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Dissemination Level		
PU	Public	√
PP	Restricted to other programme participants (including the Commission	
RE	Restricted to a group specified by the consortium (including the	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Contents

1 Introduction

This report describes the demonstrator part realised in the BRIGIT project to validate the potentiality of the new biocomposite developed.

The application has been developed for transport sector and in particular in truck field (figure 1) and coach field (figure 2).

Specific testing activities, according to the automotive standards, have been performed to validate the application based on the new biocomposite.

Figure 1. Field of application in the truck area - IVECO Eurocargo.

Figure 2. Field of application in the coach area – New Solaris Urbino12.

Environmental aspects such recyclability of the new material have been considered and here described.

2 Demonstrator part 1: Internal pillar cover

A component in the interior of a truck cabin hasbeen identified as case study to demonstrate the BRIGIT project development.

It is an interior front pillar cover of Eurocargo truck by IVECO, shown in figure 3.

Figure 3. Case study selected: interior front pillar cover of Eurocargo IVECO.

The component selected is characterized by a 3D geometry including some geometrical features allow its assembling in the body of the cabin. The normal production component is manufactured by thermo-compression forming and it is made of phenolic polymer reinforced by 60% fabric fibers.

The thickness of the part is approximately 4,5mm. The dimension and the geometry is shown in figure 4.

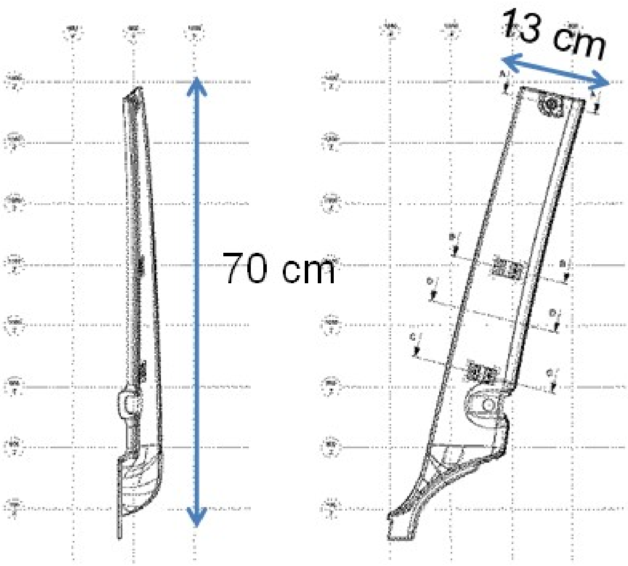

Figure 4. Drawing of interior front pillar cover of Eurocargo IVECO.

2.1 Material

The part has been produced using the followingcomposite layerstructure:

Formulation: F/B/F/B/F/C/F/B/F/B/F (11 layers)

where:

- B=the blend, (PHB/PBS(40/60)+25% FR)
- F=flax fibres (Woven flax fabric 50/52 with FR, Sd= 316g/m^2)
- C=cork,(corecorkNL11, 2mm thickness, FR treatment, d=16 kg/m^3)

An aesthetic TNT (Textile Non-Textile) has been added to provide good appearance to the part that is a visible element in the truck cabin.

2.2 Component

The component produced is shown in figure 5.

Figure 5. Front pillar cover for truck realised using new developed Brigit material.

2.3 Part testing

The interior components for trucks have the requirement to maintain their function at temperatures ranging from -30° C to 105° C and relative humidity levels ranging from 0% to 100%. They shall not show any signs of functional and appearance degradation when exposed to these temperature conditions throughout the vehicle's design life.

For interior components recommended verification tests for environmental resistance (aging) are given by internal standards. In particular the BRIGIT demonstrator has been subjected to the following tests:

- Thermal cycle
- Heat age exposure
- Humidity ageing exposure

The componenthas been evaluated post test to determine its ability to meet the defined acceptance criteria: appearance and functions (dimensionality).

For appearance no deformations, breaks, splits, swellings, alteration of any aesthetic finishing or other defects are allowed.

For functionality:

- Efforts measurements shall fall within specified tolerances.
- There shall be no squeaking, creaking, or negative change in sound quality.

Finally fire resistance test are done to guarantee the safety in the truck cabin.

Thermal cycle

The component does not show any dimensional instability, loss of function or surface degradation (or leakage of polymer through the aesthetic fabric due to changes in temperatures and humidity. The component is exposed to the conditions shown in table 1. The cycle is repeated 4 times, for a total of 96 hours.

Table 1– Thermal cycle exposure

Environment	Time (hours)
In humidity (92% ± 3%) at 40° C± 2°C	8
In high temperature 90° C environment, 105° C ± 2°C surface temperature	8
In cold temperature -30° ± 2° C	8

Temperatures of the upper surface are controlled by the placement of thermocouples in various locations as identified in figure 6.

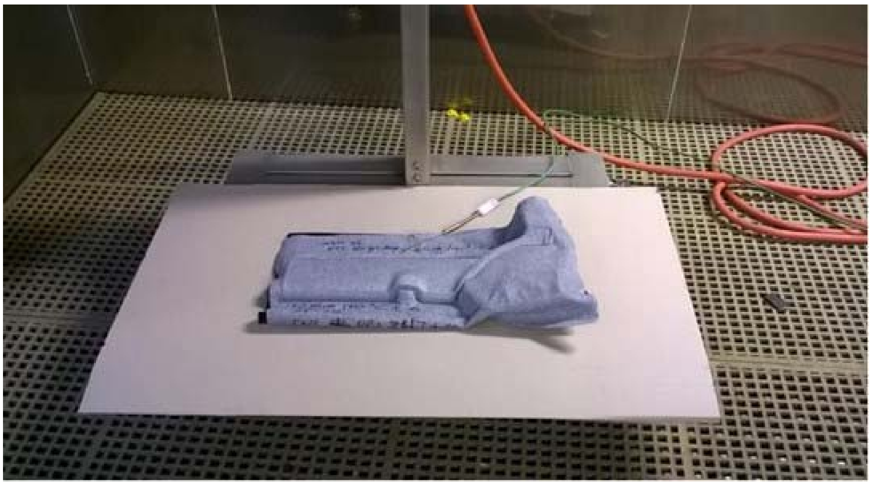

Figure 6. Component positioned in climatic chamber. Thermocouples to the upper surface of each test sample have been applied.

Heat age exposure

The component is exposed to 90°C (185° F) cabin temperature for 7 days (168 hours). Heat lamp loading is applied in such a way that region the entire upper surface of the component maintains a surface temperature of 105° C± 2°C. A force draft recirculation heating chamber is used with a spot heating unit like an infrared lamp above the test sample.

After the test no deformation is detected.

Humidity ageing exposure

The component is exposed at 40°C temperature and 92% ± 3 % relative humidity for 240 hours.

Every 24 hours the sample under test is evaluated for any aesthetical degradation including but not limited to, warpage, sagging, delamination or gloss change.

The component does not show any signs of warpage when exposed to heat and humidity.

Fire test

The flammability of Brigit panels was assessed according to the standard UL94 horizontal flammability (HB), and according to the internal procedure of FCA (standard FMVSS302).

The panels were classified as “self-extinguishing” according to the UL94 as the speed of flame spread was < 40 mm/minute for samples with thicknesses between 3 and 13 mm. In our case the flame didn’t reach the first mark so the speed of flame spread couldn’t be measured and was considered to be 0m/min.

In addition, Brigit panels were classified as “fire resistant” according to the standard FMVSS302, as the flame barely affected the panel after the test (see figure 7).

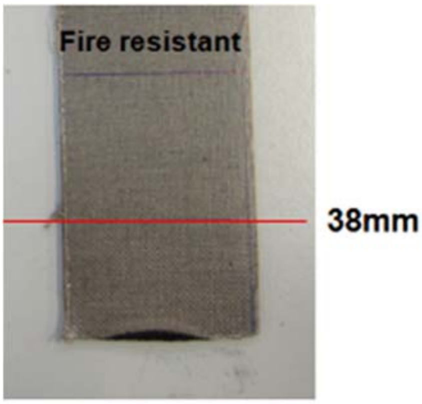

Figure 7. Results of internal flammability test over sandwich panels following the internal procedure of Fiat according to FMVSS302 standard.

3 Demonstrator part 2: Interior sidewall panels

Two parts in the interior of a coach have been identified as case study to demonstrate the BRIGIT project development. They are interior sidewall panels addressed to the New Solaris Urbino12 coach as shown in figure 8.

Figure 8. Case study selected: two interior sidewall panels of New Solaris Urbino 12.

Currently used component is 2,5mm thick, made of self-supporting material consisting of layers of kraft paper impregnated with thermosetting resins and an outer layer – on one or both sides – of decorative paper impregnated with aminoplastic resins. All is bonded together by means of high pressure (9MPa) and heat (150˚C). It comes in sheets 1300x3050mm that later are cut and fitted in the bus.

3.1 Material

The part has been produced using the following layer structure:

Formulation: F/B/F/F/B/F/C/F/B/F/F/B/F (11 layers)

where:

- B=the blend, (PHB/PBS(40/60)+25% FR)
- F=flax fibres (Woven flax fabric 50/52 with FR, Sd= 316g/m^2)
- C=cork,(corecorkNL11, 2mm thickness, FR treatment, d=16 kg/m^3)

3.2 Component

The component produced is shown in figure 9.

Figure 9. Front pillar cover for truck realised using new developed Brigit material.

3.3 Part testing

The main goal of the testing activity has been to verify it the Brigit material can replace the panels that are currently used in coaches. With a view to checking the whole treatment cycle of panels the following tests have been analyzed:

- Tooling test
- Adhesives test
- Aggressive test

Tooling test

The tooling test was devoted to assess if tools which are commonly used in coaches' factory are beneficial to be used when working with Brigit panels (for example cutting with jigsaw, cutting with circular saw etc.). The activities included in this tests are presented on the figures below:

Figure 10. Tooling test – using fretsaw.

Figure 11. Tooling test – using hole saw.

Figure 12. Tooling test – using saw.

Figure 13. Tooling test – using table saw.

All the experiments have demonstrated the possibility to working the panels using current methods and techniques.

Adhesive test

The chemical composition of Brigit panel coating is different than coating which is currently used in factory. This implies the necessity of examining which adhesives are the most suitable as far as sticking of Brigit panels is concerned.

The activities which are presented on the pictures below refers to adhesives test using SikaBond-T52 which proved to be the most suitable when sticking Brigit panels.

This process was preceded by covering the panel surface with the primer (Sika Primer – 215). Sika Remover 208 is a solvent based cleaner for removing traces of uncured adhesives or sealants from application tools or from soiled wood floors. The aim of that step was to improve an adhesive properties of the panel surface.

Figure 14. Adhesives tests primer (left) and adhesive (right) application.

Figure 15. Adhesives tests - panel sticking.

Aggressive test

The bus usually tends to get dirty during the manufacturing process. There are some chemicals enabling to clean the bus precisely before client's approval. The chemicals included in the tests are as follows:

- Nitro - a mixture of organic solvents;
- Degreaser – degreaser;
- Window cleaner;
- Sika remover – 208.

The results of aggressive chemicals resistance test can be observed on Figure 16.

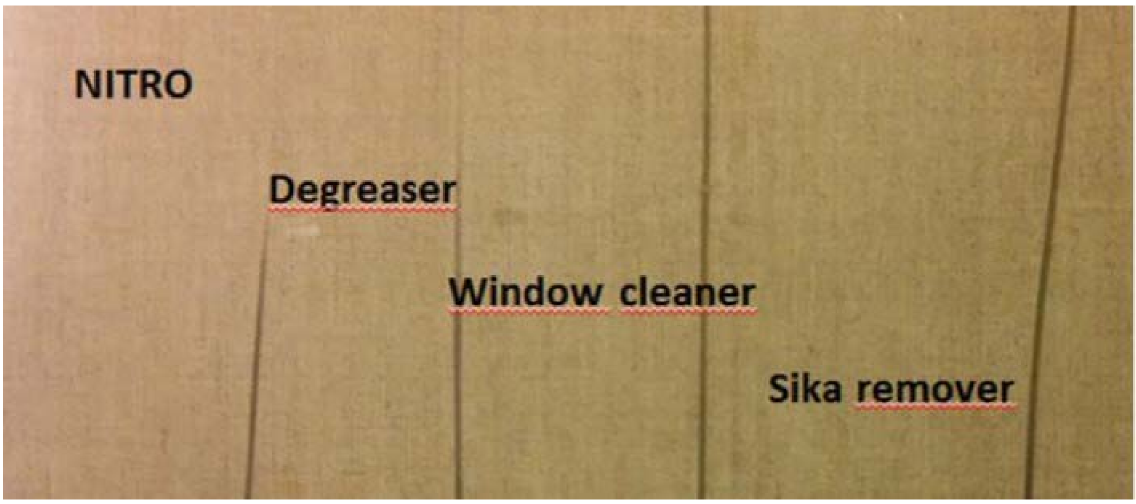

Figure 16. Aggressive tests results.

The results of the test implicate that none of the chemicals used caused damage on the external surface of the panel.

4 Technical data sheets.

Different panel structures were developed within the project, mainly changing the PHB to PBS ratio in the blend from 60/40 to 40/60, the number of layers in the structure 13 - 11 and the addition of a mineral filler. In the following tables the material data sheets of different combinations are shown for reference values.

Table 2 – Panel TDS: Blend composition PHB/PBS(60/40)+25wt%FR (13 layers)

Panel structure	**F/B layer ratio**	**Blend thickness (µm)**	**Cork thickness (mm)**	**Panel final Thickness (mm)**
F/B/F/F/B/F/C/F/B/F/F/B/F	2:1	450 - 500	2	3.535±0.075

Formulation: PHB/PBS (60/40)+25wt%FR		
Property	**Value**	**Standard**
Flexural modulus (MPa)	5160 ± 926	UNE-EN ISO 178 (September 2011).
Flexural strength (MPa)	74.6± 3.0	UNE-EN ISO 178 (September 2011).
Deflection at flexural strength (mm)	8.1 ± 0.8	UNE-EN ISO 178 (September 2011).
Charpy Unnotched impact strength (KJ/m^2)	47 ± 4	UNE-EN ISO 179-1 (April 2011)
Heat deflection temperature, HDTmethod B (0.45MPa) (ºC)	113.4 ± 0.5	UNE-EN ISO 75-2 (January 2005)
UL 94 horizontal burning Classification	HB	UL94 (July 1997).
Speed of flame spread (mm/min)	0	
Bulk density (kg/m^3)	1327 ± 29	Mass / Volume
Water absorption (%)	7.7 ± 0.1	UNE-EN ISO 62 (October 2008)

Table 3 – Panel TDS: Blend composition PHB/PBS(40/60)+25wt%FR. (13 layers)

Panel structure	**F/B layer ratio**	**Blend thickness (µm)**	**Cork thickness (mm)**	**Panel final Thickness (mm)**
F/B/F/F/B/F/C/F/B/F/F/B/F	2:1	450 - 500	2	3.535±0.075

Formulation: PHB/PBS (40/60)+25wt%FR		
Property	**Value**	**Standard**
Flexural modulus (MPa)	4610 ± 328	UNE-EN ISO 178 (September 2011).
Flexural strength (MPa)	65.2± 2.5	UNE-EN ISO 178 (September 2011).
Deflection at flexural strength (mm)	6.0 ± 0.3	UNE-EN ISO 178 (September 2011).
Charpy Unnotched impact strength (KJ/m^2)	55 ± 7	UNE-EN ISO 179-1 (April 2011)
Heat deflection temperature, HDTmethod B (0.45MPa) (ºC)	111.5 ± 0.2	UNE-EN ISO 75-2 (January 2005)
UL 94 horizontal burning Classification	HB	UL94 (July 1997).
Speed of flame spread (mm/min)	0	
Bulk density (kg/m^3)	1317 ± 49	Mass / Volume
Water absorption (%)	6.7 ± 1.1	UNE-EN ISO 62 (October 2008)

Table 4 – Panel TDS: Blend composition PHB//PBS(40/60)+25wt%FR (11 layers, industrial panel).

Panel structure	F/B layer ratio	Blend thickness (μm)	Cork thickness (mm)	Panel final Thickness (mm)
F/B/F/B/F/C/F/B/F/B/F	3:2	700	2	4.445±0.11

Formulation: PHB/PBS (40/60)+25wt%FR

Property	Value	Standard
Flexural modulus (MPa)	6110 ± 420	UNE-EN ISO 178 (September 2011).
Flexural strength (MPa)	78.1± 2.3	UNE-EN ISO 178 (September 2011).
Deflection at flexural strength (mm)	5.7 ± 0.2	UNE-EN ISO 178 (September 2011).
Charpy Unnotched impact strength (KJ/m^2)	15 ± 1	UNE-EN ISO 179-1 (April 2011)
Heat deflection temperature, HDTmethod B (0.45MPa) (ºC)	120.0 ± 0.7	UNE-EN ISO 75-2 (January 2005)
UL 94 horizontal burning Classification	HB	UL94 (July 1997).
Speed of flame spread (mm/min)	0	
Bulk density (kg/m^3)	1280 ± 26	Mass / Volume
Water absorption (%)	4.31 ± 0.05	UNE-EN ISO 62 (October 2008)

Table 5 – Panel TDS: Blend composition PHB//PBS(40/60)+20wt%FR+10wt% mineral filler (13 layers).

Panel structure	F/B layer ratio	Blend thickness (μm)	Cork thickness (mm)	Panel final Thickness (mm)
F/B/F/F/B/F/C/F/B/F/F/B/F	2:1	450 - 500	2	3.747±0.031

Formulation: PHB/PBS (40/60)+20wt%FR+10wt%Mineral filler

Property	Value	Standard
Flexural modulus (MPa)	6110 ± 420	UNE-EN ISO 178 (September 2011).
Flexural strength (MPa)	70.9± 2.0	UNE-EN ISO 178 (September 2011).
Deflection at flexural strength (mm)	7.9 ± 0.5	UNE-EN ISO 178 (September 2011).
Charpy Unnotched impact strength (KJ/m^2)	50 ± 4	UNE-EN ISO 179-1 (April 2011)
Heat deflection temperature, HDTmethod B (0.45MPa) (ºC)	114.3 ± 1.3	UNE-EN ISO 75-2 (January 2005)
UL 94 horizontal burning Classification	HB	UL94 (July 1997).
Speed of flame spread (mm/min)	0	
Bulk density (kg/m^3)	1292 ± 19	Mass / Volume
Water absorption (%)	9.26 ± 0.5	UNE-EN ISO 62 (October 2008)

Table 6 – Panel TDS: Blend composition / PBS(40/60)+20wt%FR+10wt% mineral filler (11 layers).

Panel structure	F/B layer ratio	Blend thickness (μm)	Cork thickness (mm)	Panel final Thickness (mm)
F/B/F/B/F/C/F/B/F/B/F	3:2	450 - 500	2	3.258±0.036

Formulation: PHB/PBS (40/60)+20wt%FR+10wt%Mineral filler		
Property	**Value**	**Standard**
Flexural modulus (MPa)	5280 ± 370	UNE-EN ISO 178 (September 2011).
Flexural strength (MPa)	75.1± 2.3	UNE-EN ISO 178 (September 2011).
Deflection at flexural strength (mm)	7.2 ± 0.5	UNE-EN ISO 178 (September 2011).
Charpy Unnotched impact strength (KJ/m^2)	39 ± 3	UNE-EN ISO 179-1 (April 2011)
Heat deflection temperature, HDTmethod B (0.45MPa) (ºC)	112.0 ± 0.1	UNE-EN ISO 75-2 (January 2005)
UL 94 horizontal burning Classification	HB	UL94 (July 1997).
Speed of flame spread (mm/min)	0	
Bulk density (kg/m^3)	1302 ± 19	Mass / Volume
Water absorption (%)	7.2 ± 0.4	UNE-EN ISO 62 (October 2008)

Table 7 – Panel TDS: Blend composition PHB/PBS(40/60)+20wt%FR+10wt% mineral filler (11 layers, industrial panel).

Panel structure	F/B layer ratio	Blend thickness (μm)	Cork thickness (mm)	Panel final Thickness (mm)
F/B/F/B/F/C/F/B/F/B/F	3:2	700	2	3.773±0.082

Formulation: PHB/PBS (40/60)+20wt%FR+10wt%Mineral filler		
Property	**Value**	**Standard**
Flexural modulus (MPa)	5360 ± 210	UNE-EN ISO 178 (September 2011).
Flexural strength (MPa)	70.2± 2.1	UNE-EN ISO 178 (September 2011).
Deflection at flexural strength (mm)	7.6 ± 0.5	UNE-EN ISO 178 (September 2011).
Charpy Unnotched impact strength (KJ/m^2)	30 ± 3	UNE-EN ISO 179-1 (April 2011)
Heat deflection temperature, HDTmethod B (0.45MPa) (ºC)	129.3 ± 1.1	UNE-EN ISO 75-2 (January 2005)
UL 94 horizontal burning Classification	HB	UL94 (July 1997).
Speed of flame spread (mm/min)	0	
Bulk density (kg/m^3)	1300	Mass / Volume
Water absorption (%)	7.6 ± 0.2	UNE-EN ISO 62 (October 2008)

5 Environmental issue: recyclability, compostability and LCA

5.1 Recyclability

Initially, the aim was to recycle the final sandwich panel from which the cover pillar is made. However, in order to re-incorporate the recycled material into the production process the panels must be ground, and after grinding the bulk density of the material decreased drastically making difficult the handling and dosing of the material to the production process again (see figure 17).

Figure 17. Left: sandwich panel. Right: Ground sandwich panel.

For those reasons it was decided to re-use the scrap produced during the industrial extrusion process in which the polymer laminates that are used afterwards in the production of sandwich panels are made. The chosen fraction was the edge trim of the laminates generated during the industrial process. The selected fraction was properly ground and re-used in the extrusion process (see figure 18).

Figure 18. Laminate, trimmed edges of the laminate and scrap.

Up to a 30wt% of recycled laminate was reincorporated in the extrusion process with success. Only some adjustments were made to adjust the production process to the lower viscosity of the polymer blend see figure 19.

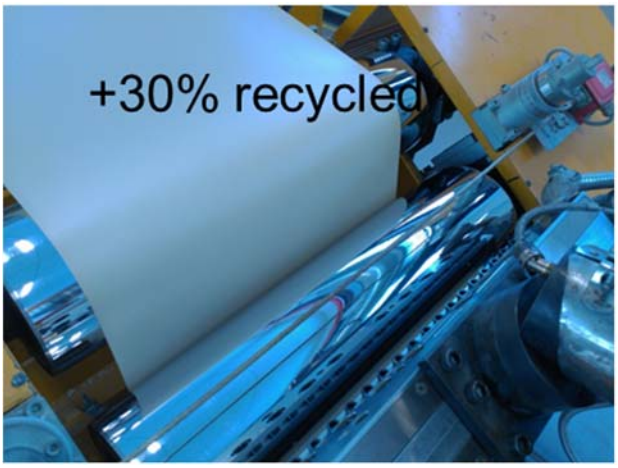

Figure 19.Extrusion of laminate with 30wt% of recycled blend.

The extruded foils with 30wt% recycled material were used to obtain sandwich panels by compression moulding.

The results showed an improvement in the stiffness and strength of the panel with the addition of a 30wt% of recycled material, whereas the impact strength was reduced. These effects were explained by a better fibre wetting and adhesion to the core material in the case of the incorporation of recycled blend due to its lower viscosity. Therefore the scrap from the extrusion process can be recycled in the same process to produce new panels.

5.2 Compostability

Concerning the end of life of the sandwich panels and the scrap produced from the production line, the option of compostability was considered due to the green nature of the main components of the panel. There the compostability of grinded Brigit sandwich panels was evaluated according the standard EN 13432: 2000. According this standard the chemical characteristics, biodegradability, and disintegration of the material during biological treatment, and effect of the biological treatment in the quality of the final compost were assessed.

The panels meet all criteria to be considered compostable; chemical characteristics, biodegradability, and quality of the compost, with the exception of the disintegration test. However, the disintegrability must be enhanced by reducing the thickness or size (for instance, grinding and sieving to the required size) of the products before composting.

5.3 Life Cycle Analysis (LCA)

The measurement of the environmental impact for the production of the 3D sandwich panels via Life Cycle Analysis (LCA) is one of the tasks of the BRIGIT project. The Agricultural University of Athens (AUA) has been assigned to accomplish this objective. The final report on LCA which will contain all the details regarding the environmental footprint of the new panels will be submitted at the end of the project. However, the latest results of the LCA, regarding the new panels, have indicated low environmental “burden” directly comparable to already existent conventional panels. The boundaries of the studied system are shown in Figure 20 where all the material balances and energy requirements for all working packages have been collected throughout the duration of the project with the collaboration of all partners. This is “a gate to gate” approach where the initiation of the system starts with the detoxification of the SSL, continuous with the production of PHB and PBS, goes through the production of fire resistant biocompounds and ends up with the compounding of the material and the formation of the 3-D panels.

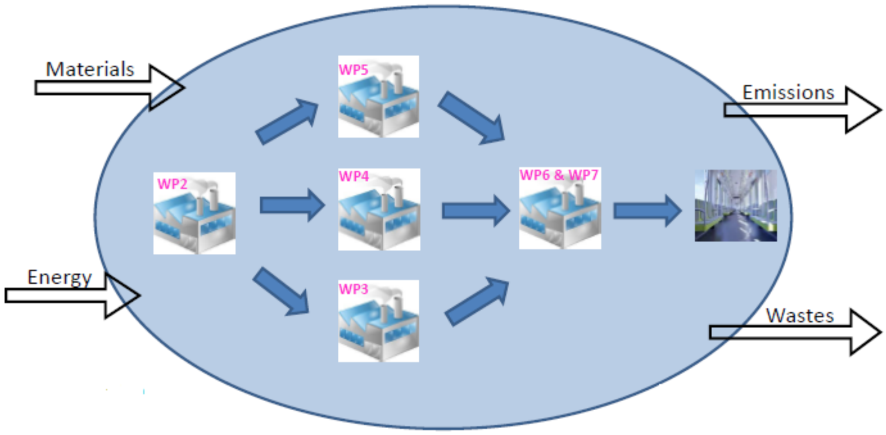

Figure 20 System’s boundaries for the conducted LCA

Results from the conducted LCA are shown in Figure 21 where three different environmental indicators have been measured: (i) the global warming potential (GWP) in kg-CO_2 Eq., (ii) the abiotic depletion in (MJ) and (iii) the primary energy demand in (MJ) for all WPs. The abiotic resource depletion includes depletion of non-renewable resources, i.e. fossil fuels, metals and minerals while the GWP is calculated as a sum of emissions of the greenhouse gases (CO_2, N_2O, CH_4 and VOCs). Most important WPs affecting the environmental performance of the produced 3D panels are WP2 (related to the digestion of wood and removal of potential inhibitors for fermentation processes) and WP6 (production of biocompounds and transformation into 3D panels). Other WP’s related with the production of PHB, succinic acid, PBS and flame retardants (WP3, WP4 and WP5) showed lower contribution to the environmental impact of the panels.

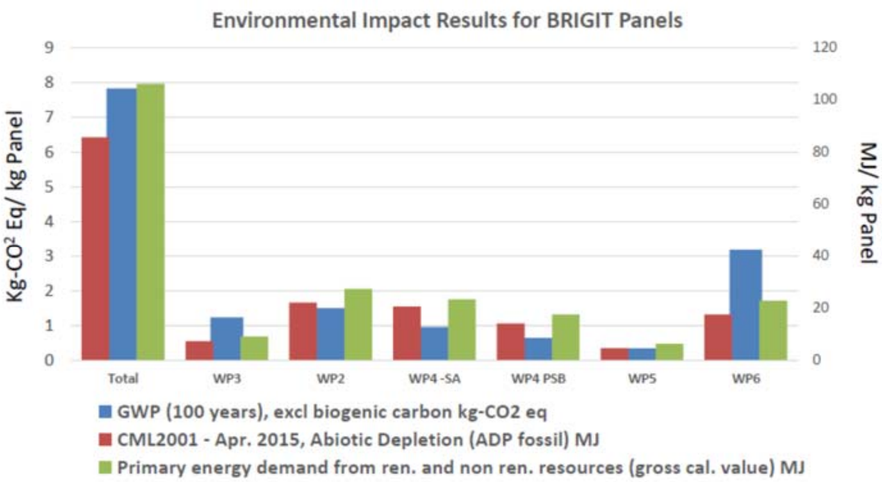

Figure 21 Measurement of the environmental indicators for the different WPs.

The environmental impact of the 3D panels is also compared with the ones that will be replaced. Conventional panels made from phenolic resins, glass fibres and Nomex honeycomb core will be replaced from fire proof biopolymer sheets, natural fibres (flax) and cork. The BRIGIT panels illustrate, at the moment, similar environmental impact with the conventional panels. However, a significant reduction is expected to take place as final experiments conducted from the industrial partners of the project aiming to construct panels with fewer layers (9 or 7 layers). This reduction will affect the weight of the panel and hence its environmental performance during its use.

6 Conclusion

BRIGIT project has demonstrated the possibility to use a laminated sheet fully based on biomaterials in the production of thermoformed complex parts for trucks and machined flat panels for coaches. The ageing tests (thermal cycle, heat and humidity, ageing exposure) and fire resistance on components made by the new biocomposite have shown positive results. Considering the result of the test the material can be enlarge its field of application beyond trucks and busses and be conveniently used in all transport sectors such us for example cars.

From the environmental point of view the Brigit material has been assessed to provide benefit compared to traditional (thermoset) materials, for example; recyclability of scrap generated in the production process, and biodegradability of the final panels.

The environmental impact of the 3D panels compared with the ones that will be replaced have similar environmental impact. However, a significant reduction is expected for panels made out of fewer layers (9 or 7 layers).

For further details on the BRIGIT development is possible to contact the project coordinator AIMPLAS.