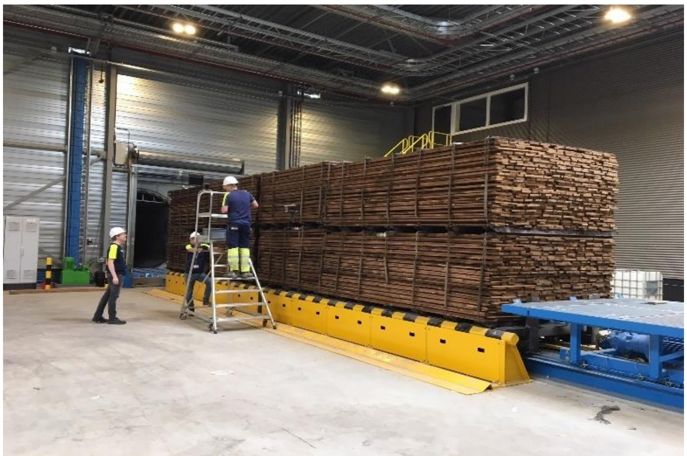
9th European Conference on Wood Modification
ECWM9

September 17 and 18, 2018, Arnhem, The Netherlands

PROCEEDINGS



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The 9th European Conference on Wood Modification
The Netherlands • Arnhem • September 17-18, 2018

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9^{th} European Conference on Wood Modification

Burgers' Zoo

Arnhem, The Netherlands

17-18 September 2018

In association with:

COST FP1407 ModWoodLife

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Nieuwe Kanaal 9b, 6709 PA Wageningen, The Netherlands

www.shr.nl

ISBN: 978-90-829466-1-1

Preface

SHR was one of the first research institutes in Europe, who already in the 1990´s did substantial research work to develop wood modification processes. It appeared, that this research area was very complex, and that for a successful application of potential processes different expertise's was needed. A good network between research partners and industry was needed and the "European Network on Wood Modification" was created. 15 years ago, in 2003, the first European Conference on Wood Modification "ECWM" was held to present the outcomes of this EU financed network. Since than, ECWM´s were held each 2-3 years at different places around Europe, and now we can celebrate the 9^{th} ECWM in the Netherlands, organized by SHR where it all began.

As already before, ECWM 9 is linked up to the European COST organisation. Thanks to the COST Action FP 1407 ModWoodLife to join and strengthen our network!

The participation of researchers of all around the world make it obvious that the name "European conference" is much too small…so: a warm welcome to researchers from industry and academia from Europe and abroad! This success has led, once again, to a large number of abstracts submitted to the organizers. In general, these abstracts were of a high quality and the members of the Scientific Committee had a hard time to select 44 full presentations and 50 poster presentations out of the many applications. We hope we have found the right balance between scientific and applied presentations to reach the key goal of ECWM: to attract researchers from academia and industry to join their expertises in this very exciting research area "wood modification".

The local conference organizers from SHR have done a great job this past year to make us feel welcome in The Netherlands and to let the conference be a success. Thank you very much to Bôke and team!

Prof. Dr. Holger Militz
Chairman of Scientific Committee
Georg-August-University Göttingen, Germany

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Mrs. Jos Gootjes, SHR	SHR; The Netherlands

Wood modification in practice

The European Conference on Wood Modification takes place on the 17th and 18th of September 2018 in Arnhem, The Netherlands and is organised by SHR. At this conference researchers and people from industry from all over the world will come together to share their knowledge and experiences with the latest developments on wood modification methods, applications and products. The conference was given the subtitle “Wood modification comes home”, which refers to the role The Netherlands and SHR have played – and still play – in the development and industrial application of modified wood.

Techniques and methods designed for improving wood properties are almost as old as mankind itself. However the scientific and industrial rise of wood modification became significant under the influence of a number of social and economic developments in the eighties and nineties of the previous century. A strong need was felt to find alternatives for the use of tropical hardwoods and preservative treated wood, which were both under pressure for a variety of reasons. The discussions regarding a clean environment, sustainable forest management, wood use and the increasing wood demands from emerging markets in Asia also had a big impact. Wood modification was recognized to have the ability to offer a more, better and sustainable way of making use of wood as a durable material in a broad range of applications. Besides that, it was found to be a supreme method for upgrading the properties of lesser used timber species and to provide technical solutions to overcome some of the natural deficiencies of wood as water uptake, decay and dimensional changes.

Over the last decades an enormous amount of scientific work has been performed and published. We have seen many innovative modification ideas, methods and techniques passing by during the previous eight ECWM’s. To make a real impact, ideas need to be developed further and put into practice. We are proud that in The Netherlands we have created a setting with a high level of knowledge, innovative thinking combined with entrepreneurship, which lead to a variety of flourishing companies involved in industrial production of modified wood. Not only producing companies, but also the wood processing industry has adopted modified wood as a highly appreciated durable material. We can declare that modified wood has become a lasting factor in the wood processing industry.

For these reasons SHR and we as the organising team, are excited to welcome you all here in The Netherlands for the 9th European Conference on Wood Modification. We hope you will enjoy your stay here in Arnhem and become inspired by all attendees, presenters and new insights this conference has to offer.

Welcome!

The organising team

COST 1407 - Foreword

It is our pleasure that COST Action FP1407 “Understanding wood modification through an integrated scientific and environmental impact approach” (ModWoodLife) in part of 9th European Conference of Wood Modification. The conference brings together researchers from across Europe and beyond that jointly are addressing the mounting pressure on renewable resources (as a material source, for recreational, ecological, and other uses). By maximising the efficiency of materials derived from them, the wood modification community plays an important role. The efficiency can only be achieved if new methods to improve the functionality, durability, properties, and environmental impacts will be developed. Wood modification addresses these requirements directly, allowing wood to be used in more applications, including increased use of under-utilised species. Wood modification also addresses undesirable characteristics of wood such as fungal resistance, UV-stability, and moisture sensitivity. The COST Action FP1407 has been successful in addressing these needs in the past 3 years. We are in the last year of the Action and therefore it is even more important for us to be at ECWM9. Only sustainable collaboration and joint efforts will deliver the impacts. That objective of the Action FP1407, to characterise the relationship between wood modification processing, product properties, and the associated environmental impacts in order to maximise sustainability and minimize environmental impacts, has great value for the forest sector, for researchers, and society at large.

Wishing you a successful and memorable conference full of fruitful discussions.

Andreja Kutnar
Chair, COST FP1407

Denis Jones
Vice-Chair, COST FP1407

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Life cycle assessment of bio-based façades during and after service life: maintenance planning and re-use

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Keywords: bio-based material, cascading, end-of-life, façade, life cycle assessment, re-use, service life

ABSTRACT

New developments in the field of wood protection, coupled with the European political determination to lower the environmental impact of the building sector, designates wood and bio-based materials as an excellent option for building façades. Despite that, the share of wood in the European wood construction market is low, with the exception of some North European countries. For that reason, it is necessary to increase a confidence in bio-based façades by demonstrating their environmental performances during and after the service life by means of solid scientific tools and experimental evidences. As a pilot study, we investigated the interactive LCA in two maintenance scenarios (high and low intensity), assuming two diverse cladding bio-materials (untreated sawn wood and chemically modified wood). A dedicated software tool was developed for the needs of these analysis allowing dynamic simulation of environmental impact and immediate visualization of the LCA contributions. The end-of-life options were assessed with a different approach. Firstly, several alternative scenarios for re-use that are available on the market were identified and listed. Secondly, we established a weight-based expert system expressing importance/advantage of each scenario in order to classify each end-of-life option according to its provision of environmental benefit. Finally, we assessed the suitability of each defined end-of-life option for all evaluated bio-based materials.

INTRODUCTION

The construction sector represents a large proportion of the consumption of the earth's non-renewable resources in terms of materials used for construction and energy consumption for operation of buildings. Aggregate, concrete and bricks are the most used construction materials in Europe, covering 45%, 42% and 6.7% of the total volumes respectively. At the same time, the share of timber structures accounts for only 1.6% of the total (Herczeg *et al.* 2014). Energy consumption of buildings in developed countries comprises 20-40% of the total energy use, more than industry and transport sectors (Pérez-Lombard *et al.* 2008). To reduce the use-phase costs of buildings, the selection of optimal building envelope systems can be crucial. However, materials for building envelope can have a high manufacturing costs (both economic and environmental). It is reported in several studies that the bio-based building materials have lower embodied energy than traditional ones (Kovacic *et al.* 2016, Lugt and Bongers 2016, Lupíšek *et al.* 2015, Werner and Richter 2007, Zabalza Bribián *et al.* 2011). Moreover, as bio-based materials are renewable, these are suitable at the end of service life for diverse paths of re-use (Thonemann and Schumann 2018). In spite of the economic crises, the production of some now well-established engineered wood products for structural use, such as cross-laminated timber (CLT), is intensively growing in Europe and globally (Brandner *et al.* 2016). Moreover, the improvements of the new wood-based products make these suitable to substitute some fossil-based raw materials. It is foreseen that there is a potential to doubling the added-value of the wood industry by 2030 (Hetemäki and Hurmekoski 2016). Furthermore, recent technological developments allow mass production of wood-based products (modified wood) that still few years ago were at the prototype stage (Mantanis 2017, Sandberg *et al.* 2017). The environmental impact of the production phase is disclosed for some modified wood products in dedicated EPD documents or LCA-related literature. For example, the carbon footprint of 1 m^3 of chemically modified wood can vary between 258 and 511 kg CO_2eq (Lambert and Daae 2015, Vogtlander 2015), while that of 1 m^3 of thermally modified wood can be between 131 and 133 kg CO_2eq (Ferreira *et al.* 2018). Nevertheless, the data differ greatly based on wood species, process-specific inputs and outputs, type of production plant, transportation, among the others. The environmental impact of the service life of wood-based façades has been rarely assessed, also because it is complicated to properly define the service-life duration, the limit state for maintenance operations and, consequently, to calculate the maintenance frequency (Grüll *et al.* 2011). In order to fill this gap, we developed a software tool that calculates the environmental impact of the maintenance of wood-based façades. The system was tested on two case scenarios of maintenance: high frequency/intensity and low frequency/intensity for two diverse wood-based façade solutions.

EXPERIMENTAL

Life cycle assessment (LCA) method was applied to four elementary maintenance operations typically executed on façades: cleaning, sanding, recoating and replacing (Petrillo *et al.* 2018). Figure 1 presents a graphical representation of the abovementioned operations/modules, including summary of the life cycle inventory data as used for environmental impact computation. All the modules can be combined together in an interactive LCA, where the user can define several variables describing the real-life scenario of the façade usage. The intensity of maintenance, material performance, local macroclimate as well as the owner's tolerance for aesthetical deficiencies are particularly important factors affecting the LCA results. We tested the cleaning operations considering both presence or absence of a detergent in addition to the water. Therefore, the output can be only water or water contaminated with the detergent. These two options were tested in two different scenarios. The use of electricity was included to account for the use of pressure-machine (power 1,5-2 kW, work efficiency 0,015-0,025 h/m^2) in the cleaning operations. The sanding operations include sandblasting with pressure machine (power 1,5-5,5 kW, work efficiency 0,025-0,008 h/m^2) and a natural abrasive media, such as corn cob or walnut shells. The type of waste flow can be different: only sawdust in the case of sanding natural, untreated wood, sawdust and waste paint in the case of coated wood, sawdust with chemicals in the case of impregnated wood. Three scenarios were calculated considering the re-use of the abrasive media. Usually, this operation is a preliminary step before re-coating.

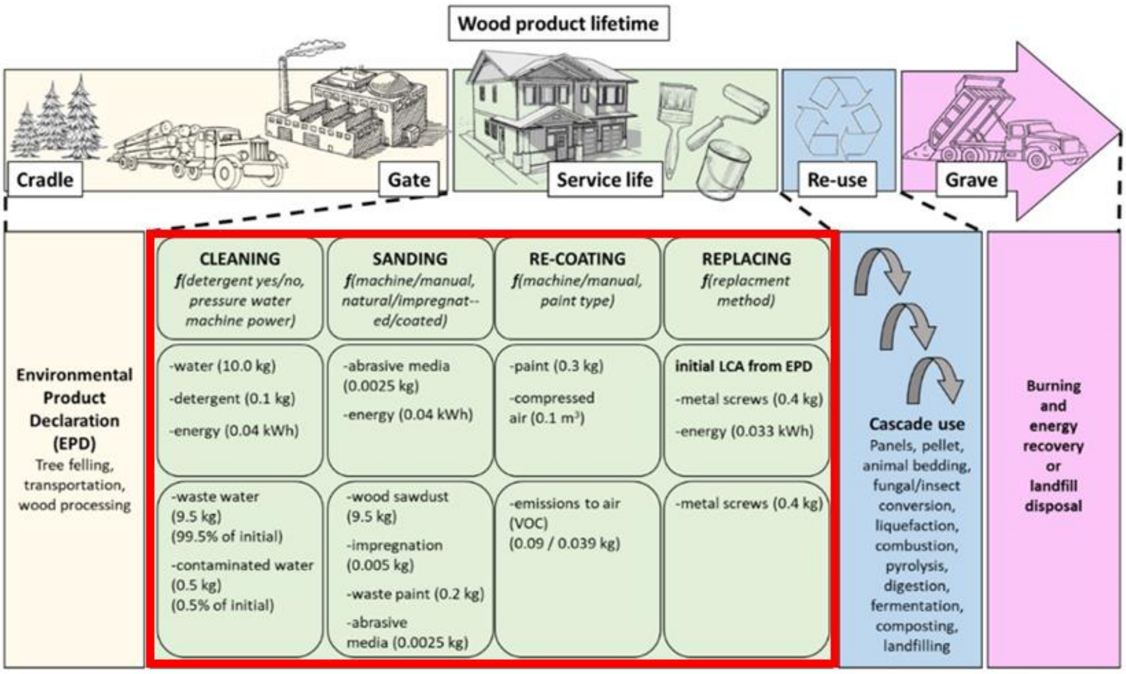

Figure 1: Lifetime of wood products with emphasis on service life. Maintenance modules are described in terms of input and output of materials and natural resources (life cycle inventory) (Petrillo et al. 2018).

The options for re-coating were based on acrylic and alkyd paints, water- or solvent-based. Moreover, all paint types were calculated for the options: hand-painting or machine-painting (spray-machine with compressed air). For the replacement operations, we considered the substitution of 25% of the façade in terms of the new material (data from available EPDs) and the environmental impact of the operations for replacement (metal screws, screwdriver energy demand). Then, we hypothesised two maintenance scenarios: high level of maintenance, due to harsh climate and high esthetical standard, and low level of maintenance, due to mild climate and low aesthetical standard. Based on practitioners' experience, scientific literature and technical data provided by material producers, we defined the maintenance options and their frequency in the four cases, as represented in Table 1.

Table 1: Condition for simulation of four case scenarios in 20 years of service life

	Case 1	**Case 2**	**Case 3**	**Case 4**
Climatic conditions	Harsh	Mild	Harsh	Mild
Material type	Natural wood (conifer)	Natural wood (conifer)	Chemically modified wood	Chemically modified wood
Owner aesthetical standard	High	Low	High	Low
Cleaning (times in 20 years)	6	2	9	3
Sanding + Re-coating frequency (times in 20 years)	2	1	0	0
Replacing frequency (times in 20 years)	1	0	0	0

Finally, we defined a system to weight different end-of-life (EOL) scenarios. The system takes into account for each EOL option the factors which are relevant for the calculation of LCA, such as: the potential for multiple re-use, the demand of additives for the new use, the energy required for the process and, finally, the possibility to recover energy at the end of the re-use cascade.

RESULTS AND DISCUSSION

The results indicate that the environmental impact of the use phase can vary greatly due to the climate and user, as represented in Figure 2.

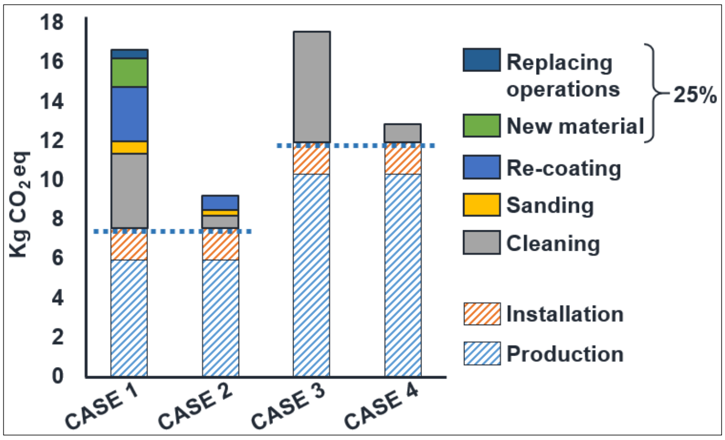

Figure 2: Environmental impact of production, installation and maintenance of 1 m² of façade made with untreated wood (case 1 and case 2) and chemically modified wood (case 3 and case 4) in high maintenance scenario (case 1 and case 3) and low maintenance scenario (case 2 and case 4).

For high frequency and intensity of maintenance, the total environmental impact of the natural wood façade and that of the chemically modified wood façade are comparable. In fact, the lower impact of the production of natural wood in comparison to the chemically modified wood is compensated by the higher impact of the maintenance operations for natural wood façade. However, in the mild climate, the natural wood has sensitively lower impact than chemically modified wood. The proposed system for interactive LCA is suitable for every possible combination of climate, material, design and customer aesthetical standard. Finally, in Table 2 we present the selection of the end-of-life scenario.

Table 2: End-of-life (EOL) features and their weights based on environmental impact. The total score indicates the environmental friendliness for each end-of-life option.

	Allow re-use	**Require additives**	**Reuse without processing**	**Reuse with processing**	**High energy**	**Low energy**	**Energy recovery**	**No energy recovery**	
Weights for EOL feature	**10**	**-5**	**7**	**3**	**-5**	**-1**	**5**	**-7**	**Total score**
Landfilling	0	0	1	0,1	0	1	0	0,9	**0**
Composting	0	0	0,1	0,9	0,1	0,9	0,2	0,2	**2**
Liquefaction	0,8	1	0	1	1	0	0,7	0,2	**3**
Fermentation	0,2	0	0,1	0,5	0,1	0,9	0,8	0,2	**5**
Anaerobic digestion	0,2	0	0,2	0,5	0,2	1	0,8	0,2	**6**
Combustion	0	0	0,1	0,9	0,1	1	1	0	**7**
Incineration	0	0	0,1	0,9	0,1	1	1	0	**7**
Pelletizing	0,4	0	0	1	0,9	0	1	0	**8**
Gasification	0,2	0	0,1	0,9	0,2	1	1	0	**8**
Pyrolysis	0,2	0	0,1	0,9	0,2	1	1	0	**8**

	Allow re-use	Require additives	Reuse without processing	Reuse with processing	High energy	Low energy	Energy recovery	No energy recovery	
Animal bedding	0,5	0	0	1	0,1	0,9	0,5	0,1	**8**
Panel manufacturing	0,9	0,5	0,2	0,8	0,8	0,2	1	0,1	**10**
Fungal conversion	0,7	0	0,8	0,4	0,1	0,9	0,4	0,2	**13**
Insect conversion	0,7	0	0,6	0,8	0,2	0,9	0,5	0,1	**14**
Re-use in solid products	1	0	1	0,1	0,1	1	1	0,1	**20**

CONCLUSIONS

In conclusions, the interactive LCA system that we propose allows rational choice of material and maintenance operation during service life. In fact, based on the location it will be possible to forecast a realistic maintenance plan, which will be customized according to the aesthetical expectation of the user.

ACKNOWLEDGEMENTS

The BIO4ever (RBSI14Y7Y4) is a project funded within the call SIR (Scientific Independence of young Researchers) by MIUR. The authors gratefully acknowledge the European Commission for funding the InnoRenew CoE project (Grant Agreement #739574) under the Horizon2020 Widespread-Teaming program.
Special acknowledgments to COST FP1303, FP1407 and TU1403 for funding STSMs that contributed to the project and all BIO4ever project partners.

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ISBN: 978-90-829466-1-1