Proyecto URBANREC - Nuevos enfoques para la valorización de los residuos voluminosos de origen urbano en productos reciclados de alto valor añadido.

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1. Resumen.

La mayoría de residuos generados en Europa son de origen urbano, de entre los que se encuentran los denominados residuos voluminosos (mobiliario, colchones, restos textiles y productos de jardín). Los actuales sistemas para la gestión de estos residuos obtienen reducidas tasas de reciclaje, por lo que más del 60 % acaban en vertederos.

A nivel local la gestión de estos residuos supone un gran reto ambiental, debido principalmente a su gran volumen, su elevado peso y escasa concienciación ciudadana para su correcta retirada. Esta situación genera graves impactos ambientales como; la aparición de vertederos incontrolados, el abandono de residuos en la vía pública, la saturación de las instalaciones municipales y la perdida de materiales en vertedero.

El proyecto URBANREC tiene como objetivo mejorar la logística, el tratamiento y aprovechamiento final de residuos como muebles, colchones, tapizados, textiles y productos de plásticos a través de técnicas innovadoras de tratamiento, tales como las fragmentación (corte 3D) y tecnología Hidro-gasificación catalítica por plasma (CHGP). Estas nuevas tecnologías aplicadas a la gestión de los residuos nos permitirán obtener productos reciclados de alto valor; polioles secundarios para la fabricación de adhesivo y espumas, disolventes y aditivos para la producción de biocombustibles, textiles y espumas para la fabricación de colchones, plásticos y maderas para la fabricación de mobiliario urbano. Además se va a trabajar en aspectos sociales, fomentando la reutilización y reciclado de residuos voluminosos, mediante instrumentos económicos capaces de involucrar a la ciudadanía en la gestión diaria de estos residuos.

Coordinado por el Instituto Tecnológico del Plástico (Valencia), este proyecto ha logrado involucrar a un total 21 organizaciones públicas y privadas de 7 países europeos (Fraunhofer, Centexbel, IOS-PIB, YTE, ACR+, IZNAB, RAMPF, RESCOLL, EUROESPUMA, PROCOTEX, VANHEEDE, IMOG, OVAM, CAPITAL CITY OF WARSAW y BORNOVA), entre las que se encuentra las empresas españolas Ecofrag, Colchones Delax y Blueplasma Power y dos entidades municipales la Diputación Provincial de Valencia y el Consorcio Valencia Interior. La Diputación de Valencia será la encargada de lograr que los avances obtenidos en URBANREC puedan ser aplicados en la gestión diaria de los residuos voluminosos en la provincia de Valencia.

Con un plazo de ejecución de 42 meses y acciones piloto demostrativas a desarrollar en 4 regiones europeas (España, Polonia, Bélgica y Turquía), URBANREC ha sido seleccionado por la Comisión Europea, otorgándole una cofinanciación de 8.618.970,39 dentro del programa de investigación e innovación Horizonte 2020 (grant agreement nº 690103.).

2. Abstract.

Most of the waste generated in Europe are coming from urban areas among which bulky waste (furniture, mattresses, textiles remains and garden products) represents an important quantity. More than 60% of bulky waste is currently landfilled in EU (around 11.5 Mt according to WRAP-UK) [ ] because there is neither specific global EU legislation nor cost-effective valorisation methods.

Bulky waste management is a major environmental challenge at local level, mainly because of its large volume, its high weight and low public awareness for proper removal. This creates serious environmental impacts such as; the appearance of uncontrolled landfills., dispose of waste on public roads, saturation of municipal facilities and a loss of resources that could be valorised.

The URBANREC project aims to improve logistics, treatment and final use of waste as furniture, mattresses, upholstery, textiles and plastic products through enhancing reuse and implementing innovative processing techniques such as fragmentation (3D cutting) and Hydro-gasification catalytic plasma (CHGP) technology. These new technologies applied to the management of waste recycled allow us to obtain high added value, such as polyols from renewable sources for the production of adhesives and foams, solvents and additives for bio fuels, textiles and foams for the manufacture of mattresses and plastics more sustainable, using fibers and wood that can be used in the manufacture of street furniture. Additionally, URBANREC project will promote social issues, promoting reuse and recycling of bulky waste through economic instruments able to involve citizens in the daily management of these wastes

Coordinated by AIMPLAS, Technological Institute of Plastics (Valencia), this project has managed to involve a total of 21 public and private organizations from 7 European countries (Fraunhofer, Centexbel, IOS-PIB, YTE, ACR+, IZNAB, RAMPF, RESCOLL, EUROESPUMA, PROCOTEX, VANHEEDE ,IMOG , OVAM, CAPITAL CITY OF WARSAW and BORNOVA), among which the Spanish companies Ecofrag, Colchones Delax, Blueplasma Power and two municipal entities; Diputación de Valencia and Consorcio Valencia Interior will be responsible for ensuring that the progress made in URBANREC can be applied in the daily management of bulky waste in the province of Valencia.

With a lead time of 42 months and demonstration to develop in 4 European regions (Spain, Poland, Belgium and Turkey) pilot actions, URBANREC has been selected by the European Commission, granting co-financing within the program 8,618,970.39 Horizon 2020 research and innovation (grant agreement nº 690103.).

3. Bulky waste management in Europe.

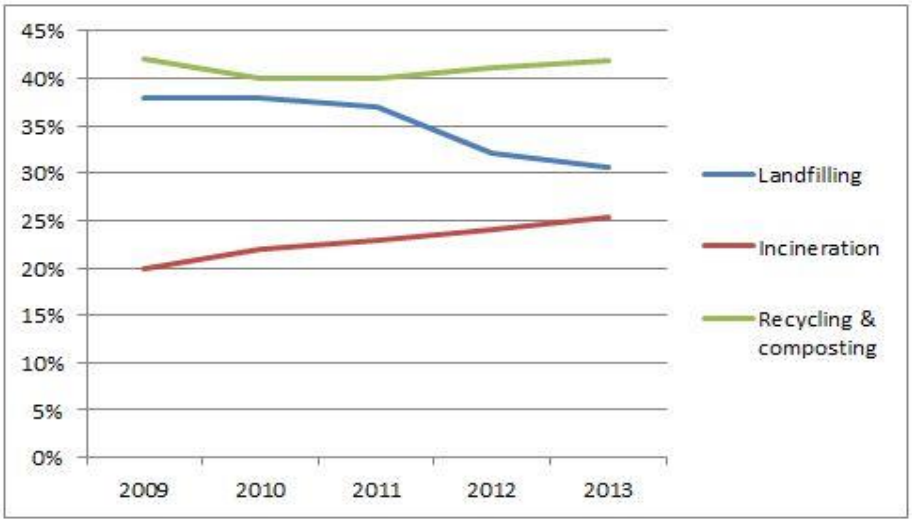
Currently, almost a 75% of the EU citizens live in cities and in their urban areas, data which is projected to reach an 82% in 2050[¡Error! Marcador no definido.]. Although the management of that waste continues to improve in the EU, the EU economy currently still loses a significant amount of potential 'secondary raw materials' such as metals, wood,

glass, paper, plastics present waste streams. In 2010, total waste production in the EU amounted to 2.5 billion tons. From this total only a limited share (36%) was recycled, with the rest was landfilled or burned, of which some 600 million tons could be recycled or reused *(//ec.europa.eu/environment/waste)*.

Figure 1. Civic amenity site or collection point.

Figure 2. Kerbside collection system.

The EU is committed to reducing the amount of waste that, is sent to landfill, while raising the proportion of waste that is recycled or composted. As stated by the "State and outlook 2015" report of the EU Environment Agency (EEA), EU appears to be progressing towards a decline in waste generated per capita but waste management will need to change radically in order to phase out completely the landfilling of recyclable or recoverable waste. According to Eurostat figures (figure 3) the trend in Europe shows that landfilling has gone down but this waste has not moved to recycling, instead it has been transferred to incineration more than to recycling options. Municipal waste is collected and treated by, or for municipalities. It covers waste from households, including bulky waste. Waste from municipal sewage networks and treatment, as well as municipal construction and demolition is excluded.[1]



[1] *WHAT A WASTE. A Global Review of Solid Waste Management. March 2012, No. 15.*

Figure 3. Evolution landfill, incineration & recycling 2009-2013 (www.zerowasteeurope.eu).

The overall amount of municipal waste generated in a country is related to the degree of urbanisation, patterns of consumption, household revenue and lifestyles. The amount of municipal waste generated per inhabitant provides a measure of the potential environmental and health pressures, for example, from soil and water contamination or poor air quality[1]. On average, each inhabitant in the EU-28 generated 499 kg of municipal waste in 2011, but these figures vary considerably according to EU regions. The amount and composition of municipal waste for final disposal by type of treatment depends on national waste management practices and consequently the same happens with bulky waste.

Based on data collected in UK; bulky waste collections account for 2.5% of all household materials collected at the kerbside and for 17% of all throughputs at Household Waste and Recycling Centres (HWRCs) or city amenity sites (CA site), which is equivalent to around 59 kg/household/year only in UK (www.wrap.org.uk) what means around 19 millions of tonnes per year in EU (estimation made based on European population).

Selection, separation and/or disassembly are important processes to obtain raw material from waste. Mixed materials come together to the city amenity sites and products are treated according to their specific nature. As detailed in table 1, different streams of materials can be obtained from bulky waste. Directive 98/2008/EC indicates the extended producer responsibility for different waste streams, however it is necessary to define how to articulate it taking into account the different actors involved (producer, public administration, waste management, etc.). Only for electrical and electronic equipment waste (WEEE), there are specific Directives which have made mandatory producer responsibility measures and WEEE is separated and treated consequently.

Table 1. Breakdown of bulky waste

Type	Legislation ((Directive number)		Raw materials to obtain
	General	***Specific***	
Garden and outdoor	2008/98/CE	None	Plastic and Mixed plastic,
Furniture	2008/98/CE	None	Wood, Metal, Plastic and Mixed plastics, Textile and mixed textiles
WEEE	2008/98/CE	2012/19/EU	Plastic and Mixed Plastic, Metal, Glass
Fixtures and fittings	2008/98/CE	None	Plastic and Mixed plastics, Metals
Textile	2008/98/CE	None	Textile and mixed textiles

Dismantling of remaining bulky wastes such as mattresses, furniture, seats, chairs, etc. can generate an interesting large amount of recovered materials such as textiles, foams, metals, plastics or wood. Market-available technologies are related to size reduction with a wide range of machines and complete systems for successful preparation of all soft to medium hard, hard, brittle, tough, elastic or fibrous materials and numerous patents[2], related are available. However, these patented technologies are high cost due to this labour-intensive processes are normally used, resulting in expensive treatments and most of the bulky waste are landfilled. Cost-competitive size reduction and separation of fractions are key factors for the subsequent residue treatment.

There are some important factors that can improve public awareness and consequently the final results of waste management rates. **Tax or ban landfill** has a direct impact to increase waste recovery, as shown in figure 4. **Innovative and Green public procurement (IPP/GPP)**,[3] of sustainable and innovative goods and services is one of the essential tools for stimulating new technological or service solutions while helping to create jobs and boost the competitiveness of EU industry and SMEs. IPP/GPP helps public authorities to achieve more efficient and effective public services providing solutions that reduce environmental impacts and are socially responsible.

The importance of innovation is internationally recognised, e.g. the OECD is developing a framework for measuring and interpreting innovation activities.[4]

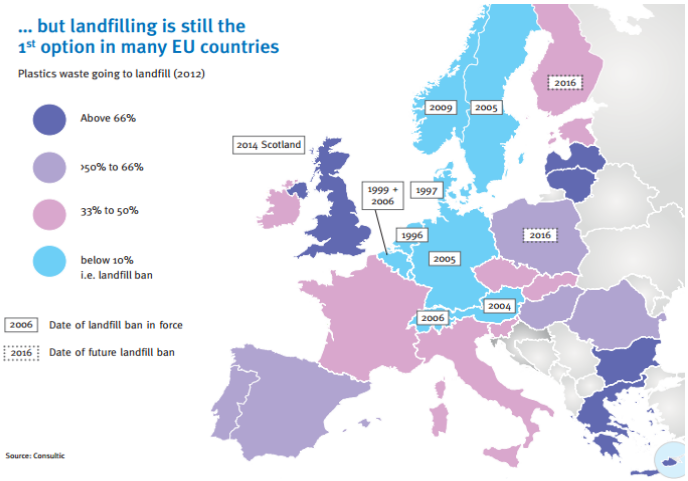


Figure 4. Relation of recovery level and ban imposed. Source: Plastics Europe.5

Another direct aspect are **eco-labels** this is a voluntary method of environmental performance certification and labelling that is practised around the world. An "ecolabel" is

[2] *WO9601149A1. 1996; CN203620716U 2014; Weima Maschb GMBH. DE102012006650A1 2012; WO2004016356A1*

[3] *http://www.innovation-procurement.org/*

[4] *OECD The OECD Innovation Strategy: Getting a Head Start on Tomorrow. 2010*

[5] *Plastics Europe. Plastics – The Facts 2014/2015: An analysis of EU plastics production, demand and waste data. 2015*

a label which identifies overall, proven environmental preference of a product or service within a specific product or service category.[6] Other important factor is **citizens'** contribution to waste management, which can be encouraged by educational and awareness campaigns, and the incorporation of incentives (i.e. tax reductions, etc...).

To sum-up, it is concluded that, currently, bulky waste stream has limited opportunities to positively contribute to generate value for the EU society for different reasons (i.e. lack of logistics, lack of stringent legislation, difficulties to find high added-value applications, etc...), being thus, finally landfilled. Moreover, the characteristics of this waste fraction greatly vary depending on the economic, social or geographical situation of every country.

According to this, the existing difficulties in bulky waste management at European level are related to the lack of:

- comparative data and legal framework between different regions,
- cost-effective collection systems easily accessible for the citizen,
- lack of sustainable methods to re-use items in good conditions or a mandatory collection scheme to collect re-usable and non re-usable bulky waste,
- alternative grinding methods that obtain single material fractions at competitive cost and
- to implement valorisation routes for the fractions obtained from bulky waste streams.

4. URBANREC project.

URBANREC project is a European project which started on 1st June 2016 and will finish on 30th November 2019.

The main objective of this project is to implement an eco-innovative and integral bulky waste management system (enhancing prevention and reuse, improving logistics and allowing new waste treatments to obtain high added value recycled products) and demonstrate its effectiveness in different EU regions: Northern, Mediterranean, Eastern and South-eastern areas in Europe, represented in URBANREC by 3 EU-28 countries and Turkey. These countries currently have very different urban waste recycling rates, from around a 70% in Belgium, 25-30% in Spain, 20% in Poland, to less than 5% in Turkey, thus being representatives of the different scenarios at European level for the evaluation of different activities proposed in URBANREC project. The consortium represents the integral bulky waste management urban metabolism approach which will be adapted at any EU area, thanks to the 4 study areas addressed in URBANREC.

[6] *www.globalecolabelling.net/*

URBANREC project **will contribute to encourage re-use and recycling supporting new bulky waste legislation development and incentives to citizens' participation** through educational programs, making special emphasis on the evaluation of recycling patterns vs. factors such as gender, sex, age, location... Eco-labels will be implemented in case studies and IPP/GPP will be supported.

Beyond the state of the art, **URBANREC** project proposes to **adapt and implement laminated cutting technology to bulky waste treatment**. Laminated cutting technology deserves special attention. This technique is developed by ECOFRAG and currently is employed as a novel system for recycling and energy recovery of tyres, cables and other complex products. Advantages of the fragmentation system are: speed of recycling, greater productive capacity, longer lifespan of plat, reduction in the size of plants, clean and differentiated components, greater flexibility in sizes and textures, lower CO_2 emissions due to reduction in energetic consumption (40-50% in energetic cost) and complete reuse of fragmented components. Innovative identification tools (IR or NIR technology) will be assessed within **URBANREC** project to automate the sorting process, reducing the overall costs and improving the homogeneity of collected wastes further.

Additionally, URBANREC project is devoted to **valorise difficult waste fractions obtained from urban bulky waste.** These fractions (foam from mattresses and upholstery, mixed plastics from hard plastics, mixed textiles from mattresses, upholstery, clothes and curtains and wood coming from furniture) rely to the case studies described in detailed in the following points.

Case study 1: PUR foam management. Polyurethane (PU) materials are very complex to recycle, due to its thermoset nature. However, PU waste is mainly composed of very low density foams, thus recycling has become an urgent and important task since its consume has significantly increase in the last years.[7,8] Total production of flexible PU foam in 2013 in the EMEA region -Europe (38% of production), Middle East and Africa- was estimated in 2Mt (around 40 Mm^3), of which 1.6Mt was slabstock and almost 450kt was moulded foam.[9] Currently, these foams are mainly used in furniture and mattresses.

Currently, PU foam wastes management consists of following options: landfill, incineration and recycling. Incineration and landfill are ecological burden for our future generations. The development of efficient recycling processes came into focus in the recent years. The methods of recovery and recycling of PU waste have greatly contributed to improve the overall image regarding the recyclability of PU in recent years[10]. Polyurethane is recycled in two primary ways; mechanical recycling and feedstock recycling (i.e., chemical recycling).

[7] *J. Borda, «Glycolysis of polyurethane foams and elastomers,» Polymer degradation and stability, 2000.*

[8] *K. M. Zia, H. N. Bhatti et I. A. Bhatti, Reactive and Functional Polymers, 2007.*

[9] *Polyurethane Chemicals And Products Ineurope, Middle East & Africa (EMEA), 2014. IAL Consultants, London, UK*

[10] *A. Nikje et Garmarudi, Iranian Polymer Journal, 2010.*

In more detail mechanical recycling processes includes rebounding, regrinding, adhesive pressing and compression moulding. In principal those technologies use flexible foam coming from industrial waste as fillers in mostly low-price application. The chemical recycling has the advantage to build up new high-priced products. In principle the flexible foam is degraded to pre polymeric materials by solvolysis processes such as glycolysis, hydrolysis, pyrolysis and hydrogenation.

Glycolysis of polyurethanes can be economically acceptable, but still requires more development in order to tolerate more contamination in the post-consumer material.[11] Recent research in this area leads to optimism that economically viable chemical recovery processes may be possible. Up to now, polyols created by recycling PU foams are mainly used in the production of new foams in order to promote closed-loop sustainability in the process of foam's manufacturing. After a thorough literature search, we have only found one study reporting a possible use of the glycolysis mixtures of PU elastomeric wastes as urethane type universal adhesives.[12] The glycolysis mixture can be used without side products and, thus, a complete recycling of the polyurethane scrap can be achieved. The resulting adhesive provided good bonding strength to wood, metals, plastics, glass, ceramics, and leather. Advances in this area could have the potential to decrease costs and waste while improving the environmental print.

To sum up, post-industrial polyurethane foam waste is reused through mechanical or chemical methods already established. **However flexible foam coming from post-consumer (urban waste) is not reused ending up in landfills**. In this case, the challenge is related to polyurethane streams that are complex products with inhomogeneous composition and to design product with high-added value to market uptake. **URBANREC project aims to adapt and improve the current rebonding process for the manufacturing of mattress base support layers**. Moreover, a **chemical recycling process (glycolysis) will be investigated and optimized** in lab scale before and collateral to the industrial up-scaling. Polyols obtained through these chemical processes will be used to formulate **adhesives** that will be used to join the different mattress layers and **new foams**. In this way, waste materials coming for end of life mattresses turn into raw materials for mattress manufacturing, under a circular economy approach. Additionally, these products (adhesives, foams and rebonded foam) could be employed in other markets such as urban furniture components.

[11] *RAMPF, «Life ENV/D/000398 - Large scale polyurethane recycling,» 2004.*

[12] *J. Borda, A. Racz et M. ZsugaJournal of Adhesion Science and Technology, 2012.*

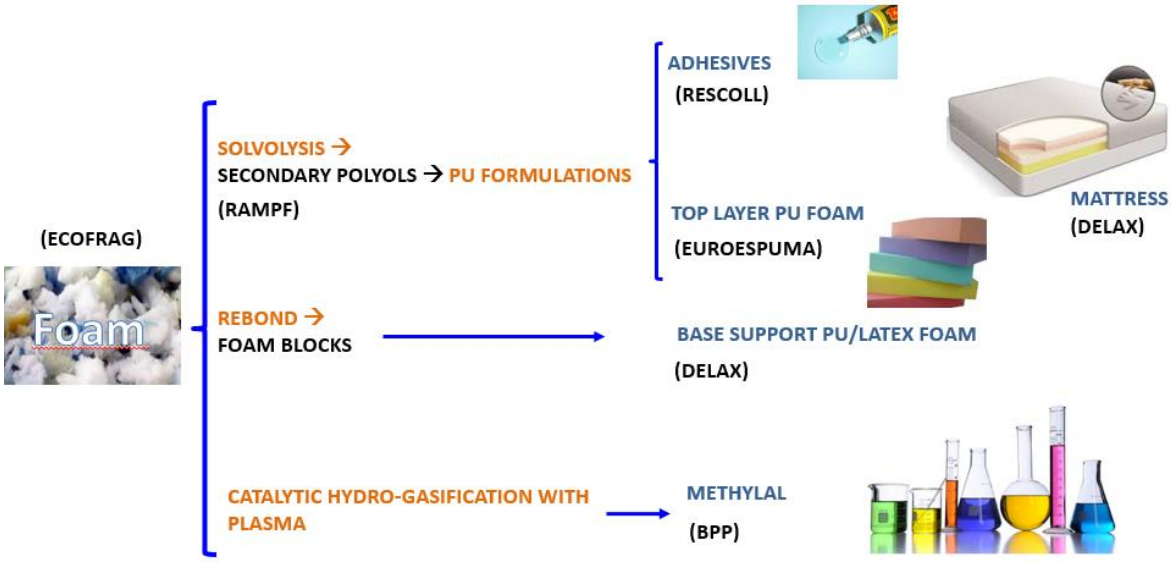


Figure 5. URBANREC valorization route for foam waste coming from bulky waste.

Case study 2: Mixed Textile waste management. EU consumers discard 5.8 Mt of textiles every year.[13] Only a smaller fraction: 1.5 Mt or 25 % of these post-consumer textiles are being recycled. Especially clothing wastes are collected by charities and industrial enterprises, sorted and valorised largely by reusing (mainly third-world countries) or as cleaning cloth according to quality level. Clothing of lower quality as well as part of the industrial textile wastes are to some extent unravelled and the recovered fibres are mostly used in production of non-woven and needlefelts. The remaining 4.3 Mt of textiles wastes -including textile wastes form bulky materials such as mattresses or furniture- goes to landfill or is burnt in municipal waste incinerators.[14]

This vast yearly amount of wastes offers a much higher potential for revalorisation than its present usage. After the improved separation process proposed at **URBANREC** project, all recovered fractions should be valorised to its maximum extent. At present already a range of end uses for the recycled fibres are available; amongst others technical and isolation felts used in automotive, mattresses, carpets underlays, agro and geotextile. The market for recycled fibres seems to be over-saturated already, leading to low prices and limited valorisation potentials of the recycling activities. When recovered textiles from bulky wastes are offering a new large volume source of recycled fibres, then it will be essential that novel applications routes are created to obtain an economical viable situation.[15] URBANREC aims to explore several routes for recycled fibre treatment to

[13] *http://ec.europa.eu/research/growth/gcc/projects/recycling-textiles*

[14] *http://ec.europa.eu/eurostat/statistics-explained/index.php/Waste_statistics*

[15] *Ernst Worrell, Markus Reuter, Handbook of recycling, Elsevier, 2014*

obtain felts from mixed textiles by fibre air lay technology to develop Novel applications: needlefelts to apply in the mattress sector and production of fibre reinforced composites. Additionally, the short fibre fractions of recycled fibres could be used in combination with recycled PP or PE or even PVC for the so called wood plastic composites (WPC) that are representing a growing market segment and are explained in detail below in Case study 3.

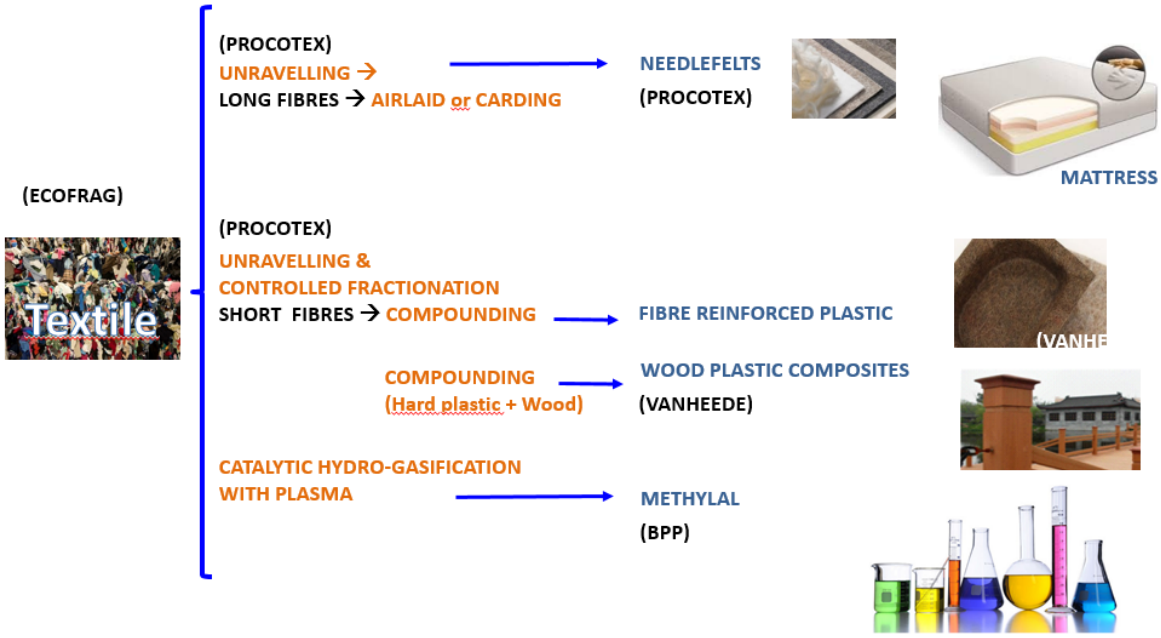


Figure 6. URBANREC valorization route for textile waste coming from bulky waste.

Case study 3: Mixed Hard plastics and wood waste management. Hard plastics include bottles, food packaging, trays, film, bags, cups, bubble wrap, furniture, and toys and can be found in large quantities in civic amenity sites. Currently, it ends up in landfilling due to their diversity of composition and origins (furniture, toys, etc.) and consequently in their chemical composition (PET, PP, ABS) being extremely difficult to recycle. Based on this, two different approaches are proposed within **URBANREC** project; wood plastic composites (WPC) and Catalytic Hydro-Gasification with Plasma (CHGP).

Wood Plastic Composites (WPC) is a hybrid material composed initially of natural wood and plastic behaving like wood using conventional woodworking tools. This material is extremely moisture-resistant and WPC are already widespread in outdoor use for decking, cladding, park benches, etc. There is also a growing market for potential indoor uses such as door frames, trim and furniture. Plastic materials generally used in the application of WPC[16] are PE, PP, PVC and ABS along with wood fibres. Saw dust from fibres like pulp,

[16] *www.ktron.com/industries_served/plastics/woodplastic.cfm*

peanut and bamboo are mixed with plastics by melt compounding. After mixing, they are extruded in thick profiles or moulded by injection machines. URBANREC project aims to use wood, mixed textiles and mixed hard plastic obtained from bulky waste in combination with virgin thermoplastics fractions to manufacture WPC for urban furniture.

Finally, URBANREC aims to adapt catalytic hidro-gasification with plasma technology (CHGP) to waste coming from bulky waste (mainly wood and hard plastic but also foam and textiles) to obtain chemicals (e.g. methylal) as raw material for added value chemicals and fuel to energy recovery.

Chemicals through **CHGP** is an innovative technology commercially available provided by partner BPP for biomass and other homogeneous materials. It has been demonstrated that this is profitable to produce electricity and chemical, being highly efficiency (66% higher compared with other ones) and high yield (up to 80%). P201330032 is a patent to treat biomass.

This technology allows treating raw materials, making it a clean syngas suitable for delivery to the electric utility, and/or a synthesis gas unit to be converted in a chemical product: 60 Mt of plastics prevented from landfill, equivalent to over 750 million barrels of oil.

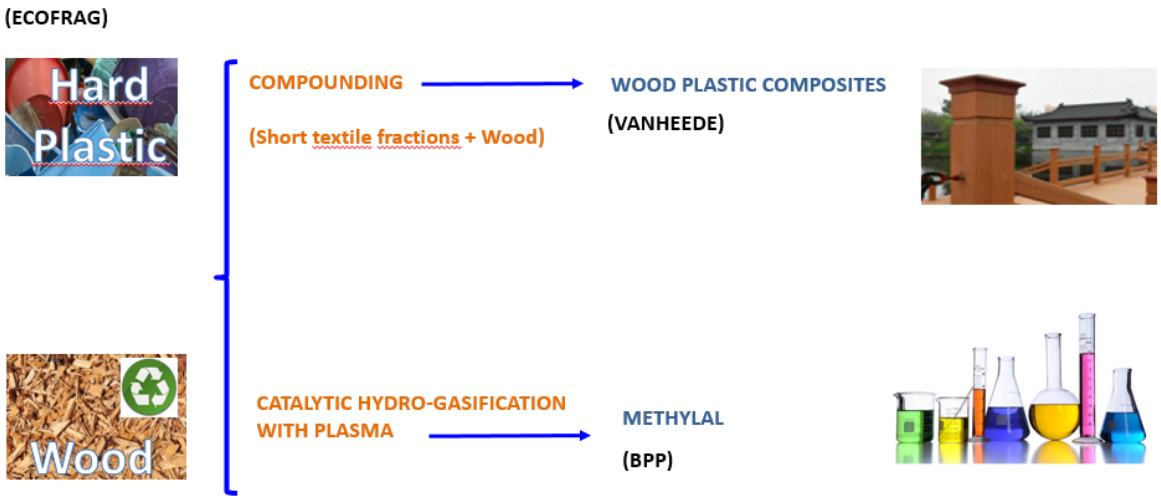


Figure 7. URBANREC valorization route for wood and hard plastic waste coming from bulky waste.

5. URBANREC project partners

URBANREC project partners represent the whole bulky waste value chain, ensuring the success of the project and its subsequent implementation at EU level. URBANREC consortium has a well-balanced composition (21 partners, from 7 countries, being 5 RO, 7 SMEs, 2 Large IND, and 7 OTHER). It brings together a wealth of expertise and resources within the areas of global bulky waste management. This value chain approach pulls the critical mass of complimentary resources that will enable the URBANREC project to

achieve its targeted organizational, technological, industrial, and societal breakthroughs and ensure commercial success.

RO Partners (AIMPLAS, ICT, CENTEXBEL, IOŚ-PIB and IYTE) have the necessary research expertise and will provide support to the SME partners to achieve their objectives; SME partners (IZNAB, ECOFRAG, BPP, RESCOLL, PROCOTEX, EUROSPUMA and DELAX) and Large IND partners (RAMPF, VANHEEDE) will provide the fundamental knowledge, technologies and expertise required to achieve the project objectives, as their activities within the project are fully in line with their own core business and research strategies; Moreover, public urban amenity sites from the 2 selected regions (IMOG, CONSORCIO) together with the correspondent local authorities from the 4 countries (OVAM, DV, The capital city of Warsaw-Municipal Waste Management Department, BORNOVA) will interact and implement the innovative waste management routes described in URBANREC and will give inputs to legislators concerning bulky waste management in the selected regions, providing a platform for further regulation and exploitation throughout EU related industries and to support the continued success of the project. OTHER partner, ACR+, an international technical network gathering about 90 members covering more than 1000 local and regional authorities active in the field of waste management, will provide essential support in data collection, as well as in communication and dissemination activities of the project. The consortium is committed to the project and is capable of achieving the objectives and exploiting the results. URBANREC project do not forget a key player: the citizens. Their participation in the management of bulky waste, delivering them in an appropriate way, allows further optimization of recovery.

6. Conclusions.

In conclusion, URBANREC aims:

From technical point of view:

- to improve the logistics – implementing collection and reuse,
- to define separation and disassembling processes of bulky waste - implementing advanced techniques such as fragmentation (3D cut),
- to promote innovative valorization routes.
- to implement new technologies (i.e. electronic cards, app, customer portal, reuse, etc.)

From social points of view:

- actions to involve citizens in bulky waste management
- to implement ECOLABELS.
- to carry out educational programs for 12.000 citizens in the province of Valencia.
- to develop new economic instruments, in the province of Valencia, to reward the citizens that make a proper bulky waste disposal, 1.000 citizens.

- to come up with concrete recommendations for the improvement of the European legislation and bulky waste management.

7. Acknowledgments.

URBANREC project is an European project which proposal was submitted to Call H2020-WASTE-2015, “A resource to recycle, reuse and recover raw materials”, Topic WASTE-6a-2015 “Eco-innovative solutions” and has received funding from the European Union’s **Horizon 2020 research and innovation programme under grant agreement nº 690103.**