# Cascading Recovered Wood (CaReWood)

## FINAL REPORT

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| **Title of the research project** | **Cascading Recovered Wood (CaReWood)** |
| **Coordinator of the project** | Prof. Dr. Klaus Richter |

## BASIC PROJECT DATA

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| **Project period** | 01.06.2014 – 31.05.2017 |
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| **URL of the project** | http://www.carewood.eu |

## FUNDING

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| **Total budget in EUR** | 1 059 100 EUR |
| **Public funding from WoodWisdom-Net Research Programme:** | Total funding granted in EUR by source: |
| Austria<br>Federal Ministry of Agriculture, Forestry, Environment & Water Management (BMLFUW) | 97 500,00 EUR |
| Finland<br>Tekes – the Finnish Funding Agency for Innovation | 90 373,00 EUR |
| France<br>French Environment and Energy Management Agency (ADEME) | 223 232,29 EUR |
| Germany<br>Agency for Renewable Resources (FNR) | 441 170,51 EUR |
| Slovenia<br>Ministry of Education, Science and Sport (MIZS) | 206 824,20 EUR |

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|---|---|---|---|---|---|
| 2014-17 | PhD | M | Privat, François, 1985, 2018 | École Supérieure du Bois | Mark Irle & Christophe Belloncle, École Supérieure du Bois |
| 2014-18 | PhD | M | Risse, Michael, 1986, 2018 | Technical University of Munich | Richter, Klaus, Technical University of Munich |
| 2017 | MSc | M | Rassel, Sebastian, 1987, 2017 | Technical University of Munich | Richter, Klaus, Technical University of Munich |
| 2017 | MSc | F | Mehlan, Diana, 1991, 2017 | Technical University of Munich | Richter, Klaus, Technical University of Munich |
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| 2017 | MSc | M | Salzger, Erwin, -, 2017 | BOKU University | Teischinger, Alfred, BOKU University |

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| 2015 | BSc | M | Slabe, Simon, 1993, 2015 | University of Ljubljana | Humar, Miha University of Ljubljana; Ugovšek, Aleš, M Sora d.d. |
| 2015 | BSc | M | Nučič, Anže, 1994, 2015 | University of Ljubljana | Humar, Miha University of Ljubljana; Ugovšek, Aleš, M Sora d.d. |
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| 2016 | Engineer Diploma | M | Silvestre, Luke, -, 2018 | École Supérieure du Bois | Mark Irle, École Supérieure du Bois |
| 2015 | Engineer Diploma + MSc | M | Bansi, Brice Sidoine, 1990, 2015 | École Supérieure du Bois | Mark Irle, École Supérieure du Bois |
| 2015 | Engineer Diploma | F | Martouzet, Chloé, 1993, 2016 | École Supérieure du Bois | Mark Irle, École Supérieure du Bois |
| 2015 | Engineer Diploma | M | Dreno, Guillaume, 1994, 2017 | École Supérieure du Bois | Mark Irle, École Supérieure du Bois |
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# PROJECT SUMMARY REPORT

The CaReWood project introduces a processing concept for recovered solid timber as a source of clean and reliable wooden products for the European industry. The objective is to develop and evaluate technologies for converting large dimension recovered wood into new, large dimension solid wood semi products. In order to develop and evaluate such a process, questions from various research fields were studied.

The research target of WP 2 had two items: the future development of recovered wood and design for reuse. Based on data from Austria, a model was development which provides the future availability of recovered wood considering the various architectural and technical construction periods and the share of wood used in the building sector in the respective periods. By considering the different architectural periods, the composition and quality of the recovered wood (e.g. wood preservation period from 1960-80) could be analysed. In order to feed the model with specific data, the building stock over the various construction periods and the timber in stock and timber intensity of the shell construction had to be analysed. Parallel to the model, a concept of a “design for recycling” was developed in order to decompose timber structures more easily in the future. The guideline for a design for reuse was focused on wood windows and was validated with the support of the industrial partners.

WP 3 prepares for the discussion whether the reverse logistics for the treatment of recovered wood can potentially be a sustainable and efficient business. To do so, a computer model was developed using MILP and Linear Programming to determine the optimal location and transportation distances and costs for sorting and decontamination sites on country level. The model was implemented in a server based software that offers the user to enter specific parameters on costs, available processing facilities and else in order to identify possible locations sites for new processing plants. The results further express the estimated costs, depending on the entered parameters. The facility sites can be visualized on a map for the studied region. The method was applied for Austria and Slovenia using the MILP approach. Due to the complexity of the model, the MILP was changed into Linear Programming with a metaheuristic approach providing approximated but good enough results.

WP4 investigated if it is technically feasible to process recovered wood into clean long lengths of finger jointed and laminated timbers. WKI and ESB collected recovered wood from waste processing centres and found that 87% of the material was softwood with an average moisture content of 22%. A system capable of differentiating between different wood product types, e.g. solid wood and panel products, and detecting contaminants like preservatives has been developed by partner PTS and RTT Steinert. The CaReWood process uses preservative-free recovered wood sawn it into lamellae which are then planed to give clean, calibrated 15 × 60 mm lamellae. The lamellae can be finger-jointed and face bonded to make beams of almost any dimension. Consequently, it is demonstrated that it is technically possible to make laminated wood products from recovered wood.

The aims of WP5 were to propose criteria for assessing the resource efficiency of cascaded wood products and determine the barriers to cascading along the chain. Resource efficiency criteria were developed and a tool for evaluating resource efficiency was created. Consumer acceptance of cascaded wood was assessed and the value of establishing labelling was evaluated. It was found that cascading provides a means of improving the sustainability of wood use, but correct decision making is required. Business currently see limited possibilities in cascading, but did acknowledge that there were some opportunities. Consumers were generally more positive and would be inclined to purchase resource-efficient wood products, particularly if certified as such. It was concluded that the business case for cascading requires further research, since at present it is difficult to envisage cascading being implemented due to the costs involved in reprocessing and the price and availability of virgin material.

In WP 6, the environmental and economic feasibility of the CaReWood-process was determined by applying Life Cycle Assessment. In close cooperation with WP 3 and 4, the CaReWood process was modeled and LCI and cost data were collected. The environmental impacts of the CaReWood process were compared to alternative treatment options for recovered timber in Europe, which are incineration, landfillig and its use for particle board manufacturing. The results indicate that the CaReWood process is environmentally feasible compared to the alternative treatments. It further offers high potential to create added value from a material currently considered as waste, especially when the recovered wood keeps its low economic value. In cooperation with WP 5, a cascading system was modeled to determine the resource efficiency of multifunctional cascade chains. Results indicate, that wood cascading has a higher resource efficiency than the current use of wood.

## 1.1 Introduction

### 1.1.1 Background

It is predicted that the demand for wood will likely succeed its supply within the next decades. To satisfy the demand, the cascading of wood became a political goal to improve the efficiency of wood utilisation. To develop cascade chains, new recycling concepts are necessary, especially for solid recovered timber, which is currently in Europe either incinerated, landfilled or used in particle board manufacturing. The downside of this is that the high value of solid timber is lost. An alternative approach is to select the larger dimension pieces, clean and then join them together to make solid wood composite timbers. To develop such a recycling concept, several aspects need to be addressed.

### 1.1.2 Objectives

Based on available European and Austrian data, the current building stock, use and flow of wood will be assessed and analysed with respect to the share of wood. Together with data on the development of wood in construction, this allows developing a model to predict the amounts and qualities of recovered wood to be expected in the future. Parallel to this, a system is to be developed to adapt selected wood constructions and wood building components (e.g. wood windows) to the concept of a “design for recycling” in order to decompose timber structures more easily in the future.

In order to analyse whether the reverse logistics of recovered wood is a sustainable and efficient business, a reverse logistic software model was developed. The model should cover the required processes and facilities of wood recycling on country level. While using parameters for the costs and emissions, the model can provide optimal locations for treatment facilities with respect to minimized transportation distances and thus costs and emissions.

For the development of the processing technology, it was necessary to investigate whether or not it is technically feasible to process recovered wood into clean long lengths of finger jointed and laminated timbers. In order to do so, the properties of the respective solid recovered wood will be studied (dimensions, species, moisture content). To detect contaminations such as preservatives or heavy metals, detection technologies will be further developed. Furthermore, it is required to demostrate the processing technologies to clean and manufacture laminated products and finally assess the properties of the resultant products.
With respect to establishing the political and social acceptance of solid wood cascading, one objective is to propose criteria for assessing the resource efficiency of cascaded wood products and assess the resource efficiency of the cascaded use of materials. In order to achieve this, the wood chain will be mapped and the barriers to cascading along the chain need to be identified. Furthermore, the consumer acceptance of cascaded wood will be assessed and the value of establishing labelling will be evaluated.

With respect to the environmental and economic viability of the processing technologies, another objective was to determine the environmental performance of the processing technologies compared to alternative waste treatment options. Furthermore, the costs and benefits of the process are analysed in order to determine its economic viability.

## 1.2 Results and discussion

A model to describe the future availability of recovered wood in Austria has been developed. This model includes the recovery of wood from buildings of different architectural periods to analyse the composition and quality of the recovered wood (e.g. wood preservation period from 1960-1980). In order to feed the model with specific data, the building stock over the various periods of constructions and the timber in stock and timber intensity of the shell construction had to be analysed. The model also considers different average lifetimes of the buildings of the different construction periods. Results show a considerable stock of timber of approx. 32 mio $m^3$ currently stored in Austrian residential buildings. This stock will increase to over 50 mio $m^3$ until 2100. Additionally one has to consider other buildings (e. g. office buildings) and non-construction wood (e.g. windows, flooring), where currently no specific data is available.

Furthermore, a guideline for a design for recycling was developed based on a framework directive of the Association of German Engineers (VDI 2243). The guideline for a design for reuse was focused on wood (-aluminium) windows and was validated with the support of the industrial partners within the consortium.

To optimize the reverse logistics, a complete system using a Mixed-Integer Linear Program (MILP) was modelled. The MILP optimizes the cost function that accounts for building, operation and transportation cost. The model could be used to solve the optimization of reverse logistics for Austria and Slovenia, although the time complexity of MILP is very high. Therefore, MILP is not applicable for countries of a size like Germany of France. Alternatively, a metaheuristic approach was applied to optimize the number and locations of the sorting facilities by replacing the mixed integer part of the model with a k-clustering approach. This leaves the model as a Linear Program more easily to solve. The quicker calculations enable a multiple calculation to compute the optimal k (=number of sorting facilities) to find an approximate solution. The model was implemented in an application that can be used when data for parameters like costs, emissions and available treatment facilities is available. The application returns the optimal locations for new processing facilities on a map and the associated transportation distances, costs and emissions.

Measurements of recovered wood samples obtained from collection centres highlighted a difference in the dispersion of timber cross-sections found in different countries. For example, a large proportion of the recovered wood volume in France was made up of smaller cross-sections and this could have an impact on the optimal design of the processing line. The average moisture content found was 22% and 87% of the collected wastewood was softwood. A system capable of differentiating between different wood product types, e.g. solid wood and panel products, and detecting contaminants like preservatives has been developed. The detection is based on the processing of Near Infrared (NIR) signals. Other contaminations were successfully measured or detected using XRF, GC-FAIMS and LIBS.

For processing recovered wood into new solid and jointed products, the surfaces of recovered wood must be cleaned for aesthetic and technical reasons. Experience in processing the collected recovered wood shows that at least 3 mm should be removed from each face in order to ensure clean faces and consistant cross-sections. The maximum yield possible is 83% if 3 mm is removed from each piece. The resultant products would have non-standard dimensions and are difficult to match for lamination. An alternative is to cut the wood into lamellae. A computer model developed for the project, shows that the optimum lamellae dimensions to be 15×30 $mm^2$, resulting in a yield of 45%. These are relatively small and so a lamellae size of 15x60 $mm^2$ was chosen giving a theoretical yield of 44%. Many hundreds of lamellae have been cut and bonded together during the project. Experiments have shown that recovered wood has similar properties to virgin wood.

A survey conducted in Finland of various industrial stakeholders highlighted that there are competing legislative requirements (increase bioenergy vs recycling society), which does not give a clear message regarding the use of solid wood. This is partly reflected in the inconclusive outcomes of life cycle studies and highlights the need for local solutions. Many respondents to the survey thought that burning for energy is the most valuable use for waste wood, particularly in regions where wood is a large and under-utilised resource and where transport distances are great and labour costs high. A further critical factor was seen to be the additional transportation and processing costs compared to virgin material. Despite this, possible opportunities were seen in specialised products, with trend aware customers and in retail for customers who have time to clean the wood.

A second survey conducted in Finland of final customers indicates that almost three quarters of respondents expressed definite interest in having more recovered wood products on the market and 43% said they would consider buying if the recovered wod products were less expensive than the virgin wood alternative. The results also indicated that consumers are more likely to pay extra for recovered wood furniture (49%) than for windows (33%) or dimensional lumber (26%). For all products there was an increase in the preference for recovered wood with more information, highlighing the need to establish certification for cascaded wood products.

A decision making tool created emphasised the sensitivty of cascading to factors such as the quality and condition of the recovered wood, the location of processing or energy producing facilities.

To determine the environmental feasability of the developed process, a LCA study was conducted. The key drivers to the environmental impacts are the adhesive production as well as the incineration of the contaminated waste. Compared to alternative waste treatment options, the CaReWood-process is an environmentally friendly alternative, although it does not generate the same benefits as the direct incination of the waste wood when it is considered to substitute fossil based energy carriers. However, this result is highly influenced by the choice of the substituted energy mix, which itself highly depends on the geographic scope. In comparison to the use of recovered wood for particle board manufacturing or landfilling, the CaReWood-process is environmentally preferable.
With respect to resource efficiency, the results of the cascade chain show that wood cascading has a higher resource efficiency (46%) compared to the use of primary wood (21%) to generate the same multiple outputs.

Despite the additional costs to process the recovered timber, it is shown that the CaReWood-process is economically viable. The key factors are the price of the recovered timber and the market price for the product. As long as the recovered wood keeps its current market price, the CaReWood-process shows high potential to create added value, especially in comparison with alternative treatment options.

## 1.3 Conclusions

- The availability of “recovered” wood will significantly rise in the future and a strategy for a cascade utilization of recovered wood is needed.
- A guideline for a design for recycling for wooden buildings and products is necessary in order to achieve a more efficient demolishing process and a resource efficient utilization of recovered wood.
- Technically viable laminated wood products can be made from recovered wood.
- Contaminated recovered wood can be detected and separated from clean wood.
- A well-designed processing line should achieve a yield of about 44% of lamellae when processing recovered wood.
- Business currently see limited possibilities but some opportunities are observed.
- Consumers may be more inclined to purchase resource-efficient material, depending on product, particularly if certified or labelled.
- The business case for cascading requires research. At the present time, it is difficult to envisage wide-scale cascading being implemented in some regions due to the low price and availability of virgin material. Conflicting bioenergy policy does not help.
- There is a paucity of data about the condition and dimensions of wood recovered from demolition projects.
- Since the MILP approach does not provide solutions for models of the considered size, the metaheuristic approach developed gives good enough approximated results. The approach is applicable for all capacitated facility location problems, also outside the wood industry.
- The implemented software offers users to specify own parameters describing individual properties of facilities encountered in a particular instance of the problem. Due to such a versatile architecture we can easily swap the underlying solver of our problem.
- The developed process is an environmentally friendly recycling alternative for recovered solid timber across Europe, with a high potential to create added value from material currently considered as low value waste.
- Wood cascading has a higher resource efficiency than the current use of wood.

## 1.4a Capabilities generated by the project

- Calibration samples for contaminate detection systems based on wood flours dosed with known quantities of pollutants.
- Process flow diagrams for transforming recovered wood into laminated wood products
- Physical and mechanical data on the characteristics of recovered wood
- Schumann-Analytics started a library for its GC-FAIMS technique, which will be used also in further projects and applications on waste wood.
- PTS was able to extend their knowledge and experience in the field of recovered paper to the field of recovered wood.
- PTS generated new knowledge on the NIR sensor based quality control and sorting of recovered wood.
- PTS extended its simulation model for the calculation of paper recycling cascades with data on wood recycling.

- M SORA established entirely new waste management, not only for wooden windows. The company is now separating wooden parts of discarded windows from glass and other wastes.
- The results and the new knowledge is incorporated in various lectures in the study programmes of partner universities
- BOKU established a regular information exchange with the University of Technology Vienna, Department for Architecture
- Data gathered on the demolition of a building in Finland has contributed to understanding of the quality and condition of wood that can be obtained from demolition projects and the potential cascading options available for such material.
- Key barriers to the implementation of solid wood cascading in several industrial sectors in the wood processing chain have been identified and certain opportunities identified. This has highlighted the need to urgently consider the business case for wood cascading and determine the conditions required in order to implement industrial scale cascading. To this end a collaboration between AAL and the School of Business at Aalto University has been established and funding obtained to research this topic.
- A preliminary computer-based decision making tool has been created to determine the most resource-efficient option for handling recovered wood.
- Life cycle inventory and economic data gathered as well as the systems modeled form a valuable basis for further and improved studies on wood cascading
- The methodological competence in LCA is further improved
- Strong partnerships between several institutes evolved during the project. Future collaborations are planned.
- The implemented software on reverse logistics can be used for any problem with specific parameters and all types of materials and facilities, also outside the wood industry.
- Abeliums activities resulted in the application of computing and mathematical knowledge to reverse logistics and mathematical modelling in the forest-wood sector. We have developed a pilot construction of information services for transport optimization.
- Although sometimes being challenging, most of the project results are directly applicable to the European forest-wood sector (e. g. reverse logistics model, LCA results, detection technologies).
- Utilization of Open LCA, Life Cycle Assessment software, for shared modelling by different partners
- PhD thesis on “High-value cascade recycling of end-of-life wood products” by François Privat
- PhD thesis on “Resource efficiency and sustainability assessment of recycling recovered solid timber” by Michael Risse
- Process flow diagrams for transforming recovered wood into laminated wood products
- Physical and mechanical data on the characteristics of recovered wood
- Award winning innovative recycled wood products have been developed by MS and the potential for optimal use of recycled wood in new future products has been investigated.

## 1.4b Utilisation of results

The results have already been published in relevant international journals and been presented at various international renowned conferences. Further dissemination for industry members was conducted via presentations of the project results on various fairs, especially at a workshop with industry partners organized LIGNA fair 2017. Several additional publications in e. g. magazines or TV shows were used to communicate the project to a broader non-scientific audience. Further publications are planned from WP 2, 4 and 6 to publish the project results in scientific and technical journal articles.

The next step is to establish a pilot-scale recovered wood processing line in collaboration with one or more companies. A few companies have shown interest in the idea of using recovered solid timber as source for manufacturing their products.

Since policy members put a strong focus on wood cascading, especially with respect to a bio-economy, frequent discussions and exchanges established and collaborations with industrial organizations are planned for the future.

The developed reverse logistics software with an underlying model constitutes a good basis for a sustainable service company, selling the service of optimal positioning the facility based on the customer requirements. The

software can also be used to provide knowledge and consultation to the market. Furthermore the model is versatile enough that legislative institutions can use it to tune the new environment protecting legislation in such a way that the potential investors will still be interested in investing into a wood recycling industry.

## 1.5 Publications and communication

a) Scientific publications

### 1. Articles in international scientific journals with peer review

*Kalcher J, Praxmarer G, Teischinger A (2017): Quantification of future availabilities of recovered wood from Austrian residential buildings. Resources, Conservation and Recycling. 123:143-152.

Mauruschat D, Plinke B, Aderhold J, Gunschera J, Meinlschmidt P, Salthammer T (2016). Application of near-infrared spectroscopy for the fast detection and sorting of wood–plastic composites and waste wood treated with wood preservatives. Wood science and technology 50(2):313-331.

*Sakaguchi D, Takano A, Hughes M (2016). The potential for cascading wood from demolished buildings: the condition of recovered wood through a case study in Finland. International Wood Products Journal, 7(6):137-143. DOI: 10.1080/20426445.2016.1180495

Sandberg D, Kutnar A (2016). Thermally modified timber: recent developments in Europe and North America. Wood and Fiber Science. Lawrence: The Society, 48 (2015 Convention) (1):28-39.

*Irle M, Privat, F, Deroubaix G, Belloncle C (2015). Intelligent recycling of solid wood. Pro Ligno 11(4):14-20.

Mauruschat D, Schumann A, Meinlschmidt P, Gunschera J, Salthammer T (2014). Application of gas chromatography - field asymmetric ion mobility spectrometry (GC-FAIMS) for the detection of organic preservatives in wood. International journal for ion mobility spectrometry 17(1):1-9.

Husgafvel R, Linkosalmi L, Hughes M, Kanerva J, Dahl O (2017). Forest sector circular economy development in Finland: a regional study on sustainability driven competitive advantage and an assessment of the potential for cascading recovered solid wood (under review).

Sakaguchi D, Takano A, Hughes M (2017). The potential for cascading wood from demolished buildings: potential flows and possible applications through a case study in Finland (submitted).

*Risse M, Weber-Blaschke G, Richter K (2017). Resource efficiency of multifunctional wood cascade chains using LCA and exergy analysis, exemplified by a case study for Germany (accepted for publication).

### 2. Articles in international scientific compilation works and international scientific conference proceedings with peer review

Hollstein F, Pigorsch E, Plinke B, Wohllebe M, Meinlschmidt P (2017). NIR-SWIR-Hyperspectral-Imaging supported surface analysis for the recovery of waste wood. 3rd Conference on Optical Characterization of Materials - OCM 2017, 22.-23.03.2017 Karlsruhe, Germany.

Irle M, Privat F, Deroubaix G, Belloncle C (2017). Increasing the profitability of wood recycling by selective processing. Submitted to IPPS 2017, 05.-06.10.2017, Llandudno, UK.

Kutnar A (2016). Environmental use of wood resources. In: Kutnar A, Muthu S (2016). Environmental impacts of traditional and innovative forest-based bioproducts, (Environmental footprints and eco-design products and processes, ISSN 2345-7651). Singapore: Springer, 1-18.

Irle M, Privat F, Deroubaix G, Belloncle C (2015). Intelligent recycling of solid wood. Proceedings of 9th International Conference of Wood Science and Engineering. 05.-07.11.2015, Brasov, Romania.

Privat F, Irle M, Deroubaix G, Belloncle C (2016). Modelling The Yield Of Clean Solid Wood From Recovered Wood. Poster at 6th International Conference on Engineering for Waste and Biomass Valorisation. 23.-26.05.2016, Albi, France.

Schwarzkopf M, Burnard M (2016). Wood-plastic composites-performance and environmental impacts. V: Kutnar A, Muthu S S (ur.). Environmental impacts of traditional and innovative forest-based bioproducts, (Environmental footprints and eco-design products and processes, ISSN 2345-7651). Singapore: Springer, 19-43.

Teischinger A, Kalcher J, Salzger E, Praxmarer G, Vanek M (2016). General systematic for a design for recycling-guideline for wooden windows and wood aluminium windows. In: Eberhardsteiner J, Winter W, Fadai A, Pröll M (2016). Proceedings of the World Conference on Timber Engineering (WCTE 2016), 22.-26.08.2016, Wien, Austria. Vienna University of Technology, Austria; ISBN: 978-3-903039-00-1

Burnard M, Cerinšek M, Kutnar A, Horvat B (2015). Comparative Analysis of the European Forest Sector Production 2008-2013. In: Barnes H M, Levan-Green S L (2015). Proceedings of the 58th International Convention of Society of Wood Science and Technology, 07.-12.06.2015, Grand Teton National Park, Jackson/Wyoming, USA, 734-742.

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## 3. Articles in national scientific journals with peer review

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## 4. Articles in national scientific compilation works and national scientific conference proceedings with peer review

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## 5. Scientific monographs

Mauruschat D (2015). Untersuchung, Weiterentwicklung und Adaption prozessanalytischer Methoden zur Erkennung von Kontaminationen beim Recycling von Altholz, Dissertation. Technical University of Braunschweig, Braunschweig, Germany.

## 6. Other scientific publications, such as articles in scientific non-refereed journals and publications in university and institute series

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Meinlschmidt P, Mauruschat D (2015). Up- and down-cycling of waste wood in Europe. Proceedings of the InWood2015, Innovations in Wood Materials and Processes, 19.-22.05.2015, Brno, Czech Rebublic, 161-162.

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Seidemann C, Tempel L (2015). Entwicklung Altpapierqualität - Ursachen und Folgen, Veränderte Altpapierzusammensetzung und ihr Einfluss auf die Faserstoffqualität. Wochenblatt für Papierfabrikation 08/2015, Deutscher Fachverlag, Frankfurt a. M., Germany, 514-518.

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### a) Other dissemination

Presentation of the CaReWood project on the WKI booth at the LIGNA fair in 2015 and 2017, Hannover, Germany.

Presentation of the CaReWood project in a dedicated workshop on the LIGNA fair on 23.05.2017 in Hannover, Germany. During the workshop, all work package leaders presented the results from the project.

M Sora (2015). Organisation of ReWin - M SORA talent competition (December 2014 – February 2015)
http://www.m-sora.si/si/rewin
http://www.woodwisdom.net/wp-content/uploads/2016/01/20160127_wwnet_success_story_rewin.pdf
http://www.era-platform.eu/news/woodwisdom-net-success-stories-timber-window-rewin
http://cordis.europa.eu/news/rcn/130475_en.html

M Sora and rest of consortium (2015). Organisation of conference "CaRe for Wood", 06.05.2015, Žiri, Slovenia. Press report on the conference: "Prek projekta CaReWood do večje uporabe odsluženega lesa" (Through the project CaReWood to increased use of used wood), https://krog.sta.si/2132928/prek-projekta-carewood-do-vecje-uporabe-odsluzenega-lesa

Newspaper article (2015). Reciklaža lesenih odsluženih oken - leseno okno Rewin (Recycling of discarded wooden windows – wooden window ReWin). Lesarski utrip, 2015, 21(4), p. 34.

Newspaper article (2015). Tudi odslužena okna so lahko priložnost (Discarded windows can also be an opportunity) http://www.delo.si/gospodarstvo/podjetja/tudi-odsluzena-okna-so-lahko-priloznost.html

Newspaper article (2015) Z lesom tudi na 10.Slovenskem forumu inovacij (With wood also at 10th Slovenian innovation forum) http://lesindom.eu/index.php/nekategorizirano/z-lesom-tudi-na-slovenskem-forumu-inovacij/

Short contribution including an interview with director of M SORA in one of the most popular TV broadcasts at national television „Prava ideja“ (translation: „The right idea“) with the focus on circular economy (29.10.2015) http://4d.rtvslo.si/arhiv/prava-ideja/174368183

Competition “Izzivi mladim” („Challenges to youngsters“) Development of business model for use of wood from discarded windows into wine packaging (ReVinUse)

Ugovšek Aleš (2015). Timber windows from cradle to cradle. Oral presentation. International circular economy conference: opportunities and challenges, 03.11.2015, Brdo, Slovenia.
http://ebm.si/p/circonf/en/program/index.html

Presentation of the CaReWood project at M SORA stand at the fair Dom 2016 in Ljubljana (8.3.2017-13.3.2017)

## 1.6 National and international cooperation

After a short warm up phase, the cooperation between the partners evolved very well. The meetings were held as two days meeting so that there was plenty time for official meetings but also for socializing between the participants.

Throughout the project, the following cooperation developed:

- A good cooperation between WKI and the Mendel University of Brno (Czech Republic) were established as well to the University of Primorska and M-SORA in Slowenia.
- Collaboration between AAL and TUM has resulted in the application for funding to enable Mark Hughes (AAL) to stay at TUM in late 2017 as a visiting professor to deepen collaboration between Aalto University and TUM in the area of wood cascading and to plan and implement further projects on cascading.
- Close collaboration between TUM, ESB and FCBA which resulted in a one month research stay of Michael Risse (TUM) at ESB and FCBA in spring 2017
- PTS collaborated with RTT as well as the institute of wood technology in Dresden, Germany.

The CaReWood project served as an important reference for Abelium to obtain the digital transformation of the forest-wood chain in Slovenia project in cooperation with the Ministry of Economic Development and Technology. Within this project ABE established cooperation with key players in Slovenia in the forest-wood chain field and presented the project at international events.

In France, different wood recycling companies who are outside of the project have shown considerable interest in the idea of making high value products from recovered wood. They have been very happy to provide access to their collection yards in order that samples of recovered wood could be collected. The companies provided these opportunities free of charge.

In Germany, various companies outside the consortium provided free of charge data on operation costs to enable the economic assessment of the CaReWood-process.

CaReWood project has a great influence on M SORA company in terms of start of collaborations with government, other companies and non-profit organizations in the field of circular economy. M SORA has become known Slovenian company in terms of circular economy and was also selected in the group of 9 Slovenian companies which are working on the common project Academy for establishment of sustainable business models in practice.

Mark Hughes (AAL) has been involved in several workshops convened in the area of improving resource efficiency in the forest-based industries sector as well as the built environment. These include sessions in the World Circular

Economy Forum, 5th and 6th June 2017 in Helsinki and the Climate Innovation Summit in Frankfurt, Germany on 8th November 2016, organized by Climate-KIC.

One national project application in Finland has so far been made as a follow-up to CaReWood and though unsuccessful, further applications are being planned. For example, initial discussions have been held with SITRA and will be followed up. A Climate-KIC demonstrator project application, led by Chalmers University, in which Aalto University is participating has been submitted. The project covers sustainable wood use in the built environment. Cascading is a topic specifically covered in the application. Seed funding from Aalto University has been obtained (€30 000) to initiate multidisciplinary research in wood cascading. Funding has been awarded to develop research between civil engineering, wood technology and business. It is expected that this research will lead to new project applications in the area of wood cascading.

Links between AAL and Professors Atsushi Takano and Daishi Sakaguchi in Japan have been maintained and collaborative visits are planned. Dr. Roope Husgafvel successfully applied for funding from the Sasakawa foundation to finance a trip to Japan in connection with furthering work on wood cascading. Hughes also plans to visit Japan on a similar mission.

The involvement of François Privat, Environment Engineer at FCBA in the research project and PhD work carried out at ESB in Nantes, under the direction of Prof. Mark Irle, ESB with co-direction from C. Belloncle (ESB) and G. Deroubaix, FCBA, has been a strong opportunity for strengthening cooperation links between the two organizations on wood waste recycling topics.

The project has been presented at a technical meeting to industrial windows manufacturers (Union des Fabricants de Menuiseries Extérieures - UFME) who have expressed an interest for the potential use of the recycled material for their production. It has also been presented at a meeting with wood packaging manufacturers (Commission Professionnelle Emballages de FCBA).