



## FINAL REPORT

**Grant Agreement number:** 314294

**Project acronym:** LIMOWOOD

**Project title:** *Advanced wood plastic composites material for the production of bath furniture resistant to moisture and free of coatings.*

**Funding Scheme:** FP7-SME-2011-1

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**Name, title and organisation of the scientific representative of the project's coordinator<sup>1</sup>:**

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<sup>2</sup> The home page of the website should contain the generic European flag and the FP7 logo which are available in electronic format at the Europa website (logo of the European flag: [http://europa.eu/abc/symbols/emblem/index\\_en.htm](http://europa.eu/abc/symbols/emblem/index_en.htm) ; logo of the 7th

# Table of Contents

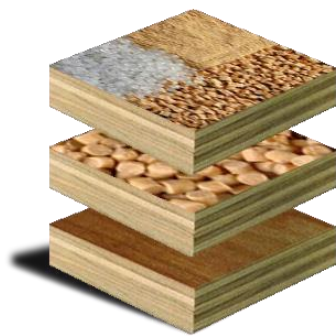
|                                                                                                                                                                                                                      |    |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|
| 1. – FINAL PUBLISHABLE SUMMARY REPORT .....                                                                                                                                                                          | 3  |
| 1.1. Executive summary .....                                                                                                                                                                                         | 3  |
| 1.2. Summary description of the project context and the main objectives .....                                                                                                                                        | 4  |
| 1.3. Please provide a description of the main S & T results/foregrounds .....                                                                                                                                        | 7  |
| 1.4. Description of the potential impact (including the socio-economic impact and the wider societal implications of the project so far) and the main dissemination activities and the exploitation of results. .... | 10 |
| 1.5. Please provide the public website address (if applicable), as well as relevant contact details.....                                                                                                             | 13 |

## 1. – FINAL PUBLISHABLE SUMMARY REPORT

Next pages contain the publishable summary as described in the guidance notes on project reporting for the Seventh Framework Programme.

### 1.1. Executive summary

A novel wood plastic composite (WPC) prepared with wastes from wood and plastic industries has been developed. The Limowood composite is applicable in the manufacture of panels for bath and kitchen furniture which combines a higher resistance to fire, humidity and fungi, and avoids the use of coatings and chemical adhesives. The knowledge acquired during the research process will reach also other sectors, since the demand of WPC is increasing all over the world for a wide variety of uses.



The research leading to these results has received funding from the European Community's Seventh Framework Programme managed by REA-Research Executive Agency under the grant agreement n° 314294. The European project Limowood has developed a novel material with very competitive manufacturing costs, which successfully covers the existing gap between the furniture made in solid wood and the most used low-end furniture with low costs but also very limited performance and quality.

After two years of work, the results of the research have been enormously satisfactory. During this period of time, the formulation and processing of the material have been developed. The composite has achieved high performance in the fire tests, humidity and fungal attack resistance. Moreover, the formulated material stands out for its ease of use during the tooling, sawing and assembly.

Limowood material includes a considerable percentage of recycled material from the wood and plastic industries, which contributes to the environmental sustainability of the sector. Its high performance to fire lets replacement of PVC products. Moreover, it is a versatile solution which can be used in extrusion processes as well as in the preparation of panels by compression.

All these characteristics turn this element into a very innovative one perfectly adequate to the current standards for the furniture and lamination manufacture, and enhance the commitment of the wooden industry with more ecological and healthier solutions complying with European Directives. The expectations for the commercialization of the product are very high since the market directly or indirectly target is the contract segment (hospitality, offices, education, work and cultural spaces, etc.).

## 1.2. Summary description of the project context and the main objectives

### PROJECT OVERVIEW

LIMOWOOD is a project originated from a group of SMEs as a response to the problems existing in the furniture industry. The proposed solution is to use a wood plastic composite (WPC) for the production of indoor furniture. WPCs are currently used for the production of outdoor components floor coverings (which are suitable for terraces, walkways, landing stages) decking, railing and many more applications.

LIMOWOOD material will be mainly used in the **manufacturing of bathroom furniture and other markets such as contract segment**. The contract segment is set up by: hospitality (hotels, resorts, bars, restaurants), retail (traditional and large distribution, food, non-food); offices (public and private working spaces and facilities); education and culture (schools, universities, museums and arts galleries); hospitals and clinical institutes; auditoriums, theaters and cinemas; airports and marine. Furthermore, results and knowledge acquired during the project can be used in the **wood plastic composite market** in sectors other than the furniture manufacturing as the demand of wood plastic composites (WPC) is increasing worldwide.

LIMOWOOD material will be produced at a cost competitive price, having a good finishing and eliminating the need for the application of treatments that would release VOC. This environmental concern is nowadays a crucial point for the European furniture industry, as this sector is directly affected by several European directives, such as those related to industrial emissions or to waste management<sup>3</sup>:

- ✓ **Directive 2008/1/EC or IPPC Directive on Integrated Pollution Prevention and Control.** Operators of industrial installations covered by Annex I of the Directive are required to obtain an authorization (environmental permit) from the authorities in EU countries. "Installations for the surface treatment of substances, objects or products using organic solvents, in particular for dressing, printing, coating, degreasing, waterproofing, sizing, painting, cleaning or impregnating, with a consumption capacity of more than 150 kg per hour or more than 200 tons per year" are in Annex I of IPPC Directive.
- ✓ **Directive 1999/13/EC or Volatile organic compounds Solvents Emissions Directive:** regulates the limitation of emissions of volatile organic compounds (VOC) due to the use of organic solvents in certain activities and installations. Wood and wood-based materials need to be protected against external agents that can have a harmful effect on them. This is usually done by the application of paints and varnishes. Although environmentally friendly products have been developed, the use of solvents is common practice. This solvents release Volatile Organic Compounds (VOCs) that are chemicals of great concern. When emitted into the atmosphere, they contribute to ozone depletion and global warming. Some may also be toxic in high concentrations in the workplace<sup>4</sup>. Among a great number

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<sup>3</sup> Environmental aspects of the furniture industry, EC, October 2010.

[http://ec.europa.eu/enterprise/sectors/furniture/environment/index\\_en.htm](http://ec.europa.eu/enterprise/sectors/furniture/environment/index_en.htm)

<sup>4</sup> Fact Sheet: Eco-Efficiency in the Wood Furniture Industry, Dalhousie University, 2008.

of VOCs, formaldehyde is recognized as one of the major causes of degrading indoor air quality<sup>5, 6</sup>.

- **Directive 2008/98/EC establishing a legal framework for the treatment of waste:** Furniture production generates waste (e.g. waste from wood processing and the production of panels and furniture, wood preservation wastes and wastes from the use of paints and varnishes). Despite efforts to reduce waste at source, a degree of wood waste is unavoidable when making furniture. Landfill disposal is still a major player accounting for 22% of waste<sup>7</sup>. This will result in generation of methane and carbon dioxide due to biodegradation of wood as well as potential leakage of noxious liquid produced in landfill sites and affecting the aquatic environment. There exist alternatives in order to recycle produced wood waste such as combustion with heat recovery, production of animal bedding, fuel briquettes and pellets, composting or use as raw material for wood-based panels. However, due to the predominance of SMEs in the furniture sector, the cost of transport required to send waste for processing is much higher than sending it to landfills.

The investment required to transform SME's manufacture of bathroom furniture processes for the use of alternative coatings will usually be too high for their subsistence. As an example, it has been estimated by European Commission consultants that the cost of implementing VOC regulations to the furniture sector would be the equivalent from 5.4 % to 10.6 % of the sector turnover in one year. Thus, an alternative solution that will help these SMEs to comply with restrictive European directives is highly desired. LIMOWOOD material is postulated as an alternative to the restrictive European legislation.

## **PROJECT OBJECTIVES**

The main scope of the LIMOWOOD project is the development of a **new wood plastic composite (WPC) made of recycled thermoplastic and natural reinforcing particles derived from wood**. This novel WPC has the following features:

- **Higher resistance/density:** Depending on their internal structure, a more resistant panel of reduced weight and thickness can withstand the same load than other panel of lower mechanical resistance.
- **Moisture and fungi resistance:** wood-based panels present low resistance to moisture and fungal attack similar to pure wood as the wood is not effectively protected from external environmental damages.
- **Use of recycled materials:** production of LIMOWOOD employs wood products wastes and recycled thermoplastic



<sup>5</sup> Z. He, Y. Zhang, W. Wei, Building and Environment 47 (2012) 197.

<sup>6</sup> Reduction of formaldehyde exposure in the woodworking industries, CEI-Bois, February 2010.

<sup>7</sup> Wood waste recycling in furniture manufacturing – a good practice guide, BFM Ltd, The Waste and Resources Action Programme, 2003.

resins which are usually disposed of at landfills (see below Legislation and environmental concerns).

- **Cost-competitive**: the production of wood-based panels largely depends on the price and availability of raw wood which as stated above is increasing. Reduction in the amount of wood required or use of recycled wood from wastes enables reducing costs.
- **Fire retardant properties**: the production of panels with fire retardant properties will allow the use of LIMOWOOD product in the manufacturing of furniture for contract segment (hospitality (hotels, resorts, bars, restaurants), retail (traditional and large distribution, food, non- food); offices, etc.

Objectives of the project can be classified in scientific and technological objectives:

**Scientific objectives** are:

- .- To improve the state of the art about the suitability of blend resins, and composite formulations to produce a low cost WPC.
- .- To develop a preparation method to modify wood particles and nanoparticles from cellulose.
- .- To research the compatibility of natural particles and thermoplastic polyester matrix.
- .- To study the behaviour of the wood plastic composite under processing conditions.

Moreover, the **technological objectives** are presented as follow:

- .- The improvement of the strength and thermal resistance and reduction of moisture absorption of natural particles by different treatments.
- .- Manufacture of a wood plastic composite prepared with thermoplastic polyester and natural treated particles. This WPC will be compatible with current available processing methods such as extrusion and injection.
- .- Adequacy to current industrial standards in the sector of furniture manufacturing.

### 1.3. Please provide a description of the main S & T results/foregrounds

The lifespan of LIMOWOOD project has been 24 months, starting on the 1<sup>st</sup> January 2013 and ending on the 31<sup>st</sup> of December 2014. Next, the most remarkable results achieved up to date are presented:

- Modification of wood particles: wood particles from partner BAUR has been modified according to different methods: thermal modification, chemo-thermomechanical treatment, treatment with hydrophobation agents such as ASA (alkenyl succinic anhydride), AKD (alkyl ketener dimer), fatty acids), treatment with EMDI (emulsifiable methylene dyphenyl diisocyanate), parafins.
- Preparation of cellulose particles at nano-scale (size of 150 nm) by emulsion technique.
- Formulation and characterization of wood plastic composites for **profile extrusion** (two compounds has been developed one based on PP /recycled PET and other based on recycled PP: thermal and mechanical properties, scanning electronic microscopy (SEM), water uptake, fungicide and fire resistance tests.
- Formulation and characterization of wood plastic for high pressure lamination panels: thermal and mechanical properties, scanning electronic microscopy (SEM), water uptake, fungicide and fire resistance tests.
- Search of suitable polymer matrices for the development of wood plastic composite (WPC).
- Search of suitable additives for WPCs: coupling agents, lubricant, plasticizers, mineral fillers, flame retardant additives, fungicide agents.
- Design of wood plastic composite (WPC) formulation. Exhaust literature survey (supported with SMEs experience) of components for wood plastic composites: coupling agent, plasticizers, flame retardant additives, mineral fillers, lubricants, fungicides.
- Industrial validation of achieved compounds has been carried out. Different validation trials were carried out:

.- Compounding of composites based on PP/recycled PET for extrusion further of profiles. 700 kg of Limowood compound were prepared.

.- Preparation of wood particles for composites.

.- Compounding of wood plastic composites based on PP/recycled PET for extrusion of profiles by Beologic. 700 kg of Limowood compound were prepared. The compound was manufacture with parameters similar to a current PP/wood compound.

.- Decking profiles extrusion with PP/recycled PET compound. Decking profiles were manufactured in standard conditions. ***According compound and decking manufacturing trials, it can be concluded that the Limowood solution could be compounded at industrial scale.***

.- Preparation of panels by high pressure compression moulding. It was demonstrated that WPC panels can be pressed using a high pressure lamination press. Flame retardant and non-flame retardant panels were pressed.

.-Validation of profiles according to standard. 15534-4:2014 “*Composite made from cellulose-based thermoplastic usually called wood-polymer composites (WPC) or natural fibre composites (NFC). Part 4: Specifications for decking profiles and tiles*”. Limowood decking profiles fulfil this standard. Besides, these profiles present fire retardancy properties (V-O, B2) and anti-fungi properties.

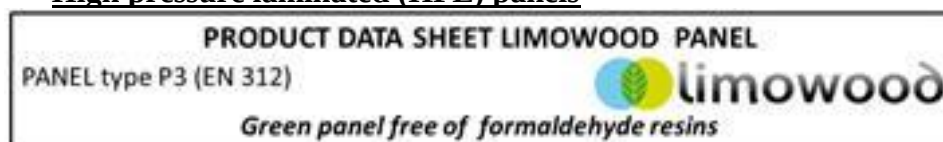
.- Validation of panels according to standard EN 312:2010 “Particleboards. Specifications”.According to test the Limowood panels can be classified as type P3: ***Non load bearing boards for use in humid conditions.***

As a result of the work performed during the project, two different LIMOWOOD materials have been developed depending on its final application. Their specific properties are presented in the technical data sheet tables:

✓ Extruded profiles

| Property                    | Reference Standard     | Value                  |
|-----------------------------|------------------------|------------------------|
| Density                     | EN ISO 1183            | 1.25 g/cm <sup>3</sup> |
| Swelling                    | EN-15534:2014 (144 h)  | 0.5% (≤ 7%)            |
| Boiling                     | EN-15534:2014 (5 h)    | 1.1% (≤ 7%)            |
| Flexural modulus            | EN 310                 | 4300 MPa               |
| Flexural strength           | EN 310                 | 27.4 MPa               |
| Flexural strain             | EN 310                 | 0.78 %                 |
| Izod impact strength        | ISO 179-1:210          | 12.1 kJ/m <sup>2</sup> |
| Heat deflection temperature | EN ISO 75-2            | 76 °C                  |
| Bending (Load 250 N)        | EN-15534:2014          | 2.3 mm                 |
| Fungistatic behavior        | ISO 16869:2001         | 0 – No growth          |
| Single flame source test    | ISO 9773:1998 // UL-94 | V-0                    |
| Reaction to fire            | EN ISO 11925-2         | B2                     |

*The compound employed is based on recycled wood and thermoplastic resins*

✓ High pressure laminated (HPL) panels**Physical-mechanical properties**

| Property                       | Reference standard                | Values                  |
|--------------------------------|-----------------------------------|-------------------------|
| Density                        | EN ISO 1183                       | 1,2 gr/cm <sup>3</sup>  |
| Length swelling                | Boiling test (5 hours, EN 1087-1) | < 0.1%                  |
| Width swelling                 | Boiling test (5 hours, EN 1087-1) | < 0.1%                  |
| Thickness swelling             | Boiling test (5 hours, EN 1087-1) | < 0.1%                  |
| Water absorption               | Boiling test (5 hours, EN 1087-1) | < 3.5%                  |
| Internal bond strength         | EN 319                            | >4 N/mm <sup>2</sup>    |
| Flexural strength              | EN 310                            | >20 N/mm <sup>2</sup>   |
| Flexural modulus of elasticity | EN 310                            | >2000 N/mm <sup>2</sup> |
| Screw withdrawal resistance    | EN 320                            | >200 N/mm               |
| Reaction to fire               | EN ISO 11925-2                    | B2                      |

*The listed values are referred to 8mm average thickness*

#### **1.4. Description of the potential impact (including the socio-economic impact and the wider societal implications of the project so far) and the main dissemination activities and the exploitation of results.**

LIMOWOOD will enter the market by filling the gap between high-standing products made of pure solid wood that have high price (1000-2700 €/m<sup>3</sup>) and require the use of coatings but have good mechanical resistance and the best finish, and low-standing products with very affordable prices (180 €/m<sup>3</sup>) but reduced mechanical properties, durability and resistance to moisture.

The developments presented in this project will enable the participating SMEs to become more competitive in the bathroom furniture, contract segment and wood plastic composite sectors and be able to face current economic, technological, environmental and legislative threats.

They will be providing a high quality material at a cost-effective value (190-200 €/m<sup>3</sup>) and achieving forecasted sales of 64 million € in 5 years during future commercial exploitation of the project's results.

At European level, savings of more than 120 million are estimated after project completion through the contribution of LIMOWOOD to the reduction of imports from outside Europe, reduction of VOCs emissions, reduction of wood waste, creation of new jobs in the industry and social security savings from work-related diseases.

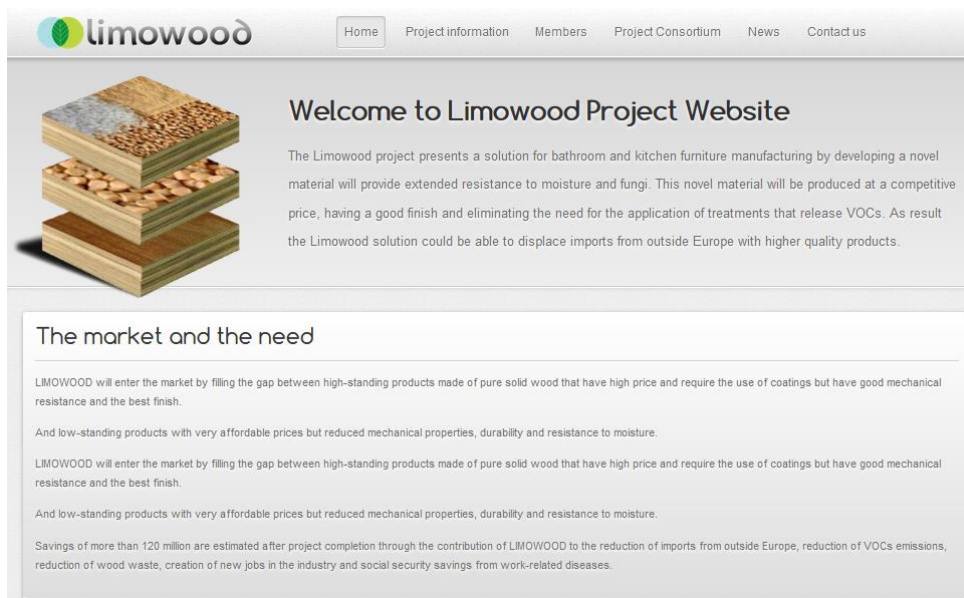
#### **MAIN DISSEMINATION ACTIVITIES**

Dissemination methods selected by the consortium and included in the dissemination plan are the following:

- Internet presence and the generation of a project website
- Preparation of dissemination material such as leaflets, presentations and videos
- Participation in public events such as conferences, seminars, workshops and trade fairs to increase public awareness about the new material
- Publication of press releases in sectorial magazines and digital newspapers
- Contact with potential customers

As explained in deliverable D6.4 *“Final Plan for the Use and Dissemination of Knowledge”*, during the second period the Consortium has performed a large number of dissemination activities, which main references are the following:

- Internet presence and **Project Website**. LIMOWOOD project website ([www.limowoodcomposites.com](http://www.limowoodcomposites.com)) went online in June 2013. It contains information about the project objective, contact data of the partners participating in the Consortium, main results achieved and most relevant dissemination activities.



- Preparation of a **project leaflet** to deliver in fairs, congress and symposium related with the furniture and WPC markets

- Preparation of a **project video** used for dissemination of the results of the project presenting the DEMO activities performed during the manufacture of the LIMOWOOD panels. The video is now available on the project's website and YouTube
- Participation in conferences and trade fairs such as:
  - *AMI's 9th edition of the Wood-Plastic Composites conference, from 25th to 27th of February 2013 in Vienna (Austria)*
  - *6th International wood fibre polymer composites Symposium, 23th- 24th of September 2013 in Biarritz (France)*
  - *K plastic fair 2013 (16-23th October 2013) in Dusseldorf, Germany*
  - *Forum dell'Innovazione del Legno Arredo, FederlegnoArredo, 21<sup>st</sup> November 2013 in Bergamo (Italy).*
  - *5<sup>th</sup> German Wood Plastic Composite (WPC) conference, 10<sup>th</sup>- 11<sup>th</sup> of December 2013 in Berlin.*
  - *5th German Wood Plastic Composite (WPC) conference, 10th- 11th of December 2013 in Berlin.*
  - *10th Congress for Biobased Materials, Natural Fibres and WPC, 24th -25th June 2014 in Stuttgart-Fellbach (Germany)*
  - *Las Vegas Furniture Market, from 27th to 31st July 2014 in Las Vegas (USA)*
  - *Composite Europe, 7th to 9th October 2014, Messe Düsseldorf ( Germany)*
  - *Presentation on "Baumaterialien der Zukunft" – Construction materials of the future, 9th October 2014 in FRAUNHOFER's headquarter in Munich (Germany)*
  - *Fakuma 2014 – the Future of Plastics Processing (from 14 – 18th October 2014), Friedrichshafen (Germany)*
  - *AMI's 10th edition of the Wood-Plastic Composites conference, from 3th to 5th of November 2014 in Vienna (Austria)*
  - *Forum dell'Innovazione del Legno Arredo, FEDERLEGNO ARREDO, 7th November 2014, Udine (Italy)*
- Publication of a press release and articles in following media:
  - *"PLASTICOS MODERNOS" magazine (www.revistaplasticosmodernos.es)*
  - *Sectorial magazines such as MADERA SOSTENIBLE, digital newspaper for the Spanish Wood and furniture sector with more than 19.410 subscribers.*
  - *Spanish digital Newspapers such as EL MUNDO, Spanish national newspaper (digital version), ARAGON LIBERAL, regional newspaper (digital version), HERALDO, regional newspaper (digital version), CINCO DIAS, Spanish national newspaper (digital version), at the Entrepreneur and SME section, INTEREMPRESAS, Spanish national newspaper (digital version)*

- *International websites such as: OpenPR – WORLDWIDE PUBLIC RELATION (digital magazine), PRESS BOX UK (digital magazine), PRESS EXPOSURE (digital magazine)*
- ***CORDIS' research\*eu magazine**. An article about Limowood project results will be published in March in a number dedicated to polymers and composite materials.*
- *General mass media publication, such as a TV reportage on the **Aragón TV channel**, which will be probably broadcasted in the “News” during the month of March 2013, and an interview in **Aragón radio** on the 24/02/2015 about the basics and utility of the Limowood project (mp3 in Spanish language)*

### 1.5. Please provide the public website address (if applicable), as well as relevant contact details.

#### List of participants:

| Participant Legal name                                                | Beneficiary type | Partner Short name | Country |
|-----------------------------------------------------------------------|------------------|--------------------|---------|
| JAVAL S.L.                                                            | SME              | JAVAL              | Spain   |
| Holzwerk Baur GmbH.                                                   | SME              | BAUR               | Germany |
| Beologic n.v.                                                         | SME              | BEO                | Belgium |
| Etablissement Andre Bondet s.a.                                       | SME              | SAB                | France  |
| Fraunhofer-gesellschaft fur foerderung der angewandten forschung e.v. | RTD              | Fraunhofer         | Germany |
| Instituto Tecnológico de Aragón                                       | RTD              | ITA                | Spain   |
| Tecnologías Avanzadas Inspiralia.                                     | RTD              | INSP               | Spain   |



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