Project Number: LIFE14 ENV/IT/001050 – LIFE ECO-PULPLAST

TECHNOLOGY ANALYSIS REPORT

Document Control Record

LIFE ECO-PULPLAST Doc. Type/ No. / Title	Deliverable / D02 / Technology analysis report
Action	A1: Technology update and detailed design of demonstration site
Date/ Version	30/11/2015 / v. 1.0 13/05/2016 / v. 1.1 29/07/2016 / v. 1.2
Document responsible	SELENE
Authors	Simone Giangrandi (Lucense), Francesca Paoli (Selene), Camillo Cardelli (Selene)
Contributions	All partners
Updates	V2 in blue; V3 in green

TABLE OF CONTENTS

1. Introduction

The LIFE ECO-PULPLAST project aims at demonstrating the possibility to recycle pulper waste – the industrial waste of paper mills that use recovered paper -, by implementing and testing a prototype line to recover pulper waste and reuse it in the manufacturing of new plastic pallets.

Today, 54% of the European paper industry's raw material comes from recovered paper and board, mostly for the production of paper for industrial use. Though the transformation chain of the recovered paper is highly optimised, recovered paper contains a share of materials that cannot be reused and are discarded, constituting the pulper waste. The Lucca paper district alone produces 100.000 ton/year of pulper waste, currently disposed in landifill and to incinerators, with significant and no more sustainable environmental and economic impacts.

The main idea behind this project is to produce plastic pallets to be reused by the same paper district that generates the material waste in the first place, creating a local Circular Economy and reducing the environmental impact due to the current management and disposal of pulper waste.

2. Action A1: Technology update and detailed design of demonstration site and scope of deliverable D02

In the latest years, new technologies have arisen to threat and recycle mixed plastics with increasingly better physical/mechanical properties. Prior the LIFE ECO-PULPLAST start, project partners have conducted preliminary studies and tests to identify a promising technology for the recycling of pulper waste in the manufacturing of new plastic compounds and products.

Ample knowledge and expertise was gained by the project partners and in particular by SELENE and LUCENSE, on the following technological aspects:

- Physical and chemical composition of pulper waste from different paper mills belonging to the Lucca Paper District;
- Development of new compounds made of mixed plastic wastes, including a pre-feasibility study at laboratory scale with the use of pulper waste, which has given promising results.
- Processing of mixed plastics to produce new secondary materials for the plastic industry.

Thanks to this know-how, a number of innovative and flexible solutions were identified, addressing the specificities of pulper waste material. The identified solutions can be divided in three main process phases:

- pre-treatment of pulper waste, to reduce the water content and remove metal and other impurities;
- a main central phase including shredder and mixer machines, densifier, etc.;
- an injection moulding machine to produce plastic pallets, with innovative solutions, such as an homogenizator and a degassing system.

Before proceeding with the final detailed design of the demonstration site, at the start of the project, an update of the technology and a review of the identified solutions was performed.

The technology update was not only based on improved 'internal' experience and competences of the project partners, but also considered new findings from other companies operating on the recycling of mixed plastics, with similar or alternative approaches that might have arisen meanwhile. The review also took into account possible economic, social and legislative changes that might have an influence in the some specific designing choices.

Furthermore, a quantitative assessment of productivity, costs and energy consumption data was also included in the update, in view of the following application at prototype and industrial scale. This assessment is included as a pre-feasibility analysis in the business plan for a plant at full industrial scale, foreseen in Action B4.

Based on the analysis and tests reported in this document, the second part of the action (months 4-6) will produce the detailed design of the demonstration site and the prototype line. The prototype line will then be used in category actions B to perform a sound evaluation of the adopted technology and solutions at industrial scale and will allow the replicability of the results at a larger industrial scale. Cost and energy efficient solutions will be adopted whenever possible.

3. Technology update and analysis

3.1. General description

The activity was conducted via desk analysis, meetings with companies in the waste treatment and plastic sectors, tests and analyses at laboratory scale and at industrial plants. The work included both technical an economic evaluations of the different solutions.

Four main distinct by correlated aspects were investigated:

- pre-treatment;
- central phase, including mixing, shredding, densifier, etc.;
- injection moulding;
- end products (market, legislation, patents, etc.).

Activities conducted on all these aspects are described in the next sessions.

3.2. Pre-treatment

One of the key ideas behind the technology to be demonstrated in the project was to limit the pre-treatment phase of the pulper waste material as much as possible, including only a drying section and the removal of the main impurities (metal, aluminum, etc.).

Concerning drying and shredding machines, no significant technology updates were present, as compared to what reported in the technical description of the project.

The drying section is necessary to reduce pulper waste's level of humidity, between 25% and 45% depending on the paper mill of origin. The drying section needs to have a flexible design, in order to adapt to different input conditions. Moreover, pulper waste contains a certain level of metal and other impurities, mostly iron and aluminium, in the order of 1-2%. The size of these impurities may vary sensibly and reach sizes up to few centimetres. For a reuse of pulper waste, it is crucial that most metal impurities are removed during the process and thereby a two-stage demetallization and deferrization step is included in the current design. The presence of such impurities would in fact be critical aspect both at the injection moulding machine, where it could damage or reduce the durability of some components, and in the end products.

On the contrary, the presence of some degree of cellulose impurities can be accepted with the required adaptation to the injection moulding machine and by adding specific additives to guarantee the required characteristics to the end product.

Nonetheless, the presence of significant levels of impurities (cellulose and textile fibers, wood, rubber), increases the moisture retained by the material and affects its physical/mechanical properties, thereby reducing the amount of pulper waste can be used in the compounds.

For this reason, during the first months of the project, an update of innovative technologies to partially remove cellulose content. More in specific, the following different approaches were considered:

- A technology for dry cleaning;
- Three different lines of separation and washing of plastic materials.

All systems require a primary shredder to reduce the homogenize the sizes of materials composing pulper waste.

The first one is based on centrifuges with both gravimetric and dimensional separation. In this way, both cellulose content and water amount can be reduced approximately by half. The whole process is simple and low-energy consuming and does not require the use of additional water.

The other two systems are based on:

- a water Trommel, used to separate small size contaminants;
- an horizontal centrifuge, based on mechanical friction combined with the use of a big quantity of water, to wash high contaminated medium or big flakes;
- a flotation tank, to settle and separate ground plastic materials by density, with a double discharge system for both floating and sinking material.

This approach can guarantee a higher removal of impurities, with the final material contaminated with few percent (< 5%) of cellulose, wood and textile. The above mentioned cleaning phases can be repeated and alternated with refined shredding in order to achieve a higher level of purity of plastic materials (up to 98-99%). The drawbacks of this system are higher costs and the necessity for a water treatment.

In order to optimize its effectiveness and efficiency, each of these machines needs specific designs and adjustments according to the waste material treated and the desired output specifications.

In addition to a technical evaluation, an economic assessment of the different solutions was carried out, in order to estimate the overall cost per ton of treated material. The economic assessment took into account, in addition to others, the following main aspects:

- Investment costs;
- Productivity: pulper waste treated per time unit;
- Operating costs, including personnel, energy and water consumption;
- Possible reuse in the paper making process of the separated cellulose fibres, which would represent an additional added value to the project;
- Disposal costs of residual waste.

Figure 1: Details of pulper waste after dry-cleaning

3.3. Central phase of treatment

The material coming from the pre-treatment (mixed plastics with some level of cellulose and other impurities, with a water content of approximately 15-25%), undergoes additional treatments, before it can enter the injection moulding machine.

These additional treatments include further, more refined, shredding, mixing with additives and other mixed plastics from waste material and a homogenising phase.

The mixed plastics flakes so produced can directly feed the moulding machine or undergo an additional densification/pelletizing/granulation steps.

While granulation is a very energy consuming process, which is not suitable for the current application and is not in line with the project approach and objectives, a densification phase could be introduced to provide better material properties (density, size, dryness, etc.). At the same time, the densification could include plastics mixing and homogenising (thereby substituting these separate steps).

Two different options for mixed plastics densification, with presence of impurities, were evaluated:

- a “light densification” process: reduction of water content from 25-30% to 5-10% and significant reduction of volume but almost no plasticisation of milled plastics;
- a “heavy densification” process, where water content reduces from 30-50% to few percent. The outcome material is almost completely plasticized and homogeneized. This step is very similar to extrusion, but it is less energy consuming and it is possible with a very wide range of water content and plastic quality.

More standard densification processes, already well-known, were also evaluated but of less interest for the project. This activity included meetings with producers, visits to operating machineries and technical and economic evaluation of the semi-finished products.

The heavy densification process looks very promising and flexible and will be further investigated, in order to evaluate if it can be adopted for the prototype line to be demonstrated during the project. It could, in fact, guarantee a more efficient moulding of plastic pallets, as it provides a milled plastic compound immediately suitable for direct injection.

It looks also suitable to add, to the mixed plastics, other ingredients like fillers (calcium carbonate or talc) and/or vegetable fibres (wood flour), in order to improve quality consistency of densified plastic.

Hereafter, a couple of pictures taken during test trials are reported, concerning a machine for plastic densification and the densified plastic material coming from pre-treated pulper.

Figure 2: Plastic densification process (left) and densified plastic material made of pulper waste (right)

3.4. Injection moulding

Concerning the injection moulding process, two different technologies to produce the final plastic pallet, were preliminarily screened and tested, in order to evaluate alternatives or slightly different solutions to those already assessed and described in the project.

In particular, these two technologies were evaluated with respect to their capacity to process plastic materials with a significant level of water content and impurities.

Both technologies include some kind of homogenizer and one has a degassing system, necessary to better distribute the residual impurities and to address the formation of vapour and gas during moulding.

The same identical lot of raw material, obtained by densification equipment of the pre-treated pulper, was delivered to both injection moulding companies.

Here below a comparative summary of pre-evaluated technologies is reported:

	Option A	**Option B**
Type of process	Low pressure injection moulding	Low pressure injection moulding
Processing temperature	180-200°C	160-180°C
Injection pressure	150-200 bars	50-60 bars
Raw material quality	Well plasticized homogeneous plastic	Just dried milled plastic (To be double checked)
Degassing	Yes	No
Homogenizer	Yes	Yes
Additional pre-drying	Yes	Yes

Both tests were successful in terms of capacity of producing plastic products starting from the material provided, composed of treated pulper waste. While Option A currently works at a higher industrial level and productivity, Option B has shown a higher flexibility to accept input materials with lower characteristics.

The products realized will be mechanically tested and evaluated during the next months of the project.

Also in this case, in addition to a technical evaluation, an economic assessment of the different injection moulding machines was carried out, in order to estimate the overall cost per pallet produced. The economic assessment is strongly influenced by the following parameters:

- Investment costs
- Line productivity: number of pallets per time unit;
- Amount of pulper waste usable in the compound;
- Operational costs, including energy.

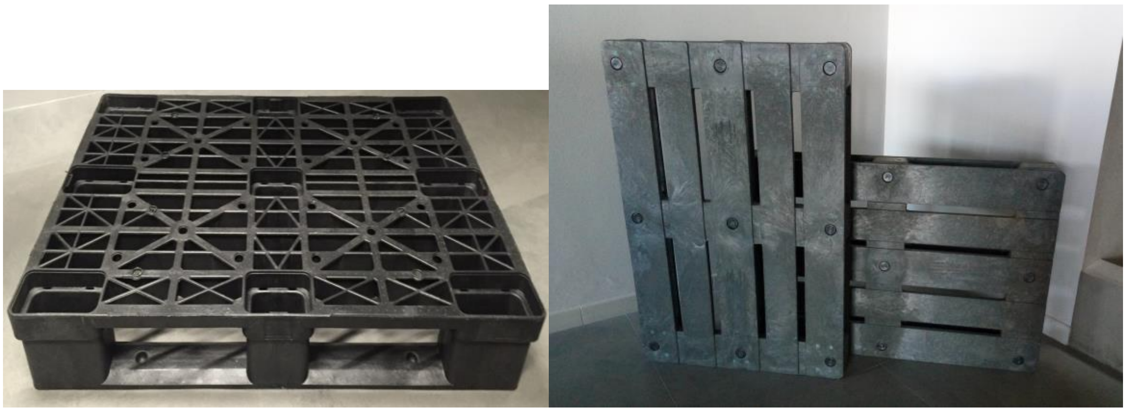

Figure 3: Examples of test pallets produced with pulper waste.

4. Conclusions

The technology update, conducted during the first three months of the project within Action A1, was extremely useful to identify and evaluate new technological solutions arisen during the course of the past year.

These solutions were evaluated in comparison to the one described in the project proposal, with the purpose to select the optimum choices to implemented in the prototype line that will be realized during the LIFE ECO-PULPLAST project. The technology update was conducted with the longer-term vision of realising a plant at full industrial scale, based on the results of the demonstration conducted during the project on the prototype line. The different solution were thereby evaluated and tested according to their performances in terms of productivity, costs, energy consumption, etc.

In particular, three different process phases were investigated:

- Pre-treament, with wet and dry removal of impurities and cellulose fibres from the pulper waste;
- Light and heavy densification process, to homogenise and densify the material, as well as to reduce the water content;
- Injection moulding, for producing large objects with thick walls and in particular plastic eco-pallets.

The results of the activity, summarised in this deliverable, will be used as starting point for the second part of Action A1, months 4 to 6, aiming at realizing the accurate design of the prototype line and the demonstration site, Deliverable D03 due at of February 2016.