Study on state of the art in reusing recyclable waste materials in orange, circular and green economy

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Abstract

Nowadays, there is an increased interest by both authorities and citizens in recycling waste, especially plastic-based waste. The negative impact of over-used landfills and incineration of waste on the environment is very *high and affects everyone. It is necessary to find ways to reuse, reduce and recycle waste to clean the environment. Several studies and projects have been investigated to find the most suited way to treat this situation. Education of citizens, the connection between waste management stakeholders and orange economy, circular economy and green economy have been found as successful solutions to manage the problem of waste. Our solution to mitigate the problem of waste and to fulfil the necessity of artists for materials in the orange economy is the RRREMAKER project that aims to develop an artificial intelligence-based maker platform that has multiple purposes. First and foremost, the platform wants to create a bridge between those who collect recyclables and eco-friendly designers/producers. Then, using information taken from knowledge communities, green design, and democratization invention, and integrating orange, sharing and circular economy, the platform will be able through artificial intelligence algorithms to redefine the purpose of an old product, providing data about the new shape of the product, whether it could be combined with another material, new uses, etc. Transfer of knowledge between experts in design, materials, manufacturing, supply management, economy and distribution on the one hand, and computational experts, on the other hand, will focus on several research layers (green and circular economy, machine learning, data management, cloud environment). The project will have a significant impact on both societal and environmental challenges of the world.*

Keywords: *Artificial Intelligence platform, reuse, waste, data management, cloud*.

1. Introduction

The baseline of circular economy of waste in Europe was supported by Council Directive 1999/31/EC of 26 April 1999 [1] on the landfill of waste, which established a common hierarchy of waste to further motivate the recovery of goods and materials.

As a solution to mitigate the negative impacts upon the planet, such as pollution, climate change or biodiversity loss, the circular economy is desired. A circular economy is an economic system that aims to extend the life cycle of products by re-sharing, refurbishing, repairing, recycling and reusing the waste products for the most prolonged period.

According to UNESCO [2], the Orange Economy, also known as the Creative Economy, role is to connect the sectors of the economy "whose main purpose is the production or reproduction, promotion, dissemination and/or the marketing of goods, services and activities that have cultural, artistic or patrimonial content".

The main goals of a Green Economy are to reduce environmental risks and ecological scarcity. This economic activity is based on sustainable development, the use of renewable natural resources and the reduction of hydrocarbon consumption. The six strategic pillars of the Green Economy are climate change, resource-saving and management, circular economy, environmental protection, ecosystem protection and recovery, water conservation and natural disaster prevention [3]. In a green economy, public or private investments made to increase income and employment are expected to reduce carbon emissions and pollution and prevent the loss of biodiversity and ecosystem services.

In the interest of providing suitable materials and tools for artisans, considering the reduction of waste and the reuse of materials by adapting production costs, favouring the "3R–Reduce, Reuse, Recycle" principle, the RRREMAKER project aims to develop an Artificial Intelligence (AI) based maker platform for the design and production of handcrafted, rapid prototyped and reconditioned products. The platform is based on the availability of used goods and recyclable waste that is collected, acquiring entries from and joining together digital manufacturers and traditional crafts, designers /creative corporations, and green corporations. Furthermore, the program will provide a new hybrid managing model based on the communities of knowledge, eco-design and democratization invention, where orange, sharing and circular economy will be incorporated [4].

This paper includes the following sections: Section 2 consists of state of the art about methods of collecting, sorting, reusing and recycling waste, Section 3 is dedicated to a description of the main objectives that the RRREMAKER project aims to implement and the impact of this project, and Section 4 present the conclusions and the future work of RRREMAKER.

2. State of the art

In the last years many studies [5-8] have been conducted in the field of circular economy and waste management, and most of them are concluding that governments need to take more responsibility and initiative in order to meet the goals of energy efficiency, water and waste management. It is important to reduce plastic production and increase plastic recyclability, and this study focuses on finding ideas and opportunities to increase the amount of waste that is recycled and use these existing resources to develop a closed-loop economy.

2.1. Orange / Maker culture

In his thesis [9] Mustafa İlhan explores the idea of transforming rubbish into art objects. This research explains how artworks created from discarded materials play an essential academic and cultural role. Several methods of reusing unconventional materials are explored, such as their use in paintings, sculptures, collages, and assemblages of three-dimensional objects. The author has developed a method of reusing packaging to produce notebooks. Notebook covers are created from Starbucks packaging and modshifters papers. The pages of these notebooks are made from Varuna Gezgin papers and the banner used in the Middle East Technical University ceremony in 2011.

The future of the textile and clothing industry is focused on a circular economy and closed-loop production. The study [10] approaches the development of emerging technologies for fabric processing, collection, classification, and use into a new recyclable product. The paper details further the efforts done by popular fashion companies (H&M, Adidas, Patagonia, etc.) to develop the circular economy around recycled clothing items. For this proposal to succeed, the idea of recycling and reuse needs to be promoted, which will lead to increased demand for these products.

In [11], the IWWG Art Gallery is described regarding the collaboration between waste management and social sciences and how this can lead to a launchpad for new businesses or charities ("Bread Tag for Wheelchairs" [12]). The people involved in the IWWG Art Gallery that are turning waste into artworks are usually young and beginner designers, students and children. Examples of such transformations are: creating handbags from car tires, plastic or newspapers, jewellery from caps or furniture from refurbished wood.

In [13], the authors carried out an interview-based study with 25 stakeholders from the areas of waste management and design. Large metropolitan areas, such as Cairo, Berlin, Pune, Santiago and Gothenburg, had been investigated from the point of view of waste management and the amount of waste generated. Gothenburg has the smallest population of all, but it has the highest amount of waste generated per capita. The study also revealed that in non-EU countries, the disadvantaged part of the population tend to be more involved in recycling as it can be a representative part of their income.

The authors also detailed a scale for waste recovery into design, starting from Design for Durability to Design for End-of-Life, Waste as input Material, Packaging for improved Recyclability and ending to Waste System interface.

2.2. Green / Circular economy

According to the European Parliament [14], 50% of the collected plastic for recycling is exported outside the EU borders, mainly due to the shortage in terms of capacity, technological development in some areas or even financial resources. The same report highlights the severe environmental effects that the absence of recycling generated through the production of new plastic materials and incineration of one-time used plastics by pumping more than 850 mil. tons of greenhouse gases in the atmosphere in 2019. Therefore, a solution to not only support but also to enable and help all the actors involved is required in order to diminish to the lowest the waste of recyclable materials.

The natural ecosystem is a complex system in continuous development, which, as it grows, consumes much more energy, thus producing more waste. The CE aims to eliminate waste and generate a super-efficient system. The circular economy wants to create 'circular' material flows that reform the linear economic rationale of producing, buying, and disposing, therefore generating economic value for its actors. The CE is aiming to rebalance human-nature interactions by redesigning economic and social relations radically. Inspired by the cradle-to-cradle design approach, the CE aims to build waste-free technical loops that imitate biological circles and make waste diminish simultaneously, being both restorative and regenerative. A broad range of economic and political entities, such as inter-governmental organizations

(OECD), influential forums (World Economic Forum), corporations (CISCO, Dell, IKEA), regions (Region Skåne, Sweden) and cities (Amsterdam and Glasgow), offered to support the purposes of the circular economy [15].

The authors in [16] analysed how the circular economy can lead a waste management revolution in cities, with a case study in Amsterdam, Netherlands. The circular economy can be the solution to economies based on individual production-consumption market chains that result in a significant amount of unvalued waste. The focus of the paper is on three topics of waste in the context of circular economy: waste recovery, reuse of materials and incineration. Incineration is highly used in the city of Amsterdam as a solution to a fossil-free future, even though, the incinerated wastes are fossil-based, therefore the other two methods need to be intensified as well. For this, significant changes need to happen in the infrastructure, policy and economic areas to develop the circular economy for better waste management and to not develop an economy based on waste production, but one complementary with the goal of reducing the amount of waste and capitalizing the existing one.

Most of the plastic waste contains a sizeable amount of Polyvinyl Chloride (PVC), which is perceived to have a negative impact on the subsequent mechanical recycling of any mixed plastic waste. The paper [17] focuses on the sink fraction of waste from packaging that was highly analysed about its composition and properties and treated to get rid of PVC and non-ferrous metals. To reduce plastic residues streams and incineration incidents, sorting actions have been taken to eliminate these problematic contaminations, followed by implementing the Design from Recycling strategy, called Greentile, which is a robust element used in the construction of slanted green roofs, aims to provide a product suitable for manufacture in the sink fraction. After conducting a FEM analysis to ensure the project's sustainability, a small green roof was successfully constructed. However, due to the complex composition as well as the PVC content remaining in the mixture, there is a possibility of discouraging the widespread use of this material.

In [18] two studies were conducted, focusing on the disposal conditions and economising fossil resources while giving less importance to CO_2 proportion. And in the second study, the impact on health and risks lowered the acceptance of CCU (Carbon Capture & Utilisation) based products. The authors applied the conjoint analysis for individual preferences. The characteristics used in the analysis were: disposal conditions, health complaints, CO_2 proportion in the plastic products and fossil resources savings. The questionnaire had topics about demographic data, technology and environmental expertise and risk awareness, and it took place in Germany in 2015 on 145 people. The results showed an acceptance of participants regarding the use of CCU technology, reuse of CO_2 and fewer emissions during disposal were appreciated as well.

In the paper [19], it is described the use of waste materials to produce lightweight aggregates, in this way reducing the costs for disposal and valorising the waste. Several waste materials are investigated, such as fly-ash from the incineration of solid waste, which is very common in the pelletization process, and there are significant amounts of it available. This can lead to a circular economy in which modern world legislation is respected, the methods are environmentally positive and can have cost-reducing benefits.

The RECICLARM project aims to become a cutting-edge modular and robotic system that will improve the recovery rate of waste and reduce the environmental impact. The project is relevant in the context of construction companies, where it can support sorting of construction and demolition waste into separated fractions of high-purity and small size waste with use in high-grade applications in the building industry [20].

In Emilia-Romagna, Italy, the LOWaste project wants to develop a recycled materials local market to achieve the goal of reducing urban waste and preserve natural resources. The project had a citizens awareness part where waste prevention and the usage of recovered materials was promoted. At the same time, the project had the support of the municipality to develop a green public procurement programme to connect the buying procedures with the products eco-design. The hot part of the project was a contest in which over 70 participants (start-ups, designers, etc.) collaborated to propose new products from waste. All the “re-products” resulted had an impact on the environment of reducing by 11400 tons per year the amount of waste, and as secondary, 11200 tons of raw materials as savings [21].

The REPURPOSE LIFE project aims to support the development of "reuse hubs" in local enterprises for a better collection, repairing and transportation to a proper destination facility of waste items suitable for reuse or recycling, thus decreasing the illegal disposal of waste [22].

2.3. Design / prototyping

To address the problem of material costs and the large quantities of plastic produced by FFF3D printers, study [23] evaluates through a series of physical characterisation tests the benefits of using recycled high-density polyethylene (HDPE) in both pellet and flake forms as 3D printing material for in-house. Tests proved that the HDPE granule filament, with diameters in the range of 2.93–3.17 mm, with a tolerance of 0.22–0.30 mm, had positive water repellence, extrusion speed, and thermal resistance comparable to ABS granule filament. The only limitations of using HDPE that are intended to be overcome in the future are the problems of deformation and adhesion of this recycled material.

The materials sector could be developed by replacing metals and plastics with lighter composite materials such as carbon fibre reinforced polymer (CFRP), which has a smaller carbon footprint. However, this implementation is slowed by high production costs and recycling difficulties. The CRESIM project supports the implementation by creating an innovative production of CFPR from recycled carbon fibres, using lightweight composites recycled from automotive and aerospace parts, which have applications for public transport vehicles, automobiles, and leisure equipment [24].

ECO DESIGN promotes durable product design for Flemish enterprises by producing an eco-design handbook that contains all life stages of the product, from the eradication of organic matter to manufacture, product usage until the waste removal process [25].

ECO-PULPLAST project oversees the synergism among the paper and plastic industries. It aims to demonstrate the feasibility of an innovative technology to recycle waste into new plastic compounds and products, with the goal of reducing to zero the amount of waste going to landfills or incineration. In the project's pilot factory, eco-sustainable plastic pallets will be produced for use in the same paper sector, resulting in a local circular economy [26].

2.4. Data collection

In order to develop urban management and the circular economy, we must achieve efficient and sustainable solid waste management in metropolises, resulting in a reduction of the environmental and human health impacts of solid waste from households. This study [27] follows the dynamics of a Norwegian municipality, introducing a sustainable social enterprise model, with the key points being optimal waste collection and observing the effects of optimal route planning to achieve sustainable development goals. Regarding the amount of waste, data was collected in certain areas to optimally size waste bins. Optimal route planning, using algorithms such as Vehicle Routing Problem (VRP) and Capacitated Vehicle Routing Problem (CVRP), reduces costs, fuel consumption, CO_2 and other toxic gas emissions, and time used for waste collection, making it a profitable solution for the circular economy.

Due to the lack of relevant information about quality, availability or suitability of recyclable plastic materials, many producers are shifting their attention towards virgin polymers, therefore avoiding the recyclable plastics. The authors in [28] obtained promising results by testing the use of smart contracts based on blockchain technology together with multi-sensor data-fusion algorithms and AI to obtain important parameters about the plastic waste to get a reliable segregation and to provide the actors in this area a method to share data, calculate in advance the supply chain, execute orders and enlarge the usage of recycled plastics.

The Mo.re & Mo.re project designed a tool for matching the supply and demand of secondary raw materials for Italy's Lazio region. First, there were identified all the supply chains for the recovered and collected wastes derived from the municipal collection and segregation schemes. The developed online platform promotes the use of secondary materials by the interested companies and provides an economic incentive for the seller to recycle. The database lists include over 1500 contacts and following the calculation of the local waste absorption capacity, 40 different waste supply chains were found [29].

In order to close the carpet production loop, the ClosedLoopCarpet project aims to reduce the use of virgin raw materials in carpet production by using an innovative and economically feasible technology that separates discarded carpet material into high-quality primary resources used in the manufacture of other carpets. The implemented pilot line can provide data on the separation of carpet waste into homogeneous polymers, with a separation and purification capacity of 92 tons/year of carpet waste. The market is foreseen to flourish due to falling prices driven by increasing recovered materials [30].

The CitiSim project has developed a mobile application that is based on citizen input and a modular platform for an enhanced smart city management and monitoring. The application provides an user-friendly 3D visualisation interface with augmented and virtual reality features. All these aspects can boost the management of waste and help economic actors, policy makers and NGOs with interest in waste reuse to connect and co-operate to reduce costs regarding waste disposal, support the valorisation of waste, reduce its ecological impact and take knowledge-based decisions [31].

2.5. Programs / Software / AI

For EU countries to meet the European Circular Economy Action plan and the EU's 2050 climate neutrality goal, concrete measures are needed to optimise and improve the efficiency of the national waste management components by increasing the recycling capacity, implementing robotic technology / automated waste sorting for specific materials. For this to happen implementation of digitalisation and development of other technologies (such as material detection by sensors) is critical. Waste management being one of the less digitised industry nowadays [32].

Due to the significant increase in customers buying and using various goods, and the poor management of the amount of waste, a huge volume of residues has been created, requiring enormous waste management policies. In [33] it was proposed to develop an Artificial Intelligence based Hybridized Intelligent Framework that uses machine learning and graph theory to optimize the waste management process, collecting debris over short distances, and also improving the efficiency of environmental planning and urban management. Thus, reducing, reusing, recycling and recovering reduces the negative environmental impacts generated by companies.

For the last 18 months, the SARS-CoV2 pandemic has led to a significant amount of medical or infected waste being mixed with all the other waste types. In [34] it proposes an automated method for sorting waste related to COVID that is based on AI. Several types of waste are considered, such as metal, glass, paper, polyethylene terephthalate, that are further classified based on image-texture-dependent features for a higher accuracy before the recycling process. Support vector machine classifiers are used and obtained very good results of 96.5% accuracy, 95.9% specificity and 95.5% sensitivity.

LIFE M3P project identifies and profiles at least 500 industrial waste streams, facilitating their transformation into secondary raw materials for other SMEs in the local area, using an online platform called M3P (Material Match Making Platform). This project, finalized in 2019, brings together clusters of SMEs to promote alternatives to waste use. Over 200 SMEs are expected to get involved in the project, of which in 100 in the region of Flanders, Belgium, 100 in Lombardy, Italy, 25 in West Macedonia, Greece and 10 in Asturias, Spain [35].

3. Waste reuse in artisanal products – The RRREMAKER project

The RRREMAKER project aims to build an Artificial Intelligence (AI) based maker platform for designing and producing handcrafted, rapid prototyped and reconditioned products, based on the availability of used goods and recyclable waste collected. Based on the communities of knowledge, eco-design and democratization invention, a hybrid managing model will be implemented, where orange, sharing and circular economy will be integrated. The platform integrates cutting-edge algorithms of generative design, as genetic and super quadric-based algorithms, machine learning classifiers, algorithms for big data, cloud computing, and experimental data that will predict materials, ornaments, structures, colours, forms, etc., based on traditional artisan and innovative design parameters, and recycling materials.

Another platform's role is to be a "sorting point", offering the opportunity to connect the waste collectors with green manufactures/eco designers. Furthermore, based on the collected sales data, the platform will create a marketplace with available goods and automatically give suggestions to make them more attractive.

The project wants to implement sustainable co-production throughout the production chain by developing options that consider waste reduction and reuse of materials by adjusting production costs, which reduces the impact on the environment as much as possible.

The AI-based platform, when the digital design process occurs, will be capable of managing the prototyping process based on handcrafted production disciplines, providing automated design solutions based on object function, affecting shape prediction, recommendations, self-build, and materials.

The most significant goal of this project is to apply artificial intelligence and machine learning to improve circular economy principles and actions in design, crafts, rapid prototyping and intelligent manufacturing sectors, with significant overall economic benefit for European society by promoting the protection and development of the natural environment, also favouring the "Reduce, Reuse, Recycle" principle.

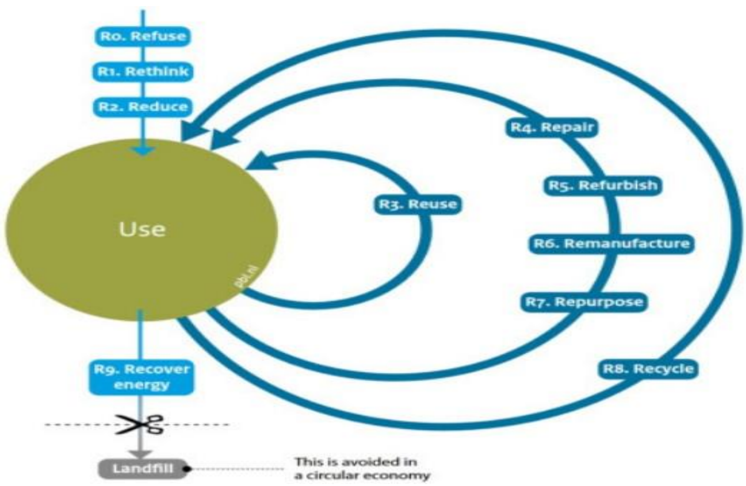

Fig. 1. The different R's [36]

3.1. Specific objectives of the RRREMAKER project

3.1.1. Identification and collection of data of parameters in design, industrial manufacturing, traditional artisanship and recycled material

The RRREMAKER project plan is to explore the fashion, jewellery, furniture, industrial and craft production typical parameters in the interest of evaluating their ability to receive and implement new forms and materials. Each object, depending on its function, is assigned a specific shape, design and material. The newly redesigned material will respect the original function, plus innovative properties in terms of shape and the use of durable materials. Further investigation and redefinition of the limits and possibilities of new recycled materials will be carried out, comparing them with traditional ones and whether they can replace and/or blend with the original ones. Machine learning will be employed to predict main characteristics of a specific complex material in textile, plastic and ceramics. Parameters to measure the transition towards a circular economy model, made up of indicators related to renewable energy, water, reuse, recycling, reduction, use of resources and negative externalities, will be identified.

The platform will contain a database that will include a classification of traditional craft styles, which will be used in the context of designing new products. Among these are Andalucia´s traditional craft styles, covering a vast spectrum of techniques - from Tartessians, the Phoenicians, Romans and Arabs culture - which has more than 100 master credited craftsmen; Araucania region, recognized with Excellence diploma by World Crafts Council, combines different indigenous cultures -Mapuche, Aymara and Rapa Nui-, and Romania, which has a rich ceramic culture - e.g. Horezu- and wall carpets inscribed on UNESCO Intangible Cultural Heritage lists.

3.1.2. Building AI-based modules to train the platform on orange/maker economy and green/circular economy

Based on the information collected and classified in the first phase, this objective aims at a modular approach on the two main independent economy areas involved, namely orange/maker and green/circular economy, before making them talk to each other in the whole platform.

An orange/maker culture (OMC) module will be developed first. This module will contain all the information on the design strategies that can be collected and will be open for the feeds coming from the outer world. In this framework, the concept of technological nutrient will be introduced (which converts a resource already used into food for another process) to define the single design information unit. Once identified the design and product categories to focus on, opportune manufacturing techniques will be selected by the OMC module, specifically tailored to the "maker" level.

The second module will be called green/circular economy module (GCE). One of its main purposes will be material selection. Cross-database search involving the most reliable compound databases (e.g., Matweb, Material connexion, ASM International, MatNavi NIMS Material Database) and waste databases (e.g. Eurostat) and national Recycling material database by country or geographic area will allow to screen and classify materials predicting their affinity to each given design proposal elaborated by the platform in the OMC module.

Similarly to what was done with the concept of technological nutrient for the OMC module, the concept of industrial symbiosis will be investigated, mandating that the “waste” of a process might be the “raw material” of another process, and offering liaisons between different domains that break the line economy model and contribute to the circular-economy one. Material-based, structure-based, generative design algorithms together with circular economy relevant in sustainable production processes will be used. The models of the products will be realized by different parts or ingredients in an innovative mix and match so that design enables higher possibilities in reuse and recycling. Moreover, engagement in a collaborative-design paradigm involving several collaborating actors could be pursued, enabling sharing of tooling and other resources and viewing products as composite items.

All the acquired information in both modules will be processed by advanced machine learning algorithms trained on a large set of profile tests and literature data. The algorithms will be based on different strategies, but mainly on a semi-supervised approach, using genetic techniques and Bayesian networks that will also give the possibility to choose among different possible sets of materials.

3.1.3. Integration of the single-level modules of the AI platform and development of a user-friendly interface

From the complex AI modules produced, an easy-to-use platform will be generated, to be available for all the potential actors of the economies involved. The most relevant challenge in this objective lies in the integration of different methodologies, implementations and economic requirements, because data coming from human-centred activities, like art, design and fashion and circular economy, will be elaborated and integrated with machine-centred algorithms based on cost-effectiveness, scalability, material availability and manufacturing techniques. Machine learning techniques will be used to mix all that data, employing a continuous flow of information from one compartment to another, which will improve the efficiency of each single-level module while finding its way of integrating them.

Regarding the innovative economic models involved, an important aspect will be to assess how the integration of those models can be done in a cost-effective and sustainable fashion. The collaborative design paradigm involving more actors in the process guided by a unifying modelling approach, as well as with the industrial symbiosis concepts utilizing “waste” as “raw material” among different domains will be implemented. The project will exploit high performance computing (HPC) capabilities to tackle the complexity of the models and afford calculations. Concerning data integration, a major problem for modellers at present is the lack of specific standards for the integration of such different requirements in AI-techniques.

The final platform will be designed to interface with other web platforms (either maker, craft, industrial or circular economy ones) that operate in the fields of design, handmade production, industrial production, material transportation, collection and recycling. Using the premises of the partners, two hubs to receive and sort used material and to host the manufacturing facility will be created. All the areas of the hubs will be interfaced with the AI-based platform, real-time revealing the amount and category of the goods in input, of the manufactured goods and of the goods in output, with the aim to train the platform to optimize the maker activities, minimizing production waste and shortening storage time of the goods.

3.1.4. Transfer of Knowledge and Multidisciplinary Integration of Competences

Transfer of Knowledge (ToK) between experts in design, materials, manufacturing, supply management, economy and distribution, on the one hand, and computational experts on the other hand, will focus on several research layers:

- orange economy and maker culture;
- green and circular economy;
- machine learning;
- data management;
- cloud environment.

The strength of RRREMAKER is the multidisciplinary integration. ToK and multidisciplinary integration of competences will depend both on the possibility to integrate modelling approaches in the computational platform, and on the definition of web-interface shape tested throughout the project by the end-users, which will provide continuous feedback on its usability.

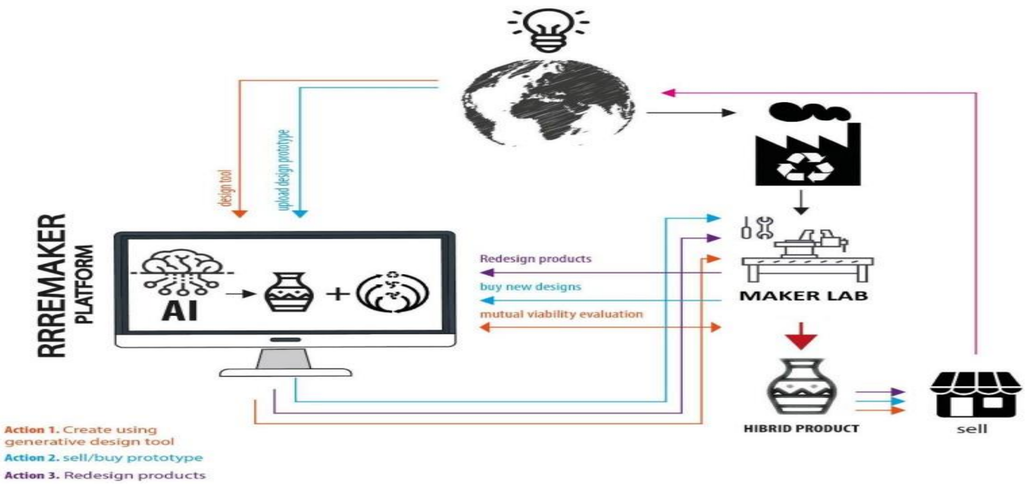

Fig. 2. General scheme of the RRREMAKER AI platform

3.2. Impact of RRREMAKER

The project RRREMAKER is consistent with the "Societal Challenges'' of the Horizon 2020 framework, particularly the challenges: 1. Climate action, environment, resource efficiency and raw materials; and 2. Europe in a changing world - inclusive, innovative and reflective societies. In fact, RRREMAKER is an outstanding occasion, since it couples the ideas of environment management, circular economy and saving of raw materials and the diffusion of innovativeness and reflectiveness over the society, directly involved in the Maker activities, stimulating a user-centred innovation process against a manufacturer-centric model. All this through an AI driven Maker platform that is the main actor in the creative process.

Artisan activity is included in cultural and Creative Industries (CCIs), that generate around €509 billion per year, representing 5.3% of the EU's total GDP and employ 12 million full-time jobs constituting 7.5% of the EU's employment and the third largest employer sector in the EU [37].

The European economy is surprisingly wasteful in its model of value creation and, for all practical purposes, continues to operate a take-make-dispose system. Resource productivity remains hugely underexploited as a source of wealth, competitiveness and renewal. Circular economy, enabled by the technology revolution, allows Europe to grow resource productivity by up to 3 percent annually. This would generate a primary resource benefit of as much as €0.6 trillion per year by 2030 to Europe's economies. In addition, it would generate €1.2 trillion in non-resource and externality benefits, bringing the annual total benefits to around €1.8 trillion versus today. This would translate into a GDP increase of as much as 7 percentage points relative to the current development scenario, with additional positive impacts on employment [38]. Furthermore, digitisation of products and services can add more than EUR 110 billion of annual revenue to the European economy in the next five years [39]. RRREMAKER provides unique training opportunities for the researchers and staff involved, encouraging cooperation, transfer of know-how and inputs from best practices among participants.

Researchers will benefit already in the short run from being involved in-depth exchange of knowledge among widely different disciplines and from acquiring hands-on experience in the platform development, analysed from points of views that are rarely combined in research. These skills will directly improve their career prospects in growing number of companies, universities and institutes involved in this sector. In the long-term the researchers and staff will benefit from boosting and nurturing their career, from fully exploiting the know-how acquired owing to RRREMAKER multi-disciplinary scope, and its supradisciplinary nature.

4. Conclusions

In this study the most recent studies and projects in the area of reusing recyclable waste materials in Orange, Circular and Green Economy were analysed from the point of view of methods and results. The majority of the selected studies conclude that responsibility and initiative need to be taken by governments to support the goals of energy efficiency, water and waste management proposed by the European Union. Circular economy can influence the European GDP by up to 7% through resource productivity.

RRREMAKER's platform integrates AI techniques side by side with artisan production, rapid prototyping, innovative manufacturing technologies and machine learning applied to the raw material search among the recyclable ones.

RRREMAKER will develop an AI-based platform that exchanges information between waste collectors and artisans/buying companies, creating marketplace opportunities in the areas related to innovation, green economy and culture industry, and to the improvement of more logical waste management, transforming resources into technological nutrients.

The RRREMAKER project will enable unique training opportunities for the researchers and staff involved, supporting partnerships, transfer of know-how and inputs from best practices among the stakeholders involved and researchers.

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