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DISPOSAL OF GREEN ROOFS: A CONTRIBUTION TO IDENTIFYING AN "ALLOWED BY LEGISLATION" END-OF-LIFE SCENARIO AND FACILITATING THEIR ENVIRONMENTAL ANALYSIS

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Abstract

The rapid and widespread deployment of green roofs imposes the need to address their disposal and to assess the environmental impact of this phase of their life cycle to understand whether their current - and presumably future - large-scale application may pose a problem.

This paper starts from the consideration that environmental modelling of the end-of-life of green roofs is a complex task because defining the waste treatments to which their individual components should be sent is itself a difficult task. Indeed, it is necessary to note the lack of *ad hoc* technical standards for the end of life of green roofs through which to identify such treatments.

To provide an operational contribution to the problem, pending a release of dedicated legislation for the disposal of green roofs, a methodological proposal is introduced to identify a tentative dismantling scenario, permissible under current waste regulations, which a technician can refer to in his/her analysis. The feasibility of this proposal was conducted through a field investigation.

Among the scheme's strengths, in addition to its ease of use, is the fact that it is based on pivotal waste management criteria valid at the European level, giving the scheme broad applicability, not limited to the Italian context alone.

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Besides facilitating the modelling of the end-of-life of green roofs, this scheme is also intended to be a contribution to the drafting of future guidelines that analyse the dismantling phase of this technology, as already exist for the other phases of their life cycle.

Keywords: green roof; disposal; environmental impact; end-of-life scenario; recovery and/or disposal treatment; European Waste Catalogue.

1. Introduction

Research background

The green roof technology first applied four thousand years ago in the Hanging Gardens of Babylon, has now been brought back and used in urban contexts because of its potential in many different areas. Indeed, in addition to some positive economic effects from the reduced building operating costs for individual users [1], they bring many energy and environmental benefits as well. For instance, they have recently taken hold among technologies aimed at improving the energy performance of building envelopes [2; 3; 4; 5; 6; 7], which in turn positively affects indoor comfort levels for occupants [8; 9]. Also, when implemented on a large scale, green roofs contribute to improving air quality in cities [10; 11; 12] and increasing urban biodiversity by providing new habitats [13]. This technology has also recently earned much attention for its capability to attenuate the urban heat island (UHI) phenomenon. [14; 15; 16] which is a major cause for concern for the quality of living in urban areas. Green roofs are also regarded as an adaptation measure that aids in dealing with the various impacts of climate change. [17]. Because of this, integrating this technology could help to support the city transition to a condition of circular resilience [4; 18]. In addition, these components are recognized as effective tools to reduce the carbon footprint of the built environment [19].

Having such a great potential in helping to address some of the current environmental issues affecting our cities, the use of green roofs has thus rapidly increased in recent decades and there is now a large market for this technology. The size of the global green roof market was estimated at $1.1 billion in 2019 and is forecast to grow at a compound annual growth rate (CAGR) of 17 percent from 2020 to 2027, reaching $4.2 billion by 2027 [20].

However, it is important to note that even if the useful life of a green roof is longer than that of a traditional roof (a lifespan of 30-50 years is reported in most green roofs studies [21], sooner or later all these installations, which exist and are expected to grow, will reach the end of their life and will become waste that will have to be disposed of. Therefore, what impact will the disposal of all these green roofs have on the environment? In other words, will the green roof waste be hazardous to the environment? Also, if so, to what extent?

In the opinion of the present authors, it is not of negligible importance to know the environmental impact of the dismantling of these components to understand whether their present - and supposedly future - large-scale implementation could be a cause for concern.

The interest of the present authors in dealing with the disposal of green roofs also derives from the fact that they are engaged in the disposal of two green roofs (195 m^2 in total) that have been used for research purposes at the University of Palermo.

In dealing with the disposal of this type of roof (understood here as the demolition of the green roof and sending of its components to recovery and/or disposal treatments), we have found that it is still an open topic, as it is not codified yet. In this regard, it is in fact necessary to point out that to date there is a lack of *ad hoc* regulations and/or guidelines that make it possible to obtain useful information on the treatments to which waste deriving from the disposal of a green roof is to be sent. This probably depends on the fact that, as already mentioned, green roofs are a technology that has become particularly attractive relatively recently and is characterized by a long life span therefore the need to regulate its disposal has not yet arisen. For the same reasons, there is not even a practice in use the treatment of waste from the disposal of a green roof, at least in Italy.

It should be noted that, to the best of our knowledge, guidelines of this type, which could represent a useful comparative reference, have not been issued even at the international level.

In view of all this, environmental modelling of the end-of-life phase of a green roof aimed at estimating the impact of this phase of the green roof's life cycle on the environment appears to be a complex task (not coincidentally, it is the phase of the green roof life cycle that is often neglected in the environmental analyses of this technology).

Research contribution

Starting from this situation, the present work aims to provide an effective contribution to the problem. In detail, pending the release of guidelines on how to manage the waste deriving from the dismantling of a green roof, an operational scheme is proposed to identify a tentative green roof dismantling scenario, to which a technician can refer in his/her analysis The procedure advanced here will make it possible to identify an end-of-life scenario for the given green roof that is "correct" (in the admissible sense) from a regulatory point of view. The proposal is based on an "attempt classification" of the materials making up the green roof performed with the combined use of the European Waste Catalogue (reported in the current European legislation on waste) and information material made available by manufacturers of individual green roof materials.

It is important to note that this scheme is in line with the priority criterion defined by the Waste Framework Directive, namely the EU Directive 2008/98 [22], which requires that preference be given to recovery over disposal.

In this work, the feasibility level of the scheme is also analysed in the field with reference to a case study, represented by a green roof currently installed on a building of the University of Palermo.

This operational scheme is intended to be a contribution by the present authors to facilitate the environmental modelling of the end-of-life phase of these components, thus contributing, in turn, to increasing the still limited (due to the few literature studies present) level of knowledge of the impact of their disposal.

It also wants to contribute to the drafting of future guidelines for the analysis of the phase of dismantling of these envelope components.

Research structure

The structure of the article is as follows: *Section 2* reports the state of the art regarding the environmental modelling of the end-of-life phase of green roofs. *Section 3* describes in detail the operation of "waste classification" since the entire proposed operational scheme is based on this. *Section 4* reports the methodological proposal advanced for the determination of the end-of-life scenario of a green roof eligible for a regulatory point of view. *Section 5* provides an example of field application of the proposed method to an extensive green roof currently installed in Palermo. *Section 6* investigates the validity of the method, particularly highlighting its strengths and limitations. *Section 7* also provides some recommendations for future research in this area.

2. State of the art concerning the environmental modelling of the end of life of green roofs

The issue of green roof disposal and especially its environmental impact is a topic that has aroused some interest in the scientific community. In the work conducted by Shafique et al. [2020], a comprehensive review of Life Cycle Assessment (LCA) studies concerning green roofs is reported.

From a critical analysis conducted by the present authors of the studies mentioned by Shafique et al., which include the end-of-life phase of the green roof, it emerged that to date there are still only a few studies that deal with this issue; specifically, the cradle-to-grave approach was found to be only 25% compared to the more common and widely employed cradle-to-gate one (75%) [21].

Moreover, some of them focus more on the recovery/disposal of waste deriving from the construction of a green roof rather than on waste deriving from its disposal (that is the subject of this work).

Table 1 summarizes the results of the aforementioned critical analysis, where for each study examined, the country to which the analysis refers, the proposed end-of-life scenario together with any considerations made by the authors on this phase of the life cycle and (when available) on the selection criterion used to identify the proposed scenario are indicated.

Table 1. End-of-life scenarios of green roofs' reported in LCA studies cited in the review work carried out by Shafique et al [21] (ND = not declared in the work; NI = not included in the analysis).

Reference	Location	End-of-life scenario	Considerations reported in the study on green roof end-of-life and (when available) on the selection criterion used to identify the proposed scenario.
Kosareo and Ries [23]	Pittsburgh, USA	ND	Although it is stated that the disposal of materials at the end-of-life span is included in the analysis conducted, the disposal scenario hypothesized is not given in the article.
Peri et al. [24]	Palermo, Italy	Partially landfilling and partially incinerating	The waste scenario hypothesized is as follows: growing medium and bitumen (waterproofing and root barrier) go to landfill, perlite (water retention) goes to inert material landfill, plastic materials (High Density Polyethylene and Polypropylene of the drainage, Polyethylene Terephthalate of the filter layer) go to incineration plant with energy recovery.
Bianchini and Hewage [25]	Canada	NI	The study does not actually consider the end stage of a green roof in the analysis (as stated instead in the article by Shafique et al.), rather it compares the impacts associated with the manufacturing process of polymeric green roof materials to assess the actual sustainability of green roofs made with recycled materials *versus* those without recycled materials. However, regarding the green roof disposal, it says: "The typical disposal phase of green roofs includes dissemble of all the layers and transport them to landfills. The growing medium can be easily reused for any other purpose and plants biodegrade fast, but not the polymers… recycling or reusing these materials becomes an attractive option. "
Angelakoglou et al. [26]	Greece	Only landfilling	While detailed information is given on disposal scenarios of the construction waste (either disposed to landfills or partially recycled), concerning the green roof dismantling and waste disposal, it appears that only landfilling was assumed.
Arodudu et al. [27]	Overijssel, Netherlands	NI	In the paper, green roofs are considered among available sources of biomass but no information is given about the management of their end of life.

Dabbaghian et al. [28]	Canada	ND	In the article, the researchers state that the end-of-life phase is among the life cycle stages considered in the analysis. However, the assumed end-of-life scenarios for the products are not explicitly stated. Furthermore, it is stated that the scenarios were defined based on the available literature, which in any case, is not indicated either.
Rincon et al. [29]	Lleida, Spain	Partially landfilling and partially recycling	The waste scenario hypothesized is as follows: all materials are sent to inert material landfills. Rubber and steel are hypothesized to be recycled; while asphalt is sent disposed to a sanitary landfill. As for substrate and plants, it is stated that they can be used as compost.
Bozorg Chenani et al. [30]	Various sites	Partially recycling partially incinerating and partially landfilling	The waste scenario hypothesized is as follows: 50% of all layers (except substrate) go to recycling and 50% to incineration; substrate goes to landfill. Furthermore, researchers state that they couldn't find disposal data from product safety data sheets from manufacturers and that “they chose a reasonable waste treatment from literature” and used that in their analysis. However, no references are indicated on purpose.
Contarini and Meijer [31]	Leiden, Netherlands	NI	The article does not consider the end-of-life phase of the roofing materials.
Gargari et al. [32]	Pisa, Italy	Partially landfilling and partially incinerating	Researchers assumed for all green roofs alternatives examined: disposal of inert material (medium) to sanitary landfill; disposal of polyethene (filter layer and root barrier) and polystyrene (drainage/insulation) to municipal incineration. Furthermore, it is stated that “there are no regulations regarding the reuse of green roof soils in agriculture. As reported by Peri et al. (2012), incineration is excluded because a large amount of inert and the sanitary landfill is the only waste processing available due to the potential/real presence of peat”.
Vacek et al. [33]	Bus, Czech Republic	Only landfilling	In the study, all materials of the green roof are supposed to be landfilled. In the paper it is stated also that the assumption is based on information provided by the Environmental Information Agency of Prague, which states that “most of the waste produced in the Czech Republic is re-used (e.g. for landscaping) or landfilled.”
Ipsen et al. [34]	Copenhagen, Denmark	NI	No information is given on the end-of-life stage.

Brachet et al. [35]	France	Partially landfilling, partially incinerating, partially recycling and partially composting;	The waste scenario for vegetation is clearly stated: it is assumed to entirely compost it. Concerning other components, treatments assigned are not clearly stated. Authors only provide figures derived by a report with an analysis of European Plastics Production, Demand and Waste Data, according to which plastic wastes are incinerated at 42%, recycled at 31% and landfilled at 27%. Also they provide data derived by a report of the National Union of Quarry Industries and Building materials (UNICEM) on the recovery and recycling of inert construction products, according to which mineral wastes are recycled at 65% and landfilled at 35%.
Pushkar, [36]	Israel	Only landfilling	Researchers declare that the landfilling practices of all materials (perlite, polystyrene, Cool Bottom Ash (CBA), and fly ash-based aggregates (FAAs) in both the substrate and drainage layers were modelled. Furthermore, it is stated that such waste scenario relies on “the currently accepted Israeli construction and demolition debris (CDB) landfilling practices, according to which, approximately 70% of all CDB is landfilled.”

As it can be seen, the information that can be deduced from these studies on the methods of disposing a green roof (and, consequently, on the environmental impact of its end of life) appears somewhat dispersed, given the numerous scenarios proposed which correspond to different impacts. Such a variety of scenarios likely depends both on the wide range of variability in terms of materials used (depending on the design options), and on the different waste management procedures implemented in different countries.

Furthermore, as demonstrated especially from the last column of the table, in most of the studies analysed a certain vagueness was found in describing how the specific scenario was defined; sometimes, the disposal scenarios hypothesized in the analysis are not even explicitly described. Only in three of these studies analysed the criterion on which the identification of treatments to start the individual components of the green roof is based is clearly stated. Generally, this criterion is represented by waste management practices typically in use in the country where the green roof is installed (this is the case reported by Vacek et al. [33] and Puskar [36]) and by European statistics concerning waste (this is the case reported by Brachet et al. [35]).

However, in both cases, the scenario arises from field data concerning waste management in general, not specific to green roofs.

Ultimately, the literature analysis indicates the lack of a standardized, commonly adopted, procedure for determining the treatments, recovery and/or disposal, to be assigned to the waste deriving from the disposal of the green roof to be used to model the end of life of green roofs.

The methodological proposal put forward in this work for the identification of such treatments is based on an “attempt classification” of the materials making up the given green roof.

The next section describes in detail the operation of waste classification as prescribed by European legislation as it is functional to the definition of the proposed operational scheme.

3. The waste classification at European level

The identification of the waste, also known by the name of “classification”, represents a phase of certainly not negligible importance; in fact, the management of the waste – and consequently its environmental impact – derives from the outcome of this operation.

Waste classification is performed through the European Waste Catalogue (EWC). This was initially established by Commission Decision 94/3/EC, which in turn was replaced by Decision 2000/532/EC [37], and then amended by the currently in force Commission Decision 2014/955 [38].

The catalogue is essentially a list of waste identified by a code that is made up of six digits, of which: the first two digits indicate the chapter of the catalogue, i.e. the activity that produced the waste; the second two digits identify the sub-chapter of the catalogue that best specifies the activity that produced the waste; the last two digits define the type of waste.

The Commission Decision 2014/955 in the Annex also illustrates the criteria to be followed to correctly identify the EWC code to be attributed to waste according to the activity and the specific production process that generated it. In detail, it is said as follows: “Identify the source generating the waste in Chapters 01 to 12 or 17 to 20 and identify the appropriate six-digit code of the waste (excluding codes ending with 99 of these chapters) …— If no appropriate waste code can be found in

Chapters 01 to 12 or 17 to 20, the Chapters 13, 14 and 15 must be examined to identify the waste. — If none of these waste codes apply, the waste must be identified according to Chapter 16. — If the waste is not in Chapter 16 either, the 99 code (wastes not otherwise specified). Must be used in the Section of the list corresponding to the activity identified in step one".

Three different circumstances relating to the classification may arise:

- waste classified with an 'absolute' dangerous EWC code (i.e. those marked with an asterisk).
- waste classified with 'absolute' non-hazardous EWC code.
- waste classified with specular EWC codes, one dangerous (with asterisk) and one non-dangerous.

A waste may be indeed dangerous or not depending on the concentration of certain substances it contains. In the latter case, it is necessary to carry out in-depth laboratory investigations to identify the properties of danger that the waste possesses.

4. Proposal of an operational scheme to identify an "allowed by legislation" disposal scenario of an existing green roof.

The proposed operational scheme predicts, given an existing green roof, initially carrying out an "attempt" classification of the waste deriving from the disposal of the green roof (step 1).

In the European Waste Catalogue none of the codes present describes the "green roof" waste. However, green roofs are a stratigraphic technological system, the layers of which are installed one on top of the other by simple support; as such it lends itself well to demolition by deconstruction, which generates homogeneous waste (selective demolition), unlike traditional demolition. The selected waste thus obtained can therefore be destined, each one individually, to the most suitable treatment.

Therefore, by ideally breaking down the green roof under study into its components (the hypothesis here is, in fact, that the green roof is still installed, i.e. it has not yet become a waste to be disposed of), it is necessary to proceed element by element identifying the type of waste to which each of them could belong.

To get to the attempt EWC codes, the procedure involves using, in addition to the European Waste Catalogue (as required by current legislation), also the technical data sheets and safety data sheets of the materials in question or – if not available – those of materials with the same function and similar characteristics of the same producer. The information contained in them allows bypassing the laborious phase of characterization of the material, previously cited in case of specular codes, thus meeting the needs of technicians, who are usually not able to carry out such complex analyses; indeed, they generally cannot carry out laboratory analyses to study the chemical composition and any dangerous characteristics of the waste sample taken.

Once the "attempt" classification is complete, the second step foreseen by the scheme is based on the priority criterion defined by the Waste Framework Directive, namely the Directive 98/2008 at Art. 4 [22], which requires that recovery be favoured over disposal. In particular, according to the concept of "waste hierarchy", when waste is not reusable, priority should be given to the recovery of raw materials, i.e. recycling. If this process also cannot be performed, other types of recovery will be considered, such as energy recovery. Finally, if none of the above treatments is feasible, the waste will be disposed of.

As for the recovery treatment, the Directive 2008/98/EC contains the following definition: "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".

Table 2 lists the activities in which the recovery treatment is declined in the Annex II of the Directive. The information provided by the table also considers the changes to 2008/98/EC introduced by the most recent EU Directive 2018/851 [39].

Table 2. Recovery operations provided by the Waste Framework Directive, namely the Directive 98/2008 [22] with changes introduced by the EU Directive 2018/851 [39].

Code	Recovery treatment description
R1	Use principally as a fuel or other means to generate energy
R2	Solvent reclamation/regeneration
R3	Recycling/reclamation of organic substances which are not used as solvents (including composting and other biological transformation processes)
R 4	Recycling/reclamation of metals and metal compounds
R5	Recycling/reclamation of other inorganic materials
R6	Regeneration of acids or bases
R7	Recovery of components used for pollution abatement
R8	Recovery of components from catalysts
R9	Oil re-refining or other reuses of oil
R10	Land treatment resulting in benefit to agriculture or ecological improvement
R11	Use of waste obtained from any of the operations numbered R1 to R10
R12	Exchange of waste for submission to any of the operations numbered R1 to R11
R13	Storage of waste pending any of the operations numbered R1 to R 12 (excluding temporary storage, pending collection, on the site where the waste is produced)

As it can be seen, in the legislation the term "recovery" refers not only to material recovery operations but also energy recovery using waste as a fuel or as another means of producing energy (R1).

It should be noted that, in this second step of the procedure, it is first necessary to check the admissibility of the material recovery treatments and then, if these are not allowed, that of the energy recovery operations. Also, in this case, the proposed procedure is in line with the concept of "waste hierarchy", aimed at preferring in the first-place activities such as reuse, material recovery and then, if this is not feasible, energy.

If no recovery activity (neither material nor energy) is allowed, the scheme foresees to assign the final disposal as the destination to the given component.

As for the disposal treatment, the Directive 2008/98/EC contains the following definition: "any operation which is not recovery even where the operation has as a secondary consequence the reclamation of substances or energy".

The possible disposal operations envisaged by the Annex I of the directive 2008/98/EC are listed in Table 3.

Table 3. Disposal operations envisaged by the Waste Framework Directive, namely the Directive 98/2008 [22].

Code	Disposal treatment description
D 1	Deposit into or on to land (e.g. landfill, etc.)
D 2	Land treatment (e.g. biodegradation of liquid or sludgy discards in soils, etc.)
D3	Deep injection (e.g. injection of pumpable discards into wells, salt domes or naturally occurring repositories, etc.)
D4	Surface impoundment (e.g. placement of liquid or sludgy discards into pits, ponds or lagoons, etc.)
D5	Specially engineered landfill (e.g. placement into lined discrete cells which are capped and isolated from one another and the environment, etc.)
D6	Release into a water body except seas/oceans
D7	Release to seas/oceans including sea-bed insertion
D8	Biological treatment not specified elsewhere in this Annex which results in final compounds or mixtures which are discarded by means of any of the operations numbered D 1 to D 12
D9	Physico-chemical treatment not specified elsewhere in this Annex which results in final compounds or mixtures which are discarded by means of any of the operations numbered D 1 to D 12 (e.g. evaporation, drying, calcination, etc.)
D10	Incineration on land
D11	Incineration at sea
D12	Permanent storage (e.g. emplacement of containers in a mine, etc.)
D13	Blending or mixing prior to submission to any of the operations numbered D 1 to D 12
D14	Repackaging prior to submission to any of the operations numbered D 1 to D 13
D15	Storage pending any of the operations numbered D 1 to D 14 (excluding temporary storage, pending collection, on the site where the waste is produced)

Fig. 1 briefly illustrates the operational scheme proposed in the present work, which clearly will be applied individually to each component of the specific green roof.

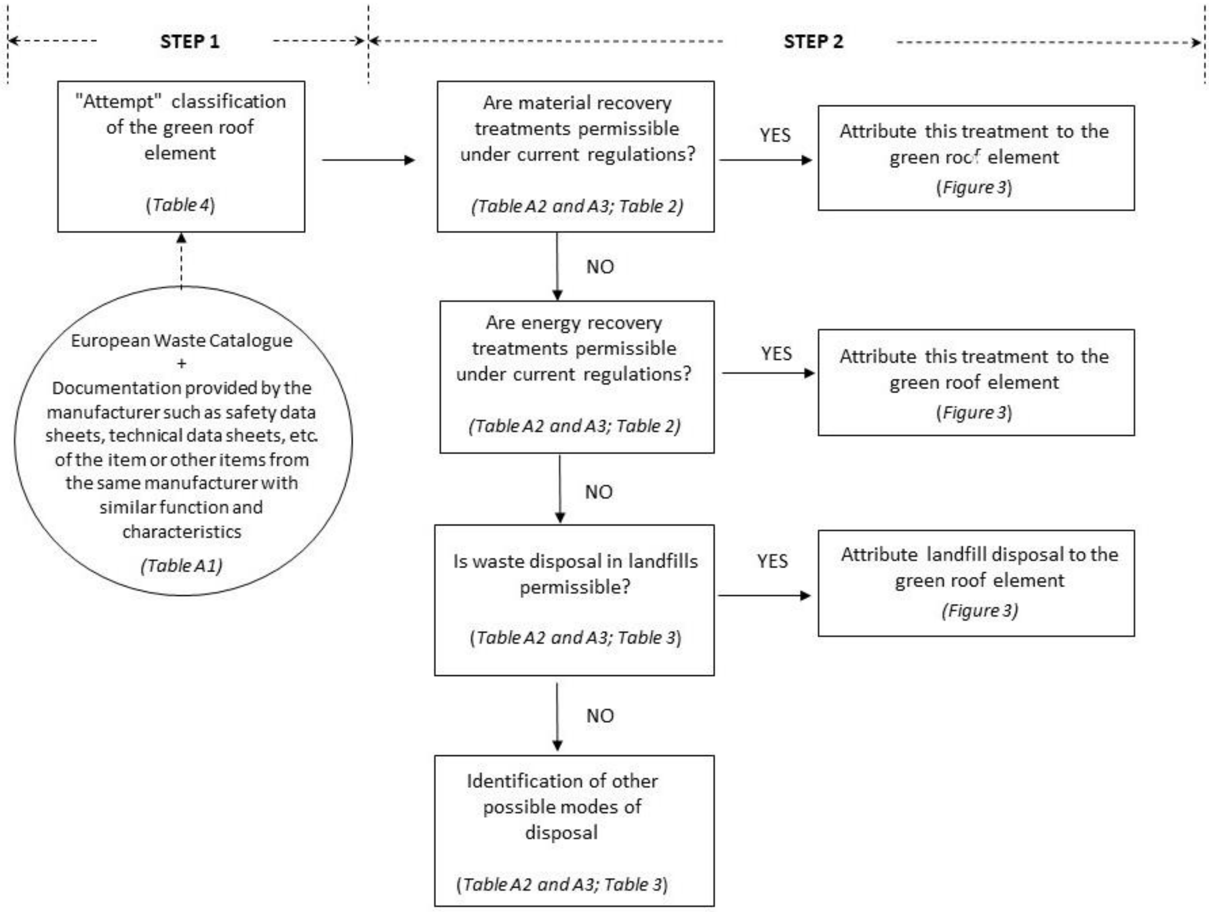

Fig. 1. Methodological scheme proposed in this work for the identification of the end-of-life scenario of a still installed green roof.

As it can be seen from Figure 1, when there is the inadmissibility of the waste in landfills, the diagram refers to the other disposal methods among those indicated in Table 3 (apart from D1).

The feasibility of the approach described in Figure 1 was tested on a case study. The following section reports the results of the field application of the proposed method to an extensive green roof currently installed on a building at the University of Palermo.

5. Field application of the operative scheme

Given the great variety of technological solutions currently available on the market, to verify the feasibility of the proposed method, it was decided to limit the application to a real green roof. In any case, it should be emphasized that the technological system of the roof chosen for the analysis is from one of the leading companies operating in Italy for green systems; as such, the case study corresponds to a widespread solution for Italian green roofs, and this makes the results obtained sharable.

5.1. The case study: an extensive green roof sited in Sicily

The object of study of the present work is a green roof installed in Building 9 of the Engineering Department of the University of Palermo (Fig. 2).

Fig. 2. Aerial image of Building 9 at the University of Palermo with the green roof under study highlighted with a red rectangle.

The case study is part of an experimental apparatus consisting of three green roofs positioned on three areas of the rooftop of Building 9, realized in the year 2015 within a research project in which the Department of Engineering of the University of Palermo took part.

The cover under study has been realized in post-installation with respect to the building and covers a total area of 67 m^2. The cover is extensive, therefore the plant species present are adapted to the Mediterranean environment and require minimal maintenance [40]; the green plant is divided into three sectors (Figure 2), each of which hosts a different plant species (from the front to the back) *Aptenia lancifolia*, *Mesembryanthenum barbatus*, and *Sedum* [41; 42], while featuring the same technology package.

The composition of the technology package employed is as follows (from bottom to top): waterproofing element with root inhibitor function, drainage element, water storage element, filter element, growing medium and vegetation. The study, being focused on the analysis of the green system itself, does not provide any considerations about the pre-existence where the cover is laid. Furthermore, the green roof studied is constituted not only by the stratigraphy previously described but also by accessory components that complete the system. These are elements for the walkway (high-density polyethene tiles) and the irrigation system. The latter is of the drop type, which is a micro-irrigation system. The system also has inspection wells located above the attic drains. The manholes are made of polypropylene, of the same type as those used for electrical systems. They are installed after the removal of the bottom.

The total weight of the green package is about 47 kg/m^2 and 3,149 kg for the whole roof, while the total weight of the accessory elements is about 2 kg/m^2 and 134 kg for the whole roof. Therefore, the total weight of 1 m^2 of coverage is about 49 kg, while that of the entire coverage is about 3.283 kg.

An in-depth description of the individual constituent elements of the case study is reported in Appendix A attached to this article, especially in Table A1, as it is functional for the attempt classification produced for each element.

5. 2 Implementation of the operative scheme proposed to the elements of the case study

Since the case study is located in Italy, to implement the operational scheme, present authors have referred to the Italian national legislation on waste that implement and transpose the European legislation on this matter.

5.2.1 “Attempt” Classification (step 1)

To perform the “attempt” classification, it has been used the Legislative Decree 152/2006 [43] especially Part IV of the decree. This Part (corresponding to Articles 177 to 216) is entitled "Regulations on waste management and remediation of polluted sites", Title I, "Waste management "and represents the legislation in force at the Italian national level on waste matters. The European Waste Catalogue can be found in Annex D of this decree.

Since the waste produced by the dismantling of a green roof is generated by a demolition activity, they are part of the construction and demolition waste category, which is often referred to as “C&D waste”[2]. As such, in the European Waste Catalogue, they belong to chapter 17 entitled "Construction and demolition wastes (including excavated soil from contaminated sites)".

The attempt EWC codes of the individual components of the case study were, therefore, searched within this chapter, which is in turn divided, according to the source that generates the waste, into the following sub-chapters:

- 17 01 concrete, bricks, tiles and ceramics;
- 17 02 wood, glass and plastic;
- 17 03 bituminous mixtures, coal tar and tarred products;
- 17 04 metals (including their alloys);
- 17 05 soil (including excavated soil from contaminated sites), stones and dredging spoil;
- 17 06 insulation materials and asbestos-containing construction materials;
- 17 08 gypsum-based construction material;
- 17 09 other construction and demolition wastes

Table 4 provides an overview of the codes that have been assigned in this work to each element of the case study.

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[2] In addition, the waste produced by dismantling a green roof is also classified as special waste under Legislative Decree 152/2006 [43], precisely because it is C&D waste.

Table 4. "Attempt" classification of the elements of the case study.

Green roof component	Attempt EWC code	Description of the assigned EWC code
Waterproofing and root-proofing element	*17 03 02*	Chapter: 17 "Waste from construction and demolition operations (including soil from contaminated sites)" Subchapter: 03 "Bituminous mixtures, coal tar and products containing tar" Type of waste: 02 "Bituminous mixtures other than those referred to in item 17 03 01*.
Drainage	*17 02 03*	Chapter: 17 "Waste from construction and demolition activities" Subchapter: 02 "Wood, glass, plastic" Type of waste: 03 "Plastic"
Water storage	*17 09 99*	Chapter: 17 "Waste from construction and demolition operations (including soil from contaminated sites)" Sub-chapter: 09 "Other construction and demolition waste" Type of waste: 99 "Waste not otherwise specified"
Filter	*17 02 03*	Chapter: 17 "Waste from construction and demolition activities" Sub-chapter: 02 "Wood, glass, plastic" Type of waste: 03 "Plastic"
Substrate	*17 05 04*	Chapter: 17 "Waste from construction and demolition activities" Subchapter: 05 "Earth (including soil from contaminated sites), rocks and dredging mud" Type of waste: 04 "Soils and rocks other than those referred to in item 17 05 03"
Accessory elements	*17 02 03*	Chapter: 17 "Waste from construction and demolition activities" Sub-chapter: 02 "Wood, glass, plastic" Type of waste: 03 "Plastic"

The considerations that, element by element, have led these authors to assign the provisional EWC codes listed in the table are reported in detail in Appendix A, attached to this article, especially in Table A1, which indicates for each individual constituent element of the case study both an in-depth description of the element and the information inferred from both the European Waste Catalogue and the material made available by the producer. The combination of these data was functional for the assignment of the provisional EWC code made by the present authors.

Only one point concerning the drainage and filter elements - as well as the accessory elements - seems worth mentioning here, namely: the attempt EWC codes attributed to these elements assuming the non-hazardous nature of the waste. For these elements it was in fact not possible to obtain information about any dangerous characteristics of the product from neither their technical data sheet (as well as from those of other products of the same manufacturer with the same function and similar characteristics) available online upon request from the manufacturer, nor from their documents/data on safety, the acquisition of which was rather laborious.

5*.2.2. Attribution of "attempt" treatments for recovery and/or disposal (step 2)*

To perform the admissibility analysis of recovery for the individual waste with the attributed attempt EWC code, present authors referred to the Italian Ministerial Decree of 5th February 1998 [44][3] as it regulates the recovery activities in Italy. Specifically:

- the material recovery is governed by "Annex 1, Sub Annex 1 - General technical standards for the recovery of material from non-hazardous waste";
- the energy recovery is governed by "Annex 2 Sub Annex 1 - Standards techniques for the use of non-hazardous waste as fuel or as other means to produce energy ".

The *modus operandi* of these authors to establish whether, for the given waste, the recovery of material is admissible according to the aforementioned legislation was the following: once the tentative EWC code was assigned to the given component of the case study, it was first checked if this EWC code is included among those envisaged in at least one of the points into which Annex 1 of the Ministerial Decree of 5 February 1998 is divided. Subsequently, after identifying the possible points in the Annex, the requirements of each point were analysed, checking whether the waste falls within the accepted types, whether the origin is among those listed, and whether all the established characteristics are met. In the case of correspondence, the material recovery operations to which

[3] Modified and integrated by the Ministerial Decree of 5 April 2006 n. 186 [45], 12 June 2002, n. 161 [46], and November 17, 2005, n. 269 [47],

the waste can be sent have been obtained, since each point contains all the operations at which a specific refusal can be initiated.

The same approach was followed to check the eligibility of energy recovery treatments.

To perform the admissibility analysis of the disposal of waste in landfills, the in-force regulation in Italy is represented by Legislative Decree 121 of 2020 (that is an implementation of Directive (EU) 2018/850) [48]). In detail, art. 6 of the Legislative Decree 121 of 2020 shows the waste not allowed in landfills, which is then detailed in table 2 of Annex 3 of the same decree. This decree has reformed Legislative Decree no. 36/2003 that originally regulated the disposal in landfills.

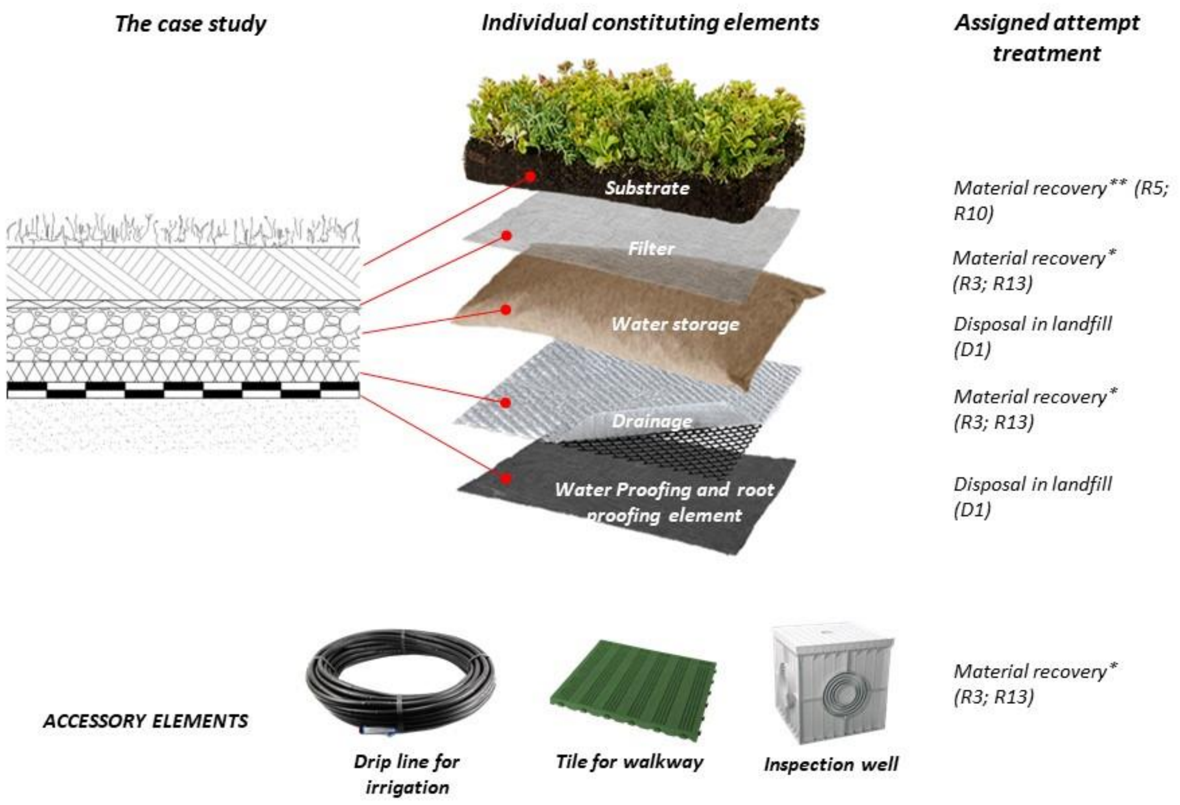
As for the verification of the admissibility of the waste in the landfill, it was simply established the presence of the attempt EWC code assigned among those indicated in table 2 of Annex 3 of Legislative Decree 121 of 2020.

Figure 3 provides an overview of the “attempt” treatments that have been assigned in this work to each element of the case study reached through the aforementioned analysis.

In Appendix A attached to this article, especially in Table A2, a synthetic summary of the Italian national waste legislation to which reference was made for the application of the proposed scheme to the case study is illustrated (starting from the “attempt” classification).

Table A3 of the Appendix shows synthetically results of the admissibility analysis of recovery and/or landfill disposal with respect to the legislation made by these authors, element by element.

Therefore, the end-of-life scenario identified for the case study (Fig. 3) relies on these results.



* The concern is related to the unclear correspondence between the item in question and waste with EWC 17 02 03 in the standard, in terms of the type and characteristics of the waste.

* * The concern is related to the non-full correspondence between the substrate and waste with EWC 17 05 04 in the standard, in terms of the type, origin and characteristics of the waste.

Fig. 3. The end-of-life scenario identified for the case study derived by applying the operational scheme of Figure 1.

As it can be seen, the recovery of material was admissible, with respect to the current legislation, for the draining and filtering elements, the accessory elements, and the substrate. However, for all these elements admissibility of the recovery treatment with "reserve" was found (indicated by the asterisks next to "material recovery"). This aspect will be dealt with in detail in the Discussions, particularly in the part concerning the strengths and limitations of the proposed operational scheme. As for the remaining two elements, namely the water accumulation and the waterproofing sheath with anti-root function, for which material recovery is not allowed by regulation, it was not necessary to investigate the admissibility of disposal operations other than landfill disposal, since this was admissible according to current legislation.

6. Discussion

Disposal of green roofs: a hot topic of the moment and still open as it has not yet been codified from a regulatory perspective

The production of waste from the disposal of green roofs is currently quite low, as the plants are relatively new and, generally, have not yet reached the end of their useful life. However, given their rapid and widespread diffusion, in the future, the production of waste in this sector will undergo a considerable increase and it will be necessary to pay attention to how to manage the waste associated with these covers.

This circumstance also imposes the need to evaluate the impact that the disposal of all these installations will have on the environment; this, in the opinion of these authors, is a question of not negligible importance, to understand whether (despite the numerous benefits they bring both to the building equipped with them and to the urban context in which they are inserted) their large-scale implementation may be a cause for concern.

On these premises, the theme we are dealing with in this work - that is the disposal of green roofs and their impact on the environment - represents a hot topic of the moment but, at the same time, it should be noted that it is also a topic still open as not yet coded. To date, there are no *ad hoc* regulations and/or guidelines that make it possible to obtain useful information on the treatments to which waste from the disposal of a green roof is to be sent. As already mentioned, this probably depends on the fact that green roofs are a technology that has become particularly attractive relatively recently and that is characterized by a long-life span (30-50 years); therefore, the need to regulate its disposal has not yet arisen. For the same reasons, there is not even a practice in use the treatment of waste from the disposal of a green roof, at least in Italy.

A very different situation was instead found for the phases of production, installation, use and maintenance of green roofs, which are instead well codified, for which there are not only internationally recognized guidelines, that is the FLL guidelines [49], but also technical standards and regulations valid at national level; among these, some examples are: “the Gro Green Roof Code” for the UK [50], the “UNI11235” for Italy [UNI11235, 2015], and the ASTM standards for the US [51, 52, 53, 54].

On the contrary, the environmental modelling of the end-of-life phase of a green roof aimed at estimating the impact of this phase of the green roof life cycle on the environment appears to be a complex task, since it depends on the dismantling scenario of the roof.

With respect to this, the present work aims to provide an effective contribution to the problem by proposing an operational scheme aimed at facilitating the modelling of this phase of the life cycle of green roofs and, in turn, at increasing the still limited level of knowledge of the impact of the disposal of green roofs on the environment, given the few studies present in the literature.

Strengths and limitations of the proposed operational scheme

The application of the operational scheme to a real green roof demonstrates the simplicity of use of the proposed method.

Furthermore, it is important to note that this scheme is based on two concepts, the “waste classification” and the “waste hierarchy” which represent key criteria of waste management at the European level. Being in line with what is prescribed at a European level on waste matters represents a strong point of the scheme, since it makes it applicable to other contexts as well, not just the Italian one to which the application presented here belongs.

Another strong point of this scheme is represented by the fact that thanks to its relative ease of use, it could be temporarily used by technicians to identify a tentative end-of-life scenario for the given green roof to be used in their energy and environmental analyses of these components, pending a release of guidelines that give indications on how to manage the disposal of these building components.

As regards, instead, the limits of the proposed approach, three main criticalities emerge from the application, which essentially depend on a) the absence of characterization, b) the limits of the current state of Italian legislation on waste and c) the laborious acquisition of data on materials from producers. Specifically, these criticalities refer to the fact that:

a) The “attempt” classification carried out in the absence of analytical characterization, involves, for some components of the green roof, a level of uncertainty about the tentative EWC codes to be assigned, which then inevitably influences the final treatments to be attributed, which in turn influence the evaluation of the end-of-life phase of the green roof that will be made under these assumptions.

This is the case with the drain element and the filter element. More in detail, with regard to the draining element, it seems important to note that for this component of the case study, another classification - in addition to the one advanced in the present work - equally reasonable could be advanced in an attempt. It is necessary to consider that the two plastics of the drainage are of different types since the geonet is hard plastic while the geotextile is a non-woven fabric with a filtering function. The draining element could therefore also be considered as consisting of two different types of waste, plastic and filter material. Excluding, through the characterization, the possibility that the non-woven fabric falls under chapter 17, it would at this point fall under Chapter 15, and more specifically it should be associated with EWC code 15 02 03 "Absorbents, filtering materials, rags and protective clothing, other than those mentioned in 15 02 02" (this latter on the contrary identifies "absorbents, filtering materials-including oil filters not otherwise specified-, rags and protective clothing, contaminated with hazardous substances").

Ultimately, the whole drainage would also be identifiable with the EWC code 17 09 99 where 17 09 stands for “Other construction and demolition waste” and 99 represents the code for waste not otherwise specified.[4]

[4]Even EWC code 17 09 04 "mixed waste from construction and demolition activities, other than those referred to in items 17 09 01, 17 09 02 and 17 09 03" cannot be attributed to this waste, as it refers to those which in jargon are called “sfabbricidi”, that is the heterogeneous set of building materials deriving from demolitions, containing rubble, tiles, sanitary ware, bricks, etc.

Similarly, in the case of the filter element, another classification - in addition to the one advanced in the present work - might be equally reasonable. If the non-woven must be considered a filter material (rather than a plastic deriving from the demolition activity), in this case, the whole filter would also be identifiable with the code CER 15 02 03 "Absorbents, filter materials, rags and protective clothing, other than those mentioned in item 15 02 02 ".

b) The current Italian national legislation on recovery does not seem updated with respect to the new types of materials used for the ecological transition. Therefore, in the assessment of the admissibility of the recovery treatments for the specific element, sometimes, despite the EWC code being the same, there is an absence or an unclear and/or not full correspondence, in terms of type, origin and characteristics of the waste, between the element in question and the waste to which the standard refers.

In this case, the lack of correspondence was found for the bituminous sheath with anti-root function (attempt EWC code 17 03 02); in fact, in Ministerial Decree 5/02/98 [44] it does not fall within the types of waste identified with CER 17 03 02 (i.e. bituminous conglomerate); as well as its origin, i.e. the demolition activity, is not among those indicated in the standard for the CER 17 03 02 (i.e. the scarification of the road surface by cold milling). Therefore, due to the failure to designate this waste within the Ministerial Decree 05/02/98, currently in Italy, the majority of bituminous conglomerate production plants for road use, despite being authorized to use recycled bituminous sheath, are not carrying out this virtuous recovery operation (https://www.siteb.it/2019/07/23/il-recupero-di-rifiuti-di-membrane-bituminose/).

On the other hand, an unclear correspondence was found between the draining and the filtering agent (attempt EWC code 17 02 03) and the types of waste corresponding to EWC 17 02 03 indicated in the decree.

Finally, a non-full correspondence was found between the substrate (attempt EWC 17 05 04) and the waste identified with EWC 17 05 04 of point 7.31 bis of Ministerial Decree 05/02/98 [44], which seem to be close to the substrate both in terms of type and characteristics, but they distance themselves from it in terms of origin (i.e. excavation activity).

c) The laborious acquisition of safety data for components of the green roof by producers sometimes imposes the need to make simplifying hypotheses.

By way of example, the case of the draining element is reported: for this product (as well as for others characterized by the same function and similar properties of the same manufacturer), having failed to acquire the relevant documents/safety data from the manufacturer, it was necessary to assume a non-dangerousness of the refusal to be able to arrive at a first attempt EWC code.

A further aspect should be discussed regarding the method presented here. As already stated several times, the proposed method identifies the “admissible” green roof end-of-life scenario from a regulatory point of view but this scenario may not necessarily be feasible compared to the situation of the waste management plant. In other words, admissibility according to current legislation is a necessary but not sufficient condition for the definition of a "correct" green roof end-of-life scenario to be referred to in the analysis of these components. By way of example, the case of the draining element is reported: the material recovery treatment, although admissible according to Ministerial Decree 5.02.1998 [44], is however not practicable due to a technical deficiency of the systems. In this regard, it should be noted that so-called hard non-packaging plastics, which is the geonet of the drainage element of the case study, do not have a well-structured recycling system, differently from packaging plastics which have a specific recovery chain run in Italy by the Corepla Consortium (www.progettoplasmare.it), so they cannot be recycled in the standard chain.

For the sake of preciseness, it should be noted that the above applies to plastic waste after its use. In the manufacturing industry of polymers, for example, polyvinyl chlorides (PVC), polystyrene (PS), and polyethene (PE), the recycling of processing waste is a widespread practice [55]. The recycling of the material in the same plant is simpler because the composition is known, the product is reused to make the same specific material, and there is also no important problem of contamination by foreign materials that can occur over time.

7 Conclusion and future recommendations

The work presented here stems from the consideration that, at present, the evaluation of the impact of the disposal of a green roof represents a complex task since it is difficult to identify the treatments to be used for the individual components of the green roof when it must be removed. In fact, in Italy (but, to the best of our knowledge, even at an international level) there are no *ad hoc* technical standards that give indications on how to manage the end-of-life phase of green roofs. From an analysis of the literature, despite the numerous scenarios of dismantling of green roofs proposed, a certain vagueness was found in describing how the specific scenario was defined. Also, it indicates the lack of a standardized, commonly adopted, procedure for determining the treatments, recovery and/or disposal, to be assigned to the waste deriving from the disposal of the green roof to be used to model the end of life of green roofs.

To provide an effective contribution to the problem, pending a release of regulations specifically dedicated to the disposal of green roofs (as already exists for the other phases of the life cycle of these envelope components, i.e. production, installation and maintenance), a methodological proposal has been introduced that allows identifying the scenario of dismantling of the green roof, to which a technician can refer in his/her analyses. The method makes it possible to identify a scenario that is admissible according to current legislation.

The feasibility of this proposal was verified through a field application on a real green roof currently installed on a building of the University of Palermo.

The application demonstrated the simplicity of use of the proposed method, which is certainly partly linked to the simplified form of the scheme that operates by macro-categories of treatment. Among the strengths of the scheme is the fact to be based on cardinal criteria of waste management valid at the European level, which give the scheme broad applicability (not limited to the Italian context only).

Clearly, this method cannot be considered definitive. Further research is certainly necessary, particularly aimed at determining appropriate solutions to also integrate the effective level of the practicability of the treatments with respect to the current state of the waste management plant park, the regional or national context in which the green roof is located. Admissibility, for example, according to current legislation is a necessary but not sufficient condition for the definition of the "correct" end-of-life scenario of the green roof to be referred to in the analysis of these components.

In any case, already in its current form, given its ease of use, the tool can be temporarily used by technicians to identify the scenario of dismantling of the green roof to be used in their energy and environmental analyses of these envelope components, pending that guidelines are issued that give indications on how to manage the disposal of these casing components.

Further research is also needed on the legislative front; in fact, it is necessary to review current legislation and update it - at least the Italian one - to also take into account the new materials used in technologies for the ecological transition. In this regard, it should be noted that already in some regional special waste management plans - such as waste from the disposal of green roofs - (at least in Italy, the regulation of waste management is a regional competence, as required by art.196 of Legislative Decree no. 152 of 2006) a specific part of the plan is dedicated to the management of waste from the ecological transition, particularly to those deriving from the disposal of photovoltaic panels.

Finally, the authors hope that the results of this work in addition to facilitating the modelling of the end of life of green roofs, can also represent a first basis for a discussion for the drafting of future guidelines for the analysis of the phase of decommissioning of these envelope components.

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[45] Decreto ministeriale 5 Aprile 2006, n. 186: Regolamento recante modifiche al decreto ministeriale 5 febbraio 1998 «Individuazione dei rifiuti non pericolosi sottoposti alle procedure semplificate di recupero, ai sensi degli articoli 31 e 33 del decreto legislativo 5 febbraio 1997, n. 22». *[Ministerial Decree 5 April 2006, n. 186: Regulation amending the Ministerial Decree of February 5, 1998 "Identification of non-hazardous waste subject to simplified recovery procedures, pursuant to Articles 31 and 33 of Legislative Decree No. 22 of February 5, 1997"*]. Official Journal. 115 of 19.05.2006 (in Italian)

[46] Decreto Ministeriale 12 Giugno 2002, n. 161: Regolamento attuativo degli articoli 31 e 33 del decreto legislativo 5 febbraio 1997, n. 22, relativo all'individuazione dei rifiuti pericolosi che è possibile ammettere alle procedure semplificate [*Ministerial Decree 12 June 2002, n. 161: Regulation implementing Articles 31 and 33 of Legislative Decree No. 22 of February 5, 1997, on the identification of hazardous waste that can be admitted to simplified procedures*]. Official Journal no. 177 of 30.07.2002, (in Italian).

[47] Decreto Ministeriale 17 Novembre 2005, n. 269: Regolamento attuativo degli articoli 31 e 33 del decreto legislativo 5 febbraio 1997, n. 22, relativo all'individuazione dei rifiuti pericolosi provenienti dalle navi, che e' possibile ammettere alle procedure semplificate [*Ministerial Decree 17 novembre 2005, n. 269: Regulations implementing Articles 31 and 33 of Legislative Decree No. 22 of February 5,*

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[48] Presidente della Repubblica italiana, 2020, DECRETO LEGISLATIVO 3 settembre 2020, n. 121 Attuazione della direttiva (UE) 2018/850, che modifica la direttiva 1999/31/CE relativa alle discariche di rifiuti [*President of the Italian Republic, 2020, LEGISLATIVE DECREE Sept. 3, 2020, No. 121 Implementation of Directive (EU) 2018/850, amending Directive 1999/31/EC on the landfill of waste*]. Official Journal n.228 of 14.09.2020) (in Italian).

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Table A1. Information on which the "attempt" classification made in this paper is based for each individual constituent element of the case study.

	Brief description of the element	On the assignment of the tentative EWC code	
		European Waste Catalogue	*Documentation made available by the manufacturer*
Waterproofing and root-proofing element	Root-resistant waterproofing sheathing is a high-performance prefabricated elastoplastomeric membrane consisting of a distilled bitumen-based compound, modified with polypropylene (PP), and a polyester staple-fibre nonwoven fabric reinforcement of high grammage, reinforced and stabilized with longitudinal glass strands.	Since the waste is identified by a "mirror entry," characterization should be done to assess the hazardousness and determine which of the two EWC codes (17 03 01* and 17 03 02) to attribute.	The waste is found to be nonhazardous according to both the product data sheet and the bitumen-polymer waterproofing membrane safety information made available online by the manufacturer.
Drainage	The horizontal and vertical drainage element consists of a geotextile made of high-density polyethylene (HDPE) hot coupled with a non-woven polypropylene (PP) geotextile with filtering action.	Since the waste is identified by a "mirror entry," characterization should be carried out to assess hazardousness and determine which of the two EWC codes (17 02 03 and 17 02 04*) to attribute.	It was not possible to derive information about any hazardous characteristics of this composite product.
Water storage	The water storage element consists of polyester bags containing expanded perlite. In detail, the mat containing the expanded perlite consists of a calendered polyester (PET) staple geotextile nonwoven.	Since the polyester bag has a significantly lower weight percentage than that of expanded perlite (1.5%), it was assumed to consider the waste consisting of expanded perlite and the PET bag, therefore, as a waste of the treatment to which the expanded perlite will be subjected. In Chapter 17 "Waste from Construction and Demolition Activities" is not present a code that can identify the waste represented by expanded perlite from deconstruction activities.	From the material safety data sheet (MSDS) for expanded perlite made available, online, by the manufacturer, it is clear that the waste is non-hazardous.

Filter	The filtration element of the green roof analyzed here is a high tenacity calendered prolipropylene (PP) nonwoven geotextile felt.	In the European Waste Catalogue, the filter element would belong to the waste class with code 17 02 "Wood, glass and plastic" because the material that makes up the filter element is plastic (PP). Therefore, the same considerations made previously for the draining element apply to this product.	It was not possible to derive information about any hazardous characteristics of this composite product.
Substrate	The substrate is a mixture of lapillus, pumice, Agrilit expanded perlite, peat, bark, coconut fibers, special clays, soil conditioners, organic fertilizers, and is free from weed seeds.	Since the waste is identified by a "mirror entry," characterization should be carried out to assess hazardousness and determine which of the two EWC codes (17 05 03* and 17 05 04) to attribute.	The waste is found to be non-hazardous according to the MSDS of a product from the same manufacturer with the same function and similar characteristics.
Accessory elements of the green system	The elements that complete the green system are the low-density polyethylene (LDPE) dripline, PP inspection pits of the irrigation system, and HDPE walkway tiles.	In the European Waste Catalogue, the ancillary elements of the case study would belong to the waste class with code 17 02 "Wood, glass and plastic" because both the elements of the irrigation system (dripline and manholes) and the tiles for the walkways are plastic type elements, more precisely hard plastic. Therefore, the same considerations made earlier for the drainage and filter element apply to these products.	It was not possible to derive information about any hazardous characteristics of this composite product.

Table A2. Italian national waste legislation used for the application of the proposed method.

Step of the operational scheme proposed		**Waste legislation used in this work**	**Specific article and/or attachment of the regulations used for implementing the scheme**
"Attempt" classification (step 1)		Part IV of the Legislative Decree 152/2006 [43] entitled "Regulations on waste management and remediation of polluted sites", Title I, "Waste management ".	Annex D
Attribution of "attempt" treatments for recovery and/or disposal (step 2)	Recovery of matter	Decree February 5, 1998, *Identification of non-hazardous waste subjected to simplified recovery procedures according to articles 31 and 33 of Legislative Decree February 5, 1997, n. 22* (version coordinated with the Ministerial Decree of 5 April 2006) [44].	Annex 1, Sub Annex 1 - General technical standards for the recovery of material from non-hazardous waste.
	Energy recovery	Decree February 5, 1998, *Identification of non-hazardous waste subjected to simplified recovery procedures according to articles 31 and 33 of Legislative Decree February 5, 1997, n. 22* (version coordinated with the Ministerial Decree of 5 April 2006) [44].	Annex 2 Sub Annex 1 - Technical standards for the use of non-hazardous waste as fuel or as other means to produce energy.
	Disposal in landfills	Legislative Decree 3 September 2020, n. 121 Implementation of Directive (EU) 2018/850, which amends Directive 1999/31/EC on waste landfills [48].	Art. 6. Waste is not allowed in landfills. Annex 3 - Table 2 Waste is not allowed in landfills according to art. 6 of this decree.

Table A3. Eligibility analysis of recovery and disposal treatments (considered in the order of priority established by the European concept of "waste hierarchy") for the case study elements according to current Italian regulations.

Treatment	***Waterproofing and root-proofing element***	***Drainage***	***Water Storage***	***Filter***	***Substrate***	***Accessory elements of the green system***
Material recovery	NO (For EWC code 17 03 02, only asphalt mix from road surface milling activities by cold milling is expected to be recovered).	YES* (It should, however, be noted the unclear correspondence between the draining element and the types of waste corresponding to EWC 17 02 03.)	NO (Waste with EWC 17 09 99 is not mentioned among non-hazardous waste that can be sent for treatment for material recovery.)	YES* (See drainage element)	YES** (It should, however, be noted the only partial correspondence between the substrate and the types of waste identified with EWC 17 05 04, in terms of type, origin and characteristics).	YES* (See drainage element
Energy recovery	NO (Waste with EWC code 17 03 02 does not appear among those that can be used as fuel or other means of producing energy).	NO (Wastes with EWC code 17 02 03 do not appear among those that can be used as fuel or other means to produce energy.)	NO (Waste with EWC code 17 03 02 does not appear among those that can be used as fuels or as another means of producing energy.)	NO (See drainage element)	NO (Wastes with EWC code 17 05 04 do not appear among those that can be used as fuel or other means to produce energy.)	NO (See drainage element)
Disposal in landfill	YES (Waste with EWC code 17 03 02 does not appear among those NOT allowed in the landfill).	NO (Since this material is suitable for recovery/recycling, landfill disposal is prohibited).	YES (Waste with EWC code 17 09 99 is not listed among those NOT allowed in landfills).	NO (See drainage element)	NO (Since this material is suitable for recovery/recycling, landfill disposal is prohibited.)	NO (See drainage element)

**The asterisk means that the material recovery for this element is considered admissible but a concern is present related to the unclear correspondence between the item in question and waste with EWC 17 02 03 in the standard, in terms of the type and characteristics of the waste.*

***The two asterisks mean that the material recovery for this element is considered admissible but a concern is present related to the non-full correspondence between the substrate and waste with EWC 17 05 04 in the standard, in terms of the type, origin and characteristics of the waste.*