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Enhancing PVC Recycling: The Waste Recycling Project (WREP) as a Model for Sustainable Waste Management

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ABSTRACT

The Waste Recycling Project (WREP), launched in 2016 by PVC Forum/VinylPlus Italia (the Italian association of the PVC value-chain) and VinylPlus® (the European PVC industry's Commitment to sustainability), aims to improve PVC waste collection and recycling in Italy. This initiative addresses the issue that less than half of PVC waste was being recycled due to challenges like scattered collection points and small-scale recyclers facing complex regulations. WREP targets the recycling of PVC waste from bulky urban waste at municipal collection centres in northern and central Italy, in partnership with multi-utilities and recyclers.

In 2023, the project expanded to include PVC from demolition and renovation activities, with new partnerships and systems for collecting and recycling PVC from construction-related items like windows and pipes.

Furthermore, WREP has advanced the development of portable devices to sort PVC from other plastics and to detect substances no more allowed today but still present in old PVC applications (the so-called legacy additives). In 2021, a handheld detector using near-infrared hyperspectral (NIR) technology was introduced, reducing PVC contamination levels from 3% to under 1%. The software has been further developed to detect the presence of DEHP(Di-(2-ethylhexyl) phthalate) in post-consumer PVC.

In 2023, further feasibility studies showed that the XRF (X-ray fluorescence spectroscopy) technology could be applied to the detection of legacy lead in PVC waste.

Based on the feasibility study, VinylPlus® has funded the design of a pilot plant aimed to test and implement XRF technology for industrial applications.

The WREP Project demonstrates that collaborative value-chain approaches combined with innovative sorting technologies provide a replicable best-practice model for enhancing PVC recycling, supporting EPR implementation, and delivering environmental and economic benefits.

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Introduction

WREP (Waste Recycling Project) was launched in 2016 by PVC Forum Italia and VinylPlus® to assess the amount of PVC available for recycling in Italy; evaluate the quantities currently recycled; and develop a pilot collection scheme to improve the collection and recycling of PVC waste.

A preliminary analysis showed, in fact, that less than half of the PVC potentially available for recycling is currently being recycled. This is mainly because collection points are scattered around the territory and most recyclers are micro and small enterprises, which are affected more by the complex regulatory framework.
In its initial phase, the WREP Project focused on the recovery and recycling of PVC waste collected from bulky urban waste at municipal collection centres, actively involving multi-utility companies and recyclers. A key achievement was the development of a training programme for plant operators, enabling effective identification, separation and sorting of PVC materials. This resulted in a 97% recycling rate for PVC collected through the project. The recycled PVC is subsequently used in products such as traffic cones, garden hoses and shoe soles.

WREP demonstrated that intercepting and recycling PVC waste is economically as well as environmentally worthwhile.

From an economic point of view, the experimentation found an average saving of over 57% compared to sending for disposal the same quantity of waste.

From an environmental point of view, the recycling of PVC since the launch of the project has avoided the emission of over 2,500 tons of CO2 into the atmosphere.

WREP in numbers
(pilot project results 2018-2023 based on the data collected through the collaboration with selected multi-utilities)

PVC recycling

- Total bulk waste managed: 128,436.72 tonnes
- PVC sent to recycling: 1,290.01 tonnes
- Recycled PVC: **1,232.73 tonnes**
- **2,500+** tonnes of CO_2 emissions avoided
- **10,000+** tonnes/year potentially collectable nationwide

Economics

- PVC waste costs management in standard conditions **€ 288,958.89**
- PVC waste costs management within **the WREP framework € 123,485.46**
- **Costs savings 57.27%**

Estimates made, based on the PVC collected during the operational phase, show that, if applied in all municipal waste collection centres, the WREP approach would allow the recycling of more than 10 ktonnes of post-consumer PVC. These quantities, which are currently going to landfill, could potentially be collected and recycled in partnership with the municipal collection centres, in addition to the quantities already recycled in Italy through the VinylPlus® network.

In 2023, the project was extended to include the collection of post-consumer PVC products from demolition and renovation activities, in collaboration with construction associations. This initiative aims to implement a system for the collection, sorting, treatment and recycling of waste from windows, shutters, pipes and other PVC products, originating from both manufacturing processes and separately collected urban demolition and installation waste.

The WREP Project evolution

Experience gained through collaboration with utilities and recyclers has shown that every productive activity must address two distinct programme perspectives throughout its lifecycle:

- Planning the future: applying ecodesign principles by developing new formulations and marketing products that meet current and future sustainability goals. This means designing plastics and their additives to be recyclable.
- Managing the past: developing methods and technologies to:
- Manage end-of-life products that were designed according to rules that were valid when they were first placed on the market but are no longer accepted today;
- Prevent products — including recycled materials — that do not comply with European standards from being placed on the European market.

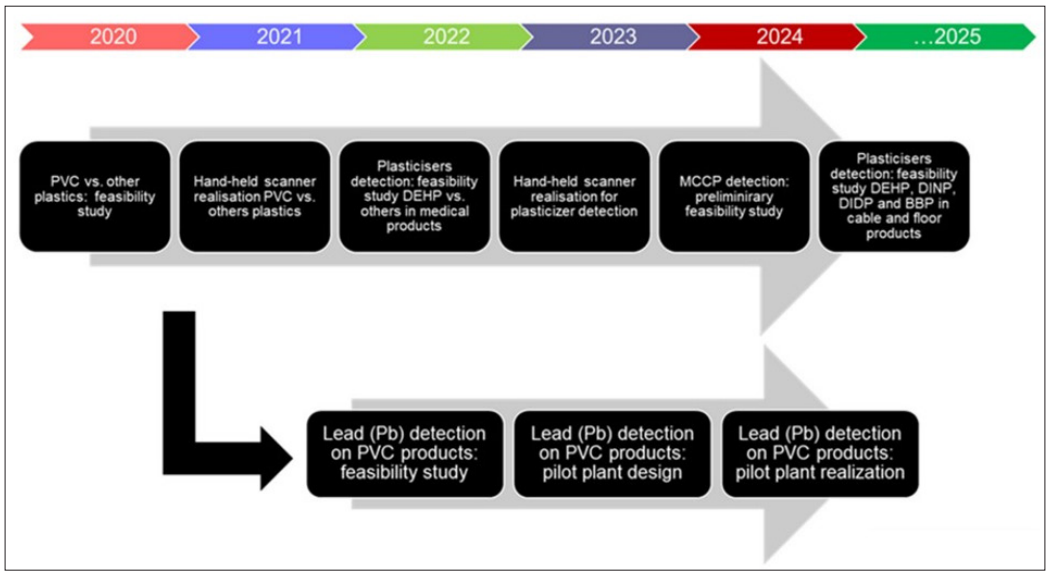
The project confirmed in fact the importance of an appropriate selection and separation of high-quality PVC waste: the more it is free from contamination, the easier it is to use the recycled material in the same application (closed loop) or in other high-performance applications (upgrading), increasing the rPVC (recycled PVC) value on the market.

Detection and Sorting of Legacy Additives from PVC Waste

Today, the vinyl formulations used to produce PVC in Europe are safe and do not contain toxic additives that would prevent its mechanical recyclability: this is what PVC must now be evaluated on, not on how it was (legally) added years ago.

However, being a durable material, used for long-life items, at the end of its useful life, these items could contain so-called "legacy additives": it was therefore necessary to find an optimal solution for managing "old" PVC that combines safety for humans and the environment with savings in raw materials and energy.

Therefore, the WREP project, in its quest to improve the circularity of post-consumer PVC, has been developed following this line of innovation:



In 2021, the company Phoenix RTO srl, an Italian high-tech company in the fields of photonics and spectroscopy, was involved in the project to design and develop a handheld device (manual scanner) to sort PVC from other plastics using near-infrared hyperspectral technology (NIR). Thanks to the use of the manual scanner, the percentage of impurities present in the collected PVC dropped from an average of 3% to less than 1%.

Figure 1: The Manual Scanner Developed by Phoenix RTO

In 2022, the software was further developed to detect the presence of DEHP/phthalates plasticiser in post-consumer PVC. In the case of different plasticisers, the NIR/SWIR measurements in reflection showed distinct responses, allowing for unique material identification. This technology applied in the manual scanner was therefore used different PVC applications such as cables and medical devices. In 2024, excellent results were achieved in detecting MCCP in PVC cable waste also in presence of other plasticisers.

Figure 2: Detection Tests for the Presence of DEHP in PVC Products

In relation to lead contamination, in 2023, further feasibility studies conducted by Phoenix RTO confirmed that the most effective technology for detecting lead in PVC products for recycling is X-ray fluorescence (XRF) spectroscopy.

Laboratory experiments were conducted by Phoenix using a modified XRF facility to analyse PVC samples prepared to simulate real-world conditions. Initial tests were carried out on samples with known lead concentrations and without lead. The spectra obtained confirmed that contaminants such as Pb are easily detectable using XRF technology.

The XRF technology would make it possible to design an industrial in-line pilot system able to select and recognize plastic materials with presence of lead. This separation line could also be integrated with the NIR technology to detect traces of other substances such as DEHP and MCCP (medium chain chlorinated paraffins).

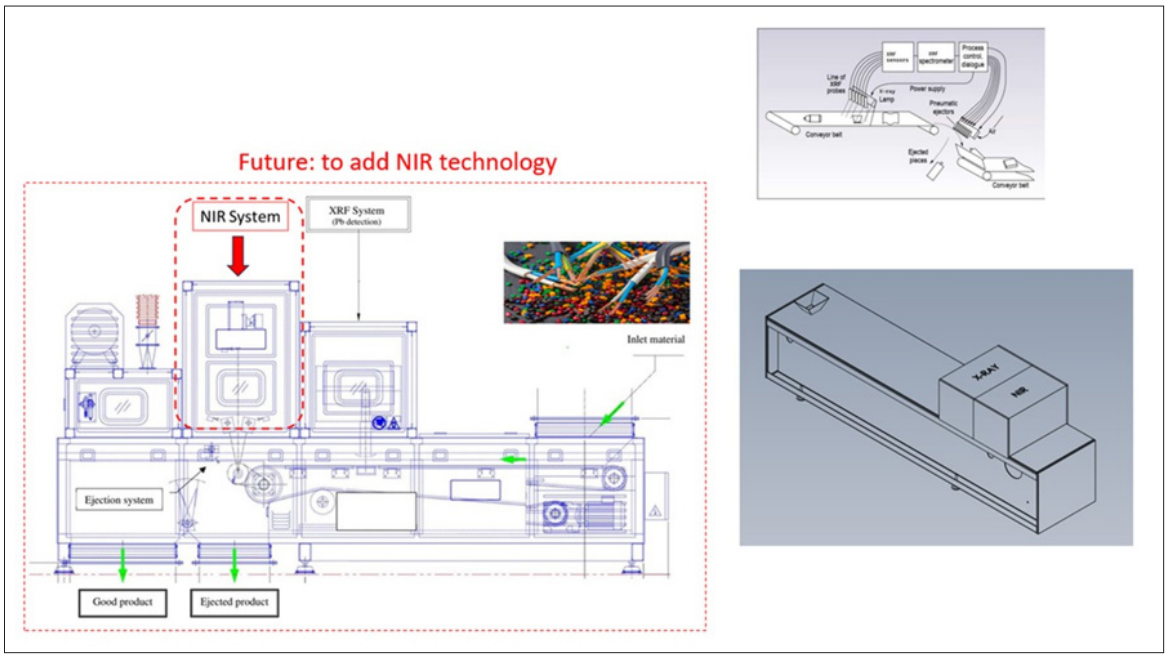


Figure 3: Schematic Diagram of a Production Machine with XRF Technology

Based on these promising results, VinylPlus® decided to finance the design and install a pilot plant located at a partner company of PVC Forum Italia where the appropriate tests will be carried out to obtain all the necessary information for an industrial project.

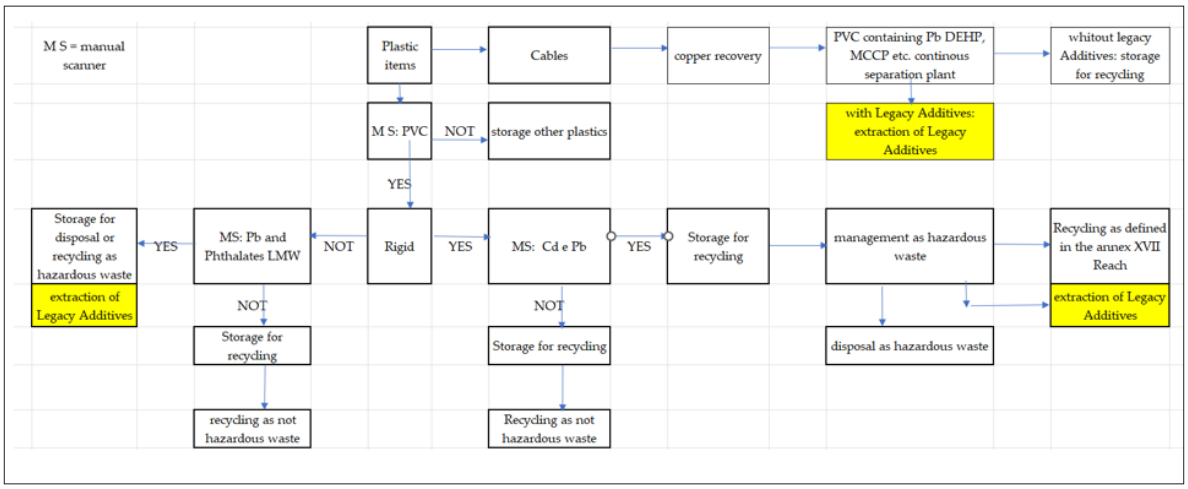
Manual Scanning and Continuous Processing: Two Useful Tools for EPR in Construction

Experience gained through the WREP Project demonstrates that it is possible to develop a virtuous collaborative model for the management of bulky waste and construction and demolition waste.

The WREP scheme has also been incorporated into the EU CIRCE2020 project and is recognised as a Best Practice both at national level (ICESP – Italian Circular Economy Stakeholder Platform) and at European level (ECESP – European Circular Economy Stakeholder Platform). In addition, it has been included as a Best Practice in the Regional Urban and Special Waste Management Plan of the Veneto Region.

Thanks to the development of suitable technologies for the sorting and separation of PVC waste, this model may also represent a useful contribution to the ongoing debate on the introduction of Extended Producer Responsibility (EPR) schemes for construction products in Italy.

Below is a selective demolition scheme applicable through the use of the aforementioned manual scanner and continuous separation process.



Conclusions

Originally developed to enhance the sorting, collection and recycling of PVC from urban bulky waste and construction and demolition activities, the WREP Project demonstrates that collaboration among the PVC value chain, multi-utility companies and construction associations can generate a virtuous cycle from both environmental and economic perspectives.

The parallel development of innovative technologies for the identification and separation of PVC potentially containing legacy additives, integrated within an efficient waste management system, may further support the implementation of EPR schemes for construction products.

WREP can therefore be considered a best practice model, offering a replicable approach to improving PVC recycling efficiency, fostering sustainability and promoting technological innovation in waste management [1-3].

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