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# Deliverable report

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**Project website:** www.creatorproject.eu

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## Abbreviations

| | |
|---|---|
| ABS | Acrylonitrile butadiene styrene |
| EAS | Electronic article surveillance |
| CFRP | Carbon fibre reinforced polymer |
| OVM | Openbare Vlaamse Afvalstoffenmaatschappij |
| PVC | Polyvinyl chloride |
| PS | Polystyrene |
| PE | Polyethylene |
| PP | Polypropylene |
| PET | Polyethylene terephthalate |
| QR | Quick Response |
| NFC | Near Field Communication |
| REACH | Registration, Evaluation, Authorisation and Restriction of Chemicals |
| RFID | Radio Frequency Identification |
| WEEE | Waste Electrical & Electronic Equipment |

# 1 DOCUMENT HISTORY AND CONTRIBUTION OF THE PARTNERS

*Table 1: Version management*

| VERSION NR | REVISER | CONTENT |
|---|---|---|
| V0 | Christina Dalla, Rocco Lagioia (ITB) | Deliverable template (V0) |
| V1 | Francisca Gaona, Rocco Lagioia (ITB) | First draft (V1) |
| V2 | Els Herremans (OVM) | Review (V2) |
| V3 | Carolyn Fisher, Irma Mikonsaari (ICT) | Review (V3) |
| V4 | Francisca Gaona, Rocco Lagioia (ITB) | Final deliverable |

*Table 2: Partners' contribution to the deliverable*

| PARTNER | SHORT NAME | ROLE IN THE WP | CONTRIBUTION TO THE DELIVERABLE |
|---|---|---|---|
| ITRB Group | ITB | Leader task 1.3 & 1.4 | Author of deliverable 1.3 |
| Fundacion Gaiker | GKR | Leader of WP, Participant T1.3 | Deliverable 1.3 (Material characteristic information). To generate this information was needed the contribution of MAIER, CYC and DAW, contributors of WP1. |
| Coolrec BV | CLR | Participant T1.3 | Information and point of view from sorting & recycling industry. This information has been used to decide what kind of label we will implement. |
| Relight SRL | REL | Participant T1.3 | |
| Volbas SA | VLB | Participant T1.3 | |
| Openbare vlaamse afvalstoffenmaatschappij | OVM | Leader of Task 1.6 | Deliverable 1.3 (Information regarding the legislation and certification schemes). |
| Fraunhofer gesellschaft zur foerderung der angewandten forschung E.V. | ICT | Participant T1.3 | Deliverable 1.3 (Information from different kind of labelling technologies) |

# 2 INTRODUCTION AND OBJECTIVES

Evidence of the environmental impact of plastic goods' mismanagement has captured the attention of scientists, policy makers and manufacturers. The European Commission has responded by publishing the first EU-wide policy framework on plastics[1]. The new recycling targets put the current waste management companies under pressure, as they are characterized by fragmentation in responsibilities and a suboptimal cost-benefit balance. The plastic value chain includes numerous kinds of companies, from oil companies and virgin plastic producers to sorting and recycling companies or plastic component producers. This situation means that the responsibility of the plastic waste management is not well defined between these different actors. Moreover, the price of virgin plastic is very low, currently even inferior due to the drop of the oil's price because of the coronavirus crisis. This state added to the cost of its recycling makes it difficult to compete with the virgin plastic.

The interconnecting of data can be useful for the self-perpetuation of the multiple companies in this value chain. Traceability mechanisms can substantiate any content claims that stakeholders within the value chain may demand. When we allocate a "digital" identity to materials at batch or component level and follow it through a value chain, we are able to capture information from its disposal or re-use in the future.

The project CREAToR focuses on process development and demonstration (to TRL 5) to remove hazardous, already banned bromine containing flame-retardants from waste streams using continuous purification technologies: supercritical $CO_2$ and cost-effective solvent-based processes using natural deep eutectic solvents (NADES) in twin-screw extruders. CREAToR will cover the whole value chain, starting from collecting thermoplastic waste streams from building and construction (B&C) and from waste electrical and electronic equipment (WEEE). The project will implement ways to collect secondary raw materials, identify the presence of hazardous flame retardants, remove these contaminants from the materials and finally reuse the materials. As case studies they will be reused as valuable secondary raw materials for new B&C insulation panels, closing the circle of economy, for automotive interior application, and for producing 3 D printed parts for aerospace applications. For further increasing the economic feasibility of the approach an optimised logistic concept and a harmonized material quality classification scheme will be developed and applied

The CREAToR deliverable "D1.3 Smart labelling system methodology report" is the first report of the task 1.3 "Development of harmonized material classification scheme / smart labelling system". This task has a close relationship with the task 1.4 "Analysis of recycling operators' conceptions & beliefs for and with the harmonized material codification scheme/smart labelling system". These tasks concur to implement one or more labels throughout the material process, from waste sorting to its transformation into recycled materials and their implementation in new applications; to control the materials through all the process steps and deliver data to the operator and to result in full traceability of the materials.

***Two initial types of smart labels have been proposed within the consortium***, one for the entry of waste into the sorting facilities that could help with the classification of the input stream, and a second label for the materials that were sorted as the output stream for a second application.

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[1] COM/2018/028 (https://ec.europa.eu/environment/waste/plastic_waste.htm)

The first (material label for the input into sorting) has been discarded after holding several meetings with recycling companies that are part of CREAToR's consortium and after conversations within the stakeholder event held at Kuhne Logistics University under the name "Plastics recycling workshop" in March 2020 with external parties. Unanimously, recyclers do not believe that the implementation of a label for classification of the input stream would be an advantage. They believe that the implementation of this label would entail both an economic and time cost that they are not willing to assume at this time and that the measures they have currently in place for quality assurance are better adapted to the specific processes.

The focus of this deliverable will therefore be a label for the output stream, which has the necessary information about material properties needed by the end users. This will facilitate the later use of these materials in their products. We will implement a label in the polymer granulate bags in which the recycled plastics are packed after sorting and purification (output from CLR). The information collected in the label is presented in CHAPTER 2.1.

In CHAPTER 2.2, dedicated to the legislation, the consortium collected data from the existing legislation and from the work being carried out in other projects (the assessment can be downloaded at the CREAToR's homepage[2], D1.7 Assessment of existing legislations and regulations). Moreover, with all the information about the needs (of recyclers and end users) gathered throughout the CREAToR project, a series of recommendations in plastics recycling legislation, chemicals legislation (REACH), etc., will be developed. These recommendations will be presented in the public deliverable 1.8 Report of process and end users' limitations and regulatory gaps (by OVM) in July 2022.

Furthermore, the certification schemes that exist in reference to recycled plastics in Europe, have been examined. All this information is gathered in order to have a global vision on the legislation and certification and to be able to locate the use of the label in the most beneficial process step in the most efficient way.

IN CHAPTER 1.3, the information about the existing labelling systems has been collected, and we will study their characteristics in order to introduce a labelling technology most in line with our project needs.

And in the CHAPTER 3, the results of the deliverable will be presented, including a summary of all the labelling technologies taken into account and the motive for rejecting them.

2 https://www.creatorproject.eu/publications/

# 3 HARMONIZED MATERIAL CLASSIFICATION SCHEME / SMART LABELLING SYSTEM

## 3.1 SPECIFICATIONS COLLECTED FROM END-USERS' PARTNERS

Throughout the period M1-M11, information on the requirements of end-users to use recycled thermoplastic materials as input material has been collected by the partner MAIER Group within the consortium's end-users (Table 3).

*Table 3: End-user specifications for CREAToR demonstrators*

| END-USER | SPECIFICATION DESCRIPTION | PARAMETERS |
|---|---|---|
| MAIER Group | Injection moulding tests must be carried out on the polymer pellets (recycled material) to ensure that they meet the targeted material requirements | Generic polymer (ABS)<br>Density<br>Melt volume-flow rate<br>Tensile modulus<br>Yield stress<br>Yield strain<br>Charpy notched impact strength<br>Charpy unnotched impact strength<br>Temperature of deflection under load<br>Vicat softening temperature |
| | Later, the products created with the recycled material will pass the tests carried out by MAI | General aesthetics<br>Accelerated artificial light resistance. WOM (1500 H)<br>Rubbing: dry, soapy water, 50% diluted ethanol<br>Sclerometer scratch > 3 N<br>Temperature resistance: 22 hours at 85 °c<br>Cold resistance: 7 days at -30°C<br>Climate cycles: 7 x (16h / 40°C +95% HR & 3 h / -20°C +5h / 85°C) |
| DAW SE | Material requirements | Apparent density<br>Flame rating<br>Blowing agent content (pentane)<br>Bead size diameter |
| | Product's requirements | Class resistance to fire<br>Irreversible change in length<br>Length tolerance<br>Width tolerance<br>Thickness tolerance<br>Flatness<br>Squareness<br>Squareness relative to board plane<br>Apparent density (after mass constancy)<br>Dimensional stability (70°C)<br>Dimensional stability (23°C, 50% RH)<br>Rated value of thermal conductivity<br>Thermal conductivity<br>Tensile strength perpendicular to the surface<br>Shear strength<br>Bending strength |

| | | |
|---|---|---|
| | | Shear modulus<br>Water vapor transmission<br>Short-term water absorption by immersion |
| Cyclefiber | 3D filament requirements | Thickness<br>Colour<br>General aesthetics<br>Class resistance to fire<br>Thermal conductivity |
| | Product requirements | Surface smoothness<br>Bending strength<br>Temperature resistance<br>Cold resistance<br>Climate cycles |

The standardization of the labelling should combine only key parameters to facilitate its use. For this reason, the project team selected and grouped important specifications that end-users usually ask for from the recyclers, and that are essential to make new material compounds for products. This specification selection was made according to a series of conversations between the partners ITRB Group, Fundación Gaiker, Coolrec BV and the information collected in the workshop for recyclers held at the Kühne Logistics University in March 2020. The selection was mainly based on the legislation that end-users must comply with, depending on the component to be manufactured or the production technology used.
Also, a flame retardant content specification has been introduced, due to the purification process that CREAToR materials must go through.
The specifications are (Table 4):

*Table 4: End-user specifications for labelling*

| TECHNICAL SPECIFICATIONS | TEST METHOD |
|---|---|
| Density | ISO 1183-1A |
| Melt -flow rate | ISO 1133-B |
| Charpy impact strength | ISO 179-1eA |
| Tensile modulus | ISO 527-2 |
| Tensile strain at break | ISO 527-2 |
| Flexural modulus | ISO 178 |
| Flexural strength | ISO178 |
| Flame rating | UL 94 |
| Flame retardant content | GC-MS |

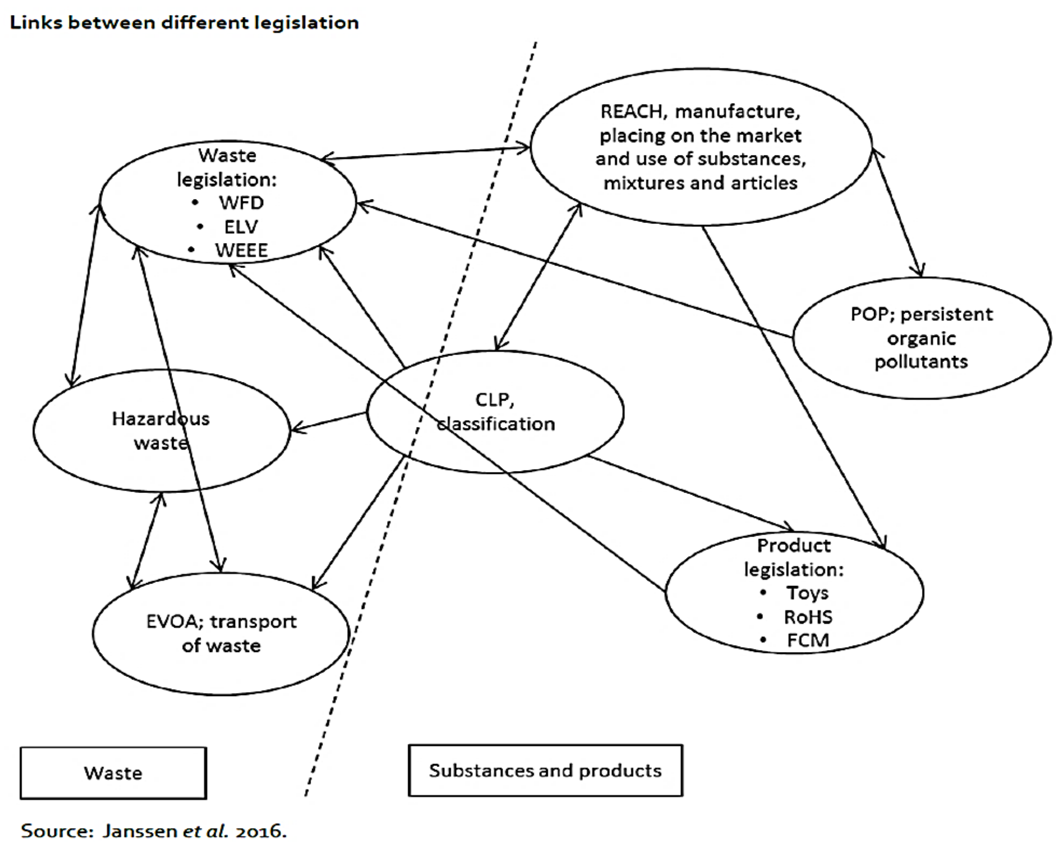
## 3.2 BENCHMARK OF EXISTING CERTIFICATION SCHEMES

The European plastics' recycling industry lacks standards and certification schemes which would support the secondary raw materials market. Various standards, mostly following the applications' individual requirements, lead to differing quality and quantities of plastics recyclates, making it hard for end users to trust constant supplies for high-quality products.

Among these, the REACH certification stands out, which is focused on the chemical content and its harmfulness. REACH establishes procedures for collecting and assessing information on the properties and hazards of substances. Moreover, manufacturers and importers have to apply for a REACH certificate or a registration number when they use or bring into circulation materials that are subject to the REACH Regulation (like the flame retardant HBCD, Hexabromcyclododecane).

The scheme[3] depicted below in Figure 1 shows the multiple regulations to which a product is subjected, both in production and in waste treatment. Some chemical substance content in plastic products is regulated through various frameworks. Some product groups, such as toys, are regulated to a high extent with higher demands, whereas others are not as strictly regulated.

*Figure 1: Relations between different legislations for plastics*

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3 Janssen M.P.M., Spijker J, Lijzen J.P.A., Wesselink L.G. (2016). Plastics that contain hazardous substances: recycle or incinerate? National Institute for Public Health and the Environment (RIVM), RIVM Letter report 2016-0025

As mentioned above, OVM prepared the deliverable *D1.7 Assessment of existing legislations and regulations* that contains further information on the regulation, giving an overview of relevant legislation and standards and identifying existing legal limitations on using the recycled materials in new products.

European standards exist for recycled PVC, PS, PE, PP and PET. There are also EU standards for the preparation of samples of recycled plastics before testing and for a system for sampling procedures for testing plastic waste and recyclates. General standards for example for food-grade materials apply to both virgin and recycled polymers.

Recently, CREAToR joined the Plastics Circularity Multiplier initiative[4], which will communicate to policy makers, the public and industry on a range of EU-funded innovations – innovations that aim to bring plastic materials into the circular economy of the future and create new business opportunities and jobs in Europe. This initiative targets synergies between projects to improve the plastic circular economy and it is expected to be a powerful tool for regulatory and scale-up challenges of a labelling system for recycled plastics.

This initiative includes the project Repair 3D[5] that aims for the development of innovative routes for end-of-life plastic and carbon fibre reinforced polymers (CFRP). One of the pillars of this project is the study of the strategy "design for recycling". In the last Plastics Circularity Multiplier Online Conference (October 2020) it was highlighted that the labelling of products/components based on recovery and/or incompatibility must be one of the guidelines of this strategy.

## 3.2.1 Legislation

The legislation to which CREAToR is subjected and the standards to be met are extensive, not only internationally, but also at European and regional level. In particular, the legislation that focuses on waste, recycling, plastic content in products and hazardous substances stands out. The following Table 5 lists the most important legislation and standards that are related to our project:

*Table 5: Legislation and standards related to CREAToR project*

| | |
|---|---|
| **International** | • SAICM (Strategic Approach to International Chemicals Management)<br>• Rotterdam Convention<br>• POPs Regulation (persistent organic pollutants) |
| **Europe** | • REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals)<br>• RoHs directive (Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic equipment)<br>• Product Safety Directive<br>• Waste Framework Directive<br>• Directive 94/62/EG on packaging and packaging waste<br>• ELV Directive (Directive 2000/53/EC on end-of-life vehicles)<br>• WEEE Directive<br>• Waste Shipment Regulation<br>• Legislation on food contact materials |

4 https://www.plasticscircularitymultiplier.eu/

5 http://www.repair3d.net/

- Toy safety directive (Directive 2009/48/EC)

At this time, the only regulation that must be followed in terms of labelling is to mark products that contain halogenated flame retardants, such as brominated flame retardants[6]. Even so, some standards that could be followed for plastic products identification or traceability are:

- ISO 11469:2000 Plastics — Generic identification and marking of plastic products.

- EN 15343:2007 (Plastics. Recycled plastics. Plastics recycling traceability and assessment of conformity and recycled content) like EuCertPlast.

- CENELEC standards: EN 50625-1 Collection, Logistics & Treatment Requirements for WEEE

To ensure compliance with the EU, WTO and the Basel convention requirements, the adaptation must include traceability matrices, data management procedures and the integration of incentives to attract waste recyclers, traders and dealers.

## 3.2.2 CERTIFICATION SCHEMES

There are different certification schemes for recycling products. Normally, each country has a different certification to highlight that the products offered are recycled or contain a percentage of recycled material. Some of these certifications follow the standards set by the EU.

It is worth mentioning the project **EuCertPlast[7]** that aimed to establish a European certification for post-consumer plastic recyclers. The EuCertPlast organization has defined requirements based on the European Standard EN 15343:2007 and guidelines to encourage recycling of plastics, particularly focusing on the process for traceability and assessment of conformity and recycled content. National bodies and product labels recognize EuCertPlast, such as:

- The Blue Angel Label (German Ecolabel)
- COREPLA (Italian consortium of Plastic Recyclers)
- LAGA (German Waste group)
- Recovinyl (European PVC industry initiative)

There is also the Ecolabel. The **European Ecolabel[8]** was created to show Europeans which products and services have the least negative impact on the environment.

EU Ecolabel meets the ISO 14020 Type 1 requirements for ecolabels. The EU Ecolabel criteria are developed and reviewed in cooperation with experts from industry, consumer organisations and environmental NGOs.

The label cannot be awarded to products containing substances classified by CLP (Classification, Labelling and Packaging of substances and mixtures) as toxic, hazardous to the environment, carcinogenic, mutagenic or toxic for reproduction (CMR), nor to goods containing substances referred to in Article 57 of REACH. For a product that has an ecolabel, only recycled plastic that

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6 Reference: RoHS2 (2011/65/EC)

7 https://www.eucertplast.eu/

8 https://eu-ecolabel.de/en/

does not contain any of the above-mentioned substances can be used. The recycler is responsible for ensuring this (Figure 2).

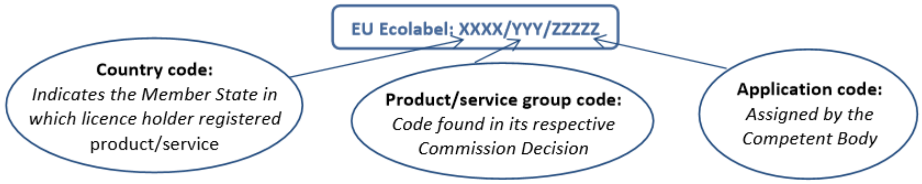



*Figure 2: Codification of European Eco-label*

Today around 40,000 products and services carry the European Ecological Label (EEA), which means that they meet the strict EU ecological criteria. The label applications and licenses are managed by the national competent bodies.

In August 2020, RecyClass[9], a cross-industry initiative that works to advance plastic packaging recyclability within Europe, presented the Recycled Plastics Traceability Certification, an audit scheme that aims to guarantee the transparency and integrity of claims regarding recycled content in plastics. This Certification adds to EuCertPlast, a traceability scheme for recycling processes.

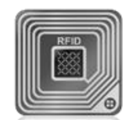
[9] https://recyclass.eu/recycled-content

## 3.3 Smart Labelling System Methodology

Labelling technologies have come on in leaps and bounds in the past few years, especially as automation has ramped up. While the end goal of labelling remains the same – to code, mark and identify products – today's labelling technologies offer much more.

The following Table 6 lists different systems of smart labelling that have been considered to decide which could be the best for the CREAToR project:

*Table 6: Types of labelling systems*

| Types | Description | Image |
|---|---|---|
| **EAS labels** | Electronic article surveillance is a technological method for preventing shoplifting from retail stores, pilferage of books from libraries or removal of property from office buildings. |  |
| **RFID labels** | Radio Frequency Identification is the wireless, non-contacting use of radio frequency waves to transfer data. Tagging items with RFID tags allows users to automatically and uniquely identify and track inventory and assets. |   |
| **Sensing labels** | There are different types of these labels: chemical sensing labels, humidity sensing labels and temperature sensing labels. These labels have a sensor which produces a response to a variation in the condition it is measuring (temperature, humidity, etc.). Usually they are used for food packing to be sure of the quality of the product. |  |
| **Electronic shelf/dynamic display labels** | An electronic shelf label system is used by retailers for displaying product pricing on shelves. The product pricing is automatically updated whenever a price is changed from a central control server. |  |
| **NFC tags** | Near Field Communication (NFC), tags are small integrated circuits designed to store information that can be retrieved by NFC-enabled devices like the smartphones. They are small stickers, in round or square shape and are about the size of a large coin. |  |
| **Digital watermarks** | It is a technology in which identification information is embedded into the data carrier in ways that cannot be easily noticed, and in which the data usage will not be affected. It could be visible or invisible. |   |
| **QR codes** | Quick Response codes is a machine-readable code consisting of an array of black and white squares, typically used for storing URLs or other information for reading by the camera on a smartphone. |  |

### 3.3.1 Tags and Their Disadvantages

Due to the nature of the different technologies, four types of labels were discarded.

- **EAS labels**: They are used for preventing shoplifting. They could have different sizes. Implementing EAS involves two sets of costs– initial and ongoing. Although relatively high in cost, this implementation is profitable because it reduces theft in establishments by 60-80%. It is not a technology used in logistics and its implementation is relatively expensive, so in our case it is not suitable.

- **Sensing labels:** The labels only provide information about the variation of a certain measure (temperature, humidity, pressure ...), rather than a variety of parameters (as is the plan in CREAToR). Consequently, it is not a technology suitable for CREAToR's label.
- **Electronic shelf/Dynamic display labels:** ESLs have high initial start-up costs, for example, a 30,000-tag system can initially cost almost $350,000[10]. Usually, the initial investment cost for a user could be marginally high. This technology is discarded, since recyclers (like CLR) are not willing to implement such a high cost technology, putting their income at risk.
- **Digital watermarks:** The potential of a digital watermark to improve the traceability of plastic waste during sorting has been considered as used in other projects (3D repair, Holy Grail 2.0).

  The label that will be considered in CREAToR will be used on the bags that contain the recycled polymer granule material exiting the recycling facility and being supplied to the end-user. This label will contain the technical characteristics of this material enabling a smooth use of the material in end-users' applications. It should be easy to use at any recycler's facility and easy to be read for all the end-users.

  The digital watermark technology seems us more suitable for the traceability of recycled materials used in final product application. We consider this technology too complex and costly to be implemented in most of the sorting companies like required in CREAToR whose main activity is landfilling or a simple sorting process[11].

There are two technologies that are similar and usually compete within the same type of markets, including the logistics field:

- **RFID labels:** An RFID tag consists of a tiny radio transponder. When it is activated by an electromagnetic pulse from a nearby RFID reader device, the tag transmits digital data, usually an identifying inventory number. Disadvantages: Several hurdles exist due to the nature of RFID technology. First, there are several, not coherent, standards for the RFID technology and global standards have not yet been developed. ISO and GS1 work together to approve standards and protocols in order to provide universal specifications for RFID equipment. By creating global standards, these organizations enable the possibility of worldwide adoption of RAIN RFID (ISO/IEC 18000-63). Some RFID devices are not projected when they leave their networks, as is the case with RFID tags used for inventory control. RFID systems easily become blocked since radio waves might be blocked or cancel each other out. Another issue with RFID occurs when signals from two or more readers overlap. This reader collision becomes problematic when tags are unable to respond to simultaneous queries.
- **NFC labels:** NFC tags are passive data stores which can be read, and under some circumstances written to, by an NFC device. NFC tags can be custom-encoded by their manufacturers or use the industry specifications. Disadvantages: Although the range of NFC is limited to a few centimetres, plain NFC does not ensure secure communications. As this technique is not part of the ISO standard, NFC offers no protection against eavesdropping and can be vulnerable to data modifications.

[10] https://www.truno.com/resources/industry-topics/how-to-justify-the-cost-of-electronic-shelf-labels-to-your-leadership

[11] https://www.mckinsey.com/industries/chemicals/our-insights/the-european-recycling-landscape-the-quiet-before-the-storm

## 3.3.2 RFID TECHNOLOGY

At the moment, RFID is more often used for tracking and location in logistic functions than NFC. Furthermore, because of the short read-range limitations, NFC devices have to be in very close proximity - usually no more than a few centimetres. For this reason NFC is often used for secure communications, especially for access controls or in the consumer sector for contactless payment.

The reason why RFID technology is used for logistics over NFC is because a lot of time is wasted reading the label since a direct contact between the reading device and the label in NFC technology is needed. Moreover, it also produces more errors than the RFID technology. Consequently, although the implementation of RFID is more expensive than NFC, in logistics or traceability RFID is preferred.

The signal that the tag would send to the receiver would be a code. This code would collect information on the characteristics of the recycled material, information that we presented in chapter 2.1 of this deliverable. But this information would come encoded following a codification system.

### 3.3.2.1 CODIFICATION SYSTEMS

Codification is used to classify properly equipment, raw materials, components and assemblies to suit the particular needs of any organisation. Types of systems are:

1. **Alphabetic system:** Letters are chosen to represent classification. Alphabet code has 26 letters. Each position in the code has 26 possible letters. Where relatively few classifications are involved, assignment of letter designates is sometimes made arbitrarily.

2. **Simple numeric or sequence system:** Numbers are assigned for classification. The obvious disadvantage of this simple numerical sequence is that there are no memory aids incorporated in the system. A good deal of time is wasted in searching for code numbers in materials code books.

3. **Combination system:** Some firms find it advantageous to combine a mnemonic and numerical or decimal system.

4. **Block system:** Blocks of numbers are reserved for specified classifications such as 1700-1799 for the raw materials and 1800-1899 for manufacturing parts, etc. The advantage is that wherever numbers are not assigned, subsequent expansion can be accommodated.

5. **Decimal system:** Numbers are assigned in such a manner that each digit represents a sub-group or sub-account of the previous digit. The principal advantage of a decimal system is its capacity to accommodate a new item. The disadvantage is that it becomes cumbersome when a basic unit has many minor assemblies which in turn consist of numerous sub-assemblies.

6. **Numeric system:** The first or basic numbers indicate specific classes with subsequent digits used to describe sub-classifications.

7. **Mnemonic system:** It is an alphabetic system designed with the objective of easy memorization.

8. **Six letter or nine letter codes:** This system is widely adopted and is of immense use.

### 3.3.2.2 RFID TECHNOLOGY COST

Although, RFID is undoubtedly the most suitable technology of all the sensing labels for our case, there is a great drawback which is the cost of the implementation of this technology.

Depending on the type of RFID system to be implemented, the costs will vary. This implementation will include 7 types of cost: equipment, installation, tag, software, ongoing license, maintenance and integrator costs. A RFID reader cost would be between 1,000 and 3.000 $[12]; the cost of label is in a range from 0.10 to 15 $ depending on the RFID technology used.

Combining these costs with the need for a specific software, we see that we have high fixed cost to implement this technology and it would be economically unviable for the majority of recyclers. Looking for a technology that had much lower implementation costs would be the most appropriate to be able to cover any type of recycled material, so that this labelling could be implemented in any recycling plant even if the product obtained was of low added value.

At the moment, other projects are considering the use of this technology (i.e. Repair 3D) to be used in recycled material traceability. Even so, due to the high implementation costs, the depreciation of virgin plastic prices and the increase of recycled plastic prices, the CREAToR consortium considers that a low-priced technology, like QR codes, would be most suitable.

## 3.3.3 QR CODE

A QR code is a type of matrix barcode, first designed for the automotive industry in Japan. A barcode is a machine-readable optical label that contains information about the item to which it is attached. In practice, QR codes often contain data for a locator, identifier, or tracker that points to a website or application. A QR code uses four standardized encoding modes to store data efficiently.

Advantages: The main advantage of a QR code is its versatility. QR codes can be used for anything and everything. They are also beneficial for both customers and businesses. A customer can scan this QR code and this allows them to store the information for future reference.

Disadvantages: There are 6 main reasons why a QR Code does not always work:

- Bad quality
- Inverted colours
- Small size
- Poor contrast ratio
- Wrong placement
- Overcrowded QR code

### 3.3.3.1 QR TECHNOLOGY COST

Although many people still do not use this technology, is widely known thanks to mobile phones and most of the implementation costs would be practically zero, except for the printing of the labels, since there are web pages that make the code for free[13] and there are also multiple free QR code reading applications for mobiles.

We must bear in mind that the information we have can be directly decoded as if it were a message or the QR code and can direct you to an internet page where this information is posted.

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[12] https://www.airfinder.com/blog/rfid-cost

[13] https://www.qrcode-monkey.com/#ur

Everything will depend on the standardization of the material, since with highly standardized materials a web page may be enough but in other cases the coded message would be a better option.

Below a QR code is shown as an example, demonstrating how the information contained can be read with a mobile application. The example contains the material specifications the partner Cyclefiber needs for its demonstrator (the data have been deleted due to confidentiality reasons) (Figure 3).

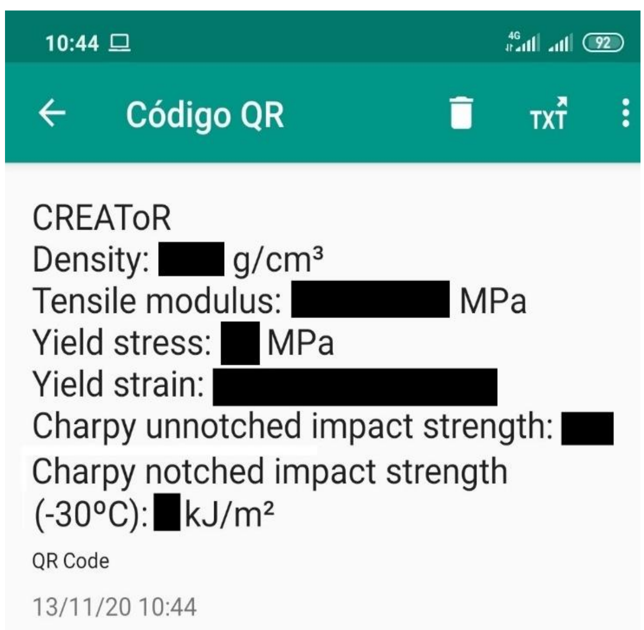


*Figure 3: QR code and the information that it contains*

# 4 CONCLUSIONS

In summary, the CREAToR consortium believes that the introduction of a label for recycled materials is of utmost benefit for their commercialization, for their use in high end applications and for their social acceptance. The minimum viable information to be contained in the label depends on the materials and their targeted application as a secondary source, but it is certainly necessary that they include, at least, information on the characteristics and composition of recycled materials.

Coolrec BV has the capacity to carry out tests on materials after sorting, looking for the characteristics of recycled materials together with their composition. The description of composition and characteristics of recycled materials by end-users simplifies their tasks in manufacturing and producing their final product. Moreover, it increases the confidence of producers to expand the use of recycled materials to the detriment of virgin materials. Despite strong growth plastic demand, penetration of recycled plastics is estimated at only 8 % of the overall plastics market[14] and forecast to reach 10 % by 2020.

The following Table 7 presents the technologies that have been taken into account and the main reason why they have not been selected.

*Table 7: Disadvantages of the different technologies that were taken into account for labelling and were rejected.*

| TYPE | |
|---|---|
| EAS LABELS | Implementation is relatively expensive |
| SENSING LABELS | Gives information about the variation of a certain measure (temperature, humidity, pressure ...). Not a technology suitable for CREAToR's case. |
| ELECTRONIC SHELF/DYNAMIC DISPLAY LABELS | Initial investment cost for a user could be marginally high. |
| DIGITAL WATERMARKS | It is a technology more suitable for recycling materials traceability labels. |
| NFC LABELS | The time required to read the label is greater than in other technologies. The error rate when reading the tag is high. |
| RFID LABELS | The significant drawback is the cost of the implementation of this technology |

In order to minimize any impact on the final cost of material recycling, the label has to be viable in terms of cost, time and resources for its implementation and, additionally, in terms of cost to be borne by the end-user for the label identification. A low-cost technology is mandatory: the consortium identified and selected the QR codes among the options described in chapter 2.2. A minor shortcoming is the poor data protection, intrinsically connected to the fact that QR codes are readable with any mobile device.

In the public deliverable *D 1.4 Analysis of recycling agents' conceptions & beliefs on SLS methodology* (May 2021), an analysis will be presented in the form of a layman-style report, taking into account the key success factors to enhance recycling profitability and social recognition that have been discussed with recycling partners. A first draft will also be provided of the label that will

[14] https://assets.kpmg/content/dam/kpmg/xx/pdf/2019/10/the-plastic-recycling-opportunity.pdf (KPMG)

be implemented in the CREAToR project (including costs, label size and information contained). Moreover, it will review the possible complications that could arise during the implementation.

Subsequently, in the public deliverable *D1.6 Smart labels for the materials utilized within CREAToR* (May 2022), the label demonstrator will be presented, which will be developed under the technology chosen in this deliverable (QR codes) and with the characteristics set out in the above mentioned deliverable 1.4.