where there is demand for two levels of quality (1st and 2nd), obviously with different price tags.

The link between valorization activities and market options is depicted in Fig. 4, where the influence of operations executed on the time required by the treatment or selling process is also shown.

A winning selling strategy has been demonstrated to generate a high turnover of re-usable clothes in shops. Commonly, the initial sales price decreases at pre-defined time intervals (i.e. weeks or months). Finally, unsold re-usable clothes can join aforementioned flows of textile waste. They get diverted to component recovery or for making industrial wiping cloths or cut up for padding sofas and chairs or, at least, get incinerated, or, finally, end up in a landfill.

Figure 3: Main steps characterising the re-use of post-consumer textile waste.
4. SUSTAINABILITY OF TEXTILE WASTE RE-USE

Re-use of used clothes and accessories has been a field of interest since the debate about waste in the European Union (EU) has highlighted the necessity of preferring re-use of waste, rather than its recycling or worst, its incineration and disposal.

Woolridge (2006) has quantified the energy used by a re-use/recycling operation and investigated whether this resulted in a net energy benefit. The energy footprint was quantified using a streamlined life cycle assessment (LCA), an LCA restricted in scope in order to target specific aspects of the footprint, in this case energy consumption. Taking into account extraction of resources, manufacture of materials, electricity generation, clothes collection, processing and distribution and final disposal of waste, the authors demonstrated that for every kilogram of virgin cotton displaced by second-hand clothing approximately 65 kWh is saved (since only 2.6% of the energy required for manufacturing new clothes is used), and for every kilogram of polyester around 90 kWh is saved (since only 1.8% of energy required for processing virgin material is used). Therefore, the re-use and recycling of donated clothing results in a reduction in the environmental burden compared to purchasing new clothing made from virgin materials. Obviously, the same impact will be amplified if the field of textile waste management is considered, rather than donations, that typically originate with only a restricted set of ecologically aware and motivated consumers.

Moreover, from an environmental perspective, the implementation of re-use consistently reduces the necessity of landfills, and consequently of sites dedicated to this purpose.

Re-use also has interesting effects on the social and the economic spheres. From an economic perspective, the availability of low-price safe clothes is of interest for low-wage earners, which in a period of economic crisis makes up a significant portion of the population. Moreover, the availability of safe low-price clothes is of interest for charity and non-profit associations, that often use donations in their humanitarian activities, rather than selling them in their charity shops. However, used clothes are mainly in demand in foreign markets, thus offering an occasion to Italians of being included in markets outside their own borders.

Finally, when post-consumer textile waste management itself is analysed, rather than the magnitude of donations, it is evident that opportunities of employment are offered. Rather, in chase of donations, often only volunteers are engaged. Hence, re-use has an important social impact. It is an interesting source of employment, particularly for roles requiring simple learning and training processes, suitable for people with physical, mental and social deficits.
Moreover, since no significant capital investment is required, this facilitates the creation of social enterprises, usually characterised by limited capital resources.

5. A CASE STUDY

The framework for supporting the re-use of used clothes presented in section 3 is now applied to an emerging company intending to carry out its operations in the north of Italy. It is a social company that has been engaged in waste management for years and is now interested in promoting the sustainable re-use of disposed clothes.

An area with 790 bulk bins distributed along streets, each with a storage capacity of 180 kg of textile waste, will be covered.

In order to obtain useful data for the study, a pilot case study was implemented. 77 bulk bins were positioned in an urban area and observed for one year. Specifically, each week, new urban zones were monitored, in order to study the behaviour of different customers of the collection service, in terms of quantity and typology of clothes confined to the bins. Results obtained are reported in Table 1.

Table 1. Pilot study results

<table>
<thead>
<tr>
<th>Data</th>
<th>77</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulky bins</td>
<td>77</td>
</tr>
<tr>
<td>Medium qty collected per bin</td>
<td>[80, 160] kg/bin</td>
</tr>
<tr>
<td>Frequency of collection</td>
<td>Weekly</td>
</tr>
<tr>
<td>Trucks engaged in collection</td>
<td>2</td>
</tr>
<tr>
<td>Mean size of a trip</td>
<td>100 km/trip</td>
</tr>
<tr>
<td>Number of trips per year</td>
<td>282 trip/year</td>
</tr>
<tr>
<td>Mean num. of bins per trip</td>
<td>8,8 bins/trip</td>
</tr>
<tr>
<td>Mean num. of clothes per kg of waste</td>
<td>3 items/kg</td>
</tr>
</tbody>
</table>

Each truck requires a team of two persons, one driver and one operator for manual activities supporting the collection of waste. A cost of 16 €/hour per driver and 12 €/hour per operator is assumed.

Data obtained during experimentation are then adapted to the final service that will be offered, by considering the whole area served, the forecast amount of waste to be collected (6000 tonnes) and the total amount of resources (bins, trucks, operators) required.

Similarly, as reported in Fig. 3, after collection, selection was studied. Non-reusable textile fraction is supposed to be sold for filling and wiping. The re-usable portion is diverted to hygienization. Deep cleaning is not economically viable. Therefore, technologies for hygienization in accordance with DM 5th February 1998 are evaluated. Moreover, refurbishing and redesign will not be implemented. Rather, an ad-hoc final selection will be pursued, in order to create three different streams of clothes:

- those diverted to local vintage shops, for which a selling price of 2,5 €/kg is expected
- those diverted to international markets, for which a selling price in the range [0,8; 1,5] €/kg is expected, depending on the quality of the clothes;
- those diverted to recycling (i.e. wiping or filling for sofa and chairs), for which a selling price of 0,35 €/kg is forecast.

The incidence of each stream on the total amount of waste is reported in Fig. 5, where the importance of international markets is evident, covering 84% of demand for used clothes.

However, local vintage shops are maintained for supporting the spread of awareness for the environment and a circular economy that aims to reintroduce into the market used items with a new residual life.

Then, an in-depth analysis of plants supporting valorization was carried out. Specifically, required area, operators, plants, equipment, energy consumption, maintenance activities, along with consumables and further minor variable costs were considered.

In Fig. 6, the incidence of main activities on the final total costs is reported. Obviously, main factors are related with collection and particularly with valorization plants, along with required capital-intensive equipment (i.e forklifts, automated handling lines).

![Figure 5: Streams following the selection step.](image-url)
However, the absence of legislative technical specifications regarding the processes to satisfy EOW criteria for textile waste has limited the diffusion of local valorization processes. Rather, the process is terminated after the first selection. Waste remains in its existing condition and is not prepared for re-use. Remaining activities are left to buyers. This adversely affects employment opportunities for categories of people who typically work in this sector, both with and without disease.

5. CONCLUSIONS

In this paper, the EU Directive on Waste is considered as the starting point for developing a process focused on the re-use of post-consumer textile waste, considering the importance of re-use within the waste management hierarchy. In particular, a framework supporting the industrial implementation of steps required for re-use of used clothes is presented. Environmental, economic and social effects are expected, but these are often left to countries outside Italy. Setting up a processing plant for the re-valorization of textile waste represents a major effort for any enterprise, but it also constitutes an opportunity for the creation of jobs for operators with physical, mental and social deficit.

Future advances of the study will be concerned with the analysis of data coming from the experimental analysis of conditions assuring a safe hygienization process, for which technical guidelines are not currently available. The authors, with their activity in the European project SIFOR - Sistema FORmativo al valore - Lavoro del riuso - 2012-1-IT1-LEO05-02781, have supported the development of the know-how for the local implementation of the full process related to the re-use of textile waste and particularly the local industrialization of the valorization step in social SMEs, in order to contribute to an organic insertion in workplaces of operators with and without deficit.

ACKNOWLEDGEMENTS

This research is financed by the European Commission contribution to the project SIFOR - Sistema FORmativo al valore - Lavoro del riuso - 2012-1-IT1-LEO05-02781. Further information is available at: www.sifor.eu.

REFERENCES
