FINAL REPORT

CircWood

Increasing the Climate Change Mitigation Potential of Wood Used in Construction

(VN/5272/2018)

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21st June 2020

Contents

1. Summary

Combining the production and use of long-lived harvested wood products (HWPs) with sustainable forest management forms an effective strategy for climate change mitigation. HWPs used in building construction can store carbon for long periods and, by substituting materials like steel and concrete, can displace the emissions associated with their production. Keeping wood within the technosphere, following cascading principles (i.e., material use first, then energy), stores C for longer and, if its reuse replaces 'energy intensive' materials, additional substitutive effects will accrue.

Because of current demolition practices, we use very little wood like this; in Finland, most wood recovered from demolitions is burned for energy generation. To recover a greater amount of usable wood we should design buildings with disassembly in mind. By adopting Design for Disassembly (DfD), we could feasibly recover a greater proportion of wood, making its use far more resource-efficient. The aim of CircWood was to model the effect that recirculating wood within the built environment in this way has on C emissions, examining different wood use scenarios and the implementation of DfD. In the first part of the project, buildings containing the greatest proportion of wood were identified. It was found that wooden buildings account for about 84% and 99% of the permanent and free-time residential buildings respectively and for 58% of non-residential buildings. Demolition and waste management practices were surveyed and a model created to demonstrate how retaining wood in the technosphere (through cascading) increases the amount of carbon stored. Augmented levels of cascading (i.e. through DfD), logically, increase the level of carbon stored.

2. Project background and objectives

The CircWood project ("*Increasing the Climate Change Mitigation Potential of Wood Used in Construction*"; VN/5272/2018), began on 1.1.2019 and ran until 31.5.2020. This final report summarizes the project activities from the beginning of the project up to its completion.

There is currently significant interest in the role that forests and harvested wood products (HWP) can play in climate change mitigation (e.g. Taverna et al. 2007). HWP store carbon (C), sequestered during tree growth until oxidised either through incineration or through biodeterioration and when incorporated into long-lasting structures such as buildings, this storage period can last many decades or even centuries. In addition to the storage of C, if HWP are used in buildings to substitute other materials such as steel or concrete, emissions of greenhouse gasses (GHG) are generally avoided.

Forests provide invaluable ecosystem services and are a source of materials to build our future cities and manufacture the myriad of products used in modern life. They are the basis of a modern bioeconomy. In Finland, considerable efforts have been directed towards the development of new material and energy solutions from forest biomass, through the concept of biorefinery. Alongside the developments in biorefinery, there is a renaissance in wood construction brought about by materials development and the introduction of new building systems. The manufacture of wood-based materials for building construction and the provision of biorefinery intermediates and products go hand-in-hand. For example, when a building product, such as sawn timber is manufactured, the co-products – chips and sawdust – provide feedstock for biorefinery. However, if wood construction develops as anticipated and if biorefinery flourishes as expected, we are presented with a dilemma – how to provide increasing levels of wood raw material for both construction and for biorefinery, without compromising the ability of forests to supply these sustainably, whilst affording an enhanced level of ecosystem services? Although in Finland there is perhaps still the possibility to increase harvesting, there is emerging evidence to suggest that if the industrial use of forests is to increase much more, then this might have a negative impact on other ecosystem services (EASAC, 2017). To avoid this situation, it is vital that we become more resource efficient in our wood use and, wherever possible, direct its use to applications that have the greatest environmental benefits as well as value adding potential.

Most studies agree that sustainable forest management, including the production of long-lived HWPs, forms an effective strategy for climate change mitigation. HWPs in this context include wood products used for construction as well as the products of biorefinery and energy. HWPs used in building construction can store C for long periods, up to the lifetime of the building and, by substituting other materials, they displace the emissions from their production. When trees are harvested, there is an immediate loss of C stored in the forest, plus the emission of C due to disturbances. What happens to the C contained in the harvested tree then depends upon how it is used. In sawlogs converted to timber building products, the C will be stored until it is oxidised, which is generally as long as the product remains in the building (likely > 50 years). If used for energy production, the C is released more-or-less immediately. For HWPs with intermediate life spans (e.g. pulp, fibre products etc.), the C is usually emitted within a few years.

There are many well-reported benefits to using wood in construction beyond reducing GHG emissions. Consequently, the use of wood in construction should be promoted. However, though wood is a renewable resource its supply is not unlimited and the harvesting of wood can, as mentioned above, have an impact on other ecosystem services. For this reason, wood should be used parsimoniously and consequently there is increasing interest in improving the resource efficiency of wood use in construction through cascading – in other words using the material through several product lifecycles (i.e., material use first, then energy). The cascade use of wood has also been highlighted by the EC as a means of "doing-more-with-less", in other words realising more economic value from wood though using it more than once in material applications (EC, 2015).

Whilst there are many potential benefits to cascading wood from buildings, currently, it is seldom practiced. Generally, wood recovered from demolished buildings is chipped and used as an energy source or, occasionally, cascaded into particleboard. Very little is either reused or recycled into other solid wood products. One of the reasons for this is that demolition is usually accomplished by heavy mechanical equipment (e.g. excavators) that breaks the wood elements and reduces the quality of the recovered wood. Furthermore, fixings (nails, screws, staples, adhesives etc.), coatings and preservatives contaminate the wood making reuse and recycling difficult. For these reasons, to recover a greater amount of usable wood we should design buildings with disassembly in mind.

Design for Disassembly (DfD), in other words designing buildings with their ultimate disassembly and recovery of materials in mind, is a way of re-thinking how we conceive of buildings, considering them not just as spaces in which to work or live, but as stores of valuable materials for the future. Applying DfD principles to wood used in construction could enable a significantly greater amount of wood to be recovered and reused making wood use in construction far more resource-efficient. After reuse, perhaps several times, the material could still be utilised for other purposes such as energy generation or as feedstock for biorefinery, adding value to the material multiple times during its lifetime thereby increasing economic opportunities.

Although it is generally acknowledged that using wood products from sustainably managed forests is a good way to combat climate change (Taverna et al. 2007), the benefits of cascading wood once it has entered the built environment, especially following the implementation of DfD, has been rather less explored (Brunet-Navarro, et al. 2016). It should be possible to increase the recovery of usable wood material by adopting 'smart' demolition processes that prioritize material recovery over speed of demolition; however, by adopting DfD it could be possible to retrieve a far greater amount, making wood use more resource-efficient and having a larger climate change mitigation potential (Brunet-Navarro, et al. 2018).

The underlying hypothesis of the CircWood project is that DfD can enhance the climate-change mitigation potential of wood products through C storage and substitution effects, whilst helping to preserve, or even enhance, the ability of forests to capture and store C and maintain biodiversity. Moreover, the increasing stock of wood products that results could form a valuable future resource for the bioeconomy.

The aim of CircWood was then to model the effect that recirculating wood products within the built environment has on climate change mitigation. In this context, recirculating means recovering and reusing or recycling wood products as materials before energy recovery, following cascade principles. More specifically, the project was to investigate how, by adopting smart demolition or DfD in wood construction, a greater proportion of wood products can be reused and the effect that this has on greenhouse gas (GHG) emissions and other sustainability indicators. The results were expected to demonstrate that by adopting DfD principles, the potential of wood products to mitigate climate change can be enhanced (through carbon storage and substitution effects) and that greater value can be added to wood products through their reuse (in line with EU and national circular economy strategies).

Since there are few practical examples of DfD or even smart demolition to draw on, this study, by its very nature has been quite theoretical. To obtain some degree of realism to the project, significant emphasis was placed on surveying demolition and waste management practices in the first phase of the project. This helped to provide more realistic scenarios for the modelling work carried out in the latter stages of the project. There remains a great deal of speculation regarding possible wood recovery levels with the introduction of DfD and smart demolition, however, it is clear to see what might be achieved if in terms of avoided GHG emissions, if DfD were to be adopted.

3. Project parties and methods

3.1 Parties involved

CircWood was led by Aalto University and, principally, researchers employed by Aalto carried out the work. However, part of the work was carried out by an external expert who was brought into the project when the main researcher on the project (Dr Chiara Piccardo) took up another appointment elsewhere mid-way through the project. The expert (Prof. Callum Hill, JCH Industrial Ltd, U.K.) developed a carbon storage model as part of the project that estimates how C storage is affected by adopting various cascading strategies.

At the project outset a post-doctoral researcher, Dr Chiara Piccardo, an architect, was hired by the project and began her appointment on 1.1.2019. She continued working full-time on the project until 30.9.2019 and, thereafter, continued to actively cooperate on the project throughout its duration and was responsible for preparing a report covering the activities covered by WP1 and WP2 (Appendix 1). At the beginning of 2020 JCH Industrial Ltd was engaged to implement part of WP3 (full report can be read in Appendix 2). A master’s thesis was also initiated in early 2020, covering part of WP3. Fredric Mosley, an Aalto University student at the School of Chemical Engineering, is carrying out his master’s thesis related to the project, investigating the substitution effects of cascading. At the time of writing, the masters thesis has not been completed, but is expected in autumn 2020. A copy of the final accepted thesis will be forwarded to the Wood Programme. MSc Bahareh Nasiri, now a doctoral candidate in the School of Chemical Engineering, worked part-time as a research assistant.

Prof. Mark Hughes led the project throughout.

3.2 Methodology

The CircWood project was executed as a series of three interlinked work packages (WP), each WP providing discreet results that fed into other WPs. The work packages are described below:

WP1: Scenario setting and estimating recovery levels

The aim of WP1 was to estimate future wood material recovery based on:

i) Current demolition practices
ii) Enhanced demolition of existing structures and
iii) Disassembly of buildings, which includes realistic scenarios for future wood construction using both existing construction practices and construction to DfD principles.

The purpose of this WP was to establish realistic levels of the amount of wood and its condition that could be fed into the model(s) developed in WP3. Since there are few practical examples of DfD, estimating future wood recovery from deconstructed buildings was based on a survey of the literature together with interviews with industry experts and architects. Further interviews were carried out with demolition and waste management contractors to better understand current practices and what might be possible with 'smart' demolition (e.g. manual dismantling) of the existing building stock, maintaining quality as far as possible. The expected output from this task was a realistic estimate for the current and future availability of recovered wood in terms of volume and 'quality' (a measure of its cascading potential) under different scenarios of demolition and disassembly. The individual tasks identified under this WP were to:

i) Create scenarios for the construction of (a) selected new building(s), including a 'baseline' scenario in which wood is used in (the) building(s) in the same way as it is today and if DfD is widely implemented
ii) Estimate the dimensions and volumes of wood used in the building scenarios identified in i) and
iii) Estimate the types, quality and quantity of wood products that could be recovered:
    - currently
    - with improved demolition methods and
    - with DfD implemented to different degrees

WP2: Materials flows and cascading options

The aim of WP2 was to develop realistic cascading options for the recovered wood emanating from the scenarios developed in WP1. The purpose of this WP was to identify the cascading options open, dependent upon the scenarios for wood material recovery. For example, it should be possible to recover material of higher quality and greater dimensions if the building is carefully dismantled manually. This material would have better cascading options since it could be used perhaps in solid wood form as well as for particleboard or energy recovery. On the other hand wood that is badly damaged by mechanical demolition might only be good for chipping and burning with energy recovery. The expected output from this WP were realistic cascading options based on the scenarios created in WP1 together with reprocessing requirements and substitution possibilities. The individual tasks identified under this WP were:

i) To identify cascading options (e.g. reuse, reprocessing into engineered solid wood products etc.) for the recovered wood products/materials.
ii) For the cascading options identified in i), determine the logistics and processing infrastructure requirements for the recovery and remanufacture or recycling of wood products.
iii) To determine realistic substitutional options for cascaded products (i.e. will the cascaded wood products replace other wood products or alternative materials?)

WP3: Modelling the impacts

The aim of WP3 was to model the impacts of the different wood use scenarios detailed in WP1 in terms of emissions savings, utilising the outputs from WPs 1 and 2. The purpose of this WP was to estimate the effect that cascading would have on C stored and emissions avoided, under business as usual and with cascading enhanced by DfD (or smart demolition). The hypothesis was that if DfD were to be implemented, not only would a greater proportion of the C embodied in wood products be retained for a longer period of time, thus increasing the C stock in the built environment, but also that greater substitution benefits would accrue. The expected output from this task was an assessment of the CO_2 mitigation potentials of the different cascading scenarios compared to the baseline (business as usual). The individual tasks identified under this WP were:

i) Calculation of the material flows of the different cascading options of DfD buildings and retrofit solutions will be made by applying environmental impact factors provided in the life cycle assessment database ecoinvent v3 and ToSIA (Tool for Sustainability Impact Assessment), which is a decision support tool for the forestry sector developed by the European Forest Institute
ii) a sensitivity analysis will allow the identification of the most relevant factors to achieve robust results

4. Project results

4.1 Achieving the project objectives and planned results

The stated objective of the CircWood project was to model how DfD affects the sustainability of wood construction. More specifically, the aim was to investigate *how DfD can enhance the potential of wood products to mitigate climate change though the effect on C emissions* and consider how economic activity is affected as a result. The goal of the project was not to specifically investigate technical solutions for DfD (though these are undoubtedly required), but to undertake the basic science needed to demonstrate the climate change mitigation potential should DfD be implemented. At the time of writing the original plan, parallel projects were in progress or were planned that would in part investigate the technical feasibility of

DfD and cascading in general. Since writing the plan, some of these projects have been completed or are still in progress. The most notable of these is the ForestValue ERA.net project "InFutUReWood" (Innovative Design for the Future – Use and Reuse of Wood (Building) Components) - https://www.infuturewood.info/.

Overall, the project objectives were achieved, though there were some deviations from the planned tasks due to practical considerations (e.g. due to changing personnel and COVID-19), as well as because, as the project proceeded, it was realised that there was a lack of knowledge and information in certain areas that required a change in emphasis and further research work. The overall goal, however, of demonstrating that cascading has a positive benefit in terms of climate change mitigation has been achieved and the relative magnitude of the change has been quantified. Further work continues to refine the estimates and to consider other aspects of the impact of cascading on climate change mitigation.

The project was structured into three work packages, each with discreet aims and expected results. The aim of work package 1 was to *estimate future wood material recovery* and the expected result from WP1 was a realistic *estimate for the current and future availability of recovered wood* in terms of volume and 'quality' (a measure of its cascading potential) under different scenarios of demolition and disassembly. This WP began with a statistical survey of wood building in Finland to understand the current stock of wooden buildings as well as to explore the future potential for wooden buildings. The analysis showed that wooden buildings represent a relevant share of the Finnish building stock. They account for about 84% and 99% of the permanent and free-time residential buildings, respectively, and for 58% of the non-residential buildings. Wooden residential buildings with one or two storeys seem to be the most relevant category in the wooden building stock. Relevant current construction methods have been identified, though there is data lacking on this. Multi-storey buildings are not representative of the wooden building stock at the moment and, in addition, they have a low wood cascading potential at present due to their recent construction and the expected service life.

Currently, there is little accurate data about the dimensions and quality of wood recovered from buildings apart from some isolated studies (e.g. Sakaguchi et al, 2016) and thus additional empirical data would be beneficial to refine the scenarios. Several demolition projects were contacted and information collected from contractors, municipalities and site visits. The data collected were not sufficient to draw definitive conclusions and the intention had been (and still is) to conduct further case studies of demolitions. At this point there is little additional empirical data on the dimensions and quality of wood (mainly due to the demolition process and the inability to take reliable measurements on site), though much data about the demolition process has been obtained from interviews that can complement the scenario building. Regrettably, due to the Coronavirus (COVID-19) outbreak in 2020 and, prior to this, difficulty in identifying and accessing suitable demolition case studies, there was no opportunity to undertake further site visits to obtain more detailed information about the dimensions and quality of wood recovered from buildings being demolished. However, in order to gather further information on the cascading potential of wood materials in existing buildings, two studies were conducted. The first study investigated the current management of wood waste generated from construction and demolition activities through a survey of waste management companies. The second study investigated the current recycling and reuse of wood materials in existing buildings, including DfD, through the analysis of real case-study buildings and interviews to designers. Despite the fact that detailed information about the quality of recovered could not be obtained first hand, WP1 yielded good results on the demolition process of (wooden) buildings and waste management processes. Please see Appendix 1 for full details of the work carried out relating to WP1. The expected output from WP2 was to be realistic cascading options based on the scenarios created in WP1 together with reprocessing requirements and substitution possibilities. As noted above, there were a number of difficulties in obtaining empirical data about the materials recovered from case study demolitions. For this reason, part of the focus of WP2 changed toward ascertaining the types and volumes of wood products contained in residential attached and detached buildings. This work has been and, is being, carried out by doctoral candidate Bahareh Nasiri. The work has concentrated on extracting data from design drawing and bills of materials about the dimensions and volumes of wood products used in different types of wood construction (i.e. residential detached and attached houses) of different sizes and built at different times. This work is ongoing and it is expected that the results will form the basis of a peer-reviewed article. As part of WP2 cascading options were investigated through desk research and interviews (see Appendix 1).

The expected output from WP3 was an assessment of the CO_2 mitigation potentials of the different cascading scenarios compared to the baseline (business as usual). A stock and flow model was created where the input was the annual volume of wood (or its equivalent in C or CO_2) entering the built environment in Finland annually. This was calculated from statistical data on wooden housing floor area and estimates of the intensity of wood use. Output, i.e. losses from the built environment through demolition, was modelled using various functions aimed representing the lifespan of buildings. Output is known to be difficult to model accurately due to the large variety of reasons for demolition and, therefore, difficulty in predicting building age at demolition. For this reason, various functions were assessed in terms of their predictive ability. The model clearly shows that cascading stores C in buildings for a longer period, that increasing the lifetime of the cascaded wood (commensurate with applying DfD and recovering wood and reusing it in the same way as it was used in the first life) increases the amount of C stored for a given cascading rate. Interestingly and intuitively, the most effective way to store C is to extend the lifetime of the building in the first instance. The overall conclusion is that the model suggests that the best strategy from the point of view of carbon storage is life extension combined with a high level of recovery and the re-use of components. The full report prepared by Prof. Callum Hill on the C storage model can be found in Appendix 2. A manuscript describing this work will be prepared and submitted for peer-review.

In parallel with the study on C storage, a master's thesis (Fredric Mosley) is being written on the substitution effects of replacing virgin wood with cascaded wood. The expected completion date of the thesis had been 31.5.2020 but, unfortunately, there have been some delays and the thesis is expected in August/September 2020. The thesis is being conducted with the cooperation of the Öko-Institut e.V. Institute for Applied Ecology, where the master's thesis student, Fredric Mosley, conducted an internship in 2019.

4.2 Deviations from plans

The main deviations form the plan have been explained above, however, to summarize, the overall goal of the project was achieved but with some change to the work carried out in the individual WPs. WP1 was carried out more-or-less as planned though a quantitative analysis of the quality and quantity of wood from demolition was not possible due to the limited number of site visits carried out. This was compensated for thorough desk-based research, surveying demolition and waste management enterprises. WP2 differed in detail from the proposal, though the work that has been conducted (and is currently ongoing) has provided much detail about the wood products actually embedded in buildings. The approach taken in WP3 has similarly altered in detail, though the overall goals were achieved. The original intention had been to employ the Ecoinvent data base in ToSIA (Tool for Sustainability Impact Assessment), however, with the change in personnel midway through the project, it was decided to implement in the modelling in a different way to that originally planned. Professor Callum Hill had been working on a model for assessing C embodied in buildings and after discussion, it was concluded that this would be a very useful addition to the study as it would provide a more useful way of assessing the effect that changes to levels of wood recirculation would have on total C stored (and CO2 equivalent). A supplemental study on the effects of substitution is ongoing (Master's thesis of Fredric Mosley)

4.3 Causes of deviations

One of the main factors affecting the project and the deviations encountered was the difficulty in conducting site surveys of buildings being demolished. Although a few visits were conducted, it was not possible to collect the quantitative data expected. This was compounded by the departure of the post-doctoral researcher midway through the project and the necessity to reconfigure the project plan to be able to finalize it. A further factor, affecting the progress of the project, particularly the ability to conduct site visits, was the COVID-19 pandemic, which prevented travel of researchers from mid-March 2020 onwards. The pandemic has had other knock-on effects on the project (e.g. not being able to contact/interview enterprises), but it is considered that these have had a fairly minor effect on the project.

5. Effectiveness of the project

5.1 Project impacts

The project explored the potential benefits to be gained in terms of climate change mitigation of recirculating wood from buildings. It also aimed to explore how different strategies, such as the adoption of DfD would affect this. The results clearly show that the extending the life of (wood) buildings and recirculating wood in other long-lived products, provides an effective strategy to increase C storage in buildings in the longer term. This work has been specific to

Finland, helping to provide information to underpin strategies on wood use in the future. The project has also generated new knowledge about demolition and waste management practices relating to wood used in construction as well as about the potential for DfD.

The project has been widely disseminated at a number of events in Finland during 2019. A video about the project has been made that can be download from the following link: https://drive.google.com/file/d/1vc5lQBBqgj7UVDiKjSu74o6CNFGa7mTT/view?usp=sharing. It is expected that the project has increased the general awareness of wood recirculation and design for disassembly in wood in general.

5.2 Other effects

The project has helped establish and develop a core of expertise about wood and the circular economy in the Wood Materials Technology group at Aalto University. It has also enabled the career advancement of one post-doctoral researcher (Dr Chiara Piccardo), a doctoral candidate (Bahareh Nasiri) and master's student (Fredric Mosley). It has also enabled the development of a C model (Prof. Callum Hill).

6. Communication implementation and results

6.1 Communication activities

The project has been presented at several public events and the results are to be written-up as manuscripts for peer-reviewed scientific articles. Because of the relatively short duration of the project, all results have not yet been analysed and so the publication of peer-reviewed articles will occur at a future date. At least two peer-reviewed journal articles are planned. One master's thesis has begun and is expected to be completed in August 2020.

Following the Ministry of Environment kick-off event, the CircWood project was presented at a number of occasions in 2019. These include the following:

World Circular Economy Forum (WCEF) 2019

Place: Finlandia Hall, Helsinki

Date: June 3-5, 2019

Description of the event: The WCEF is an international event aimed at bringing together circular economy experts from business, academia and institutions. In 2019, the forum had a strong emphasis on how to scale-up the transition towards circular economy.

Project activity: Participation in the WCEF fair at the Aalto University and Helsinki University stand. Presentation of CircWood project through digital material (interactive presentation and power-point presentation), and display of wood waste sample in order to educate visitors about the issues related to wood waste, as well as the wood cascading potential.

WCEF (source:https://www.flickr.com/photos/140833168@N04/48001045102/in/album-72157708802714327/)

Departmental seminar day

Place: Haukilahden lukio, Espoo

Date: June 14, 2019

Description of the event: Annual symposium organized by the Department of Bioproducts and Biosystems of Aalto University to highlight the research activities conducted within the department and to enhance the scientific debate among the researchers.

Project activity: Power-point presentation of the project "Analyzing cascading options for wood waste from construction and demolition works" in the session "Research and analytical tools in the field of biomaterials".

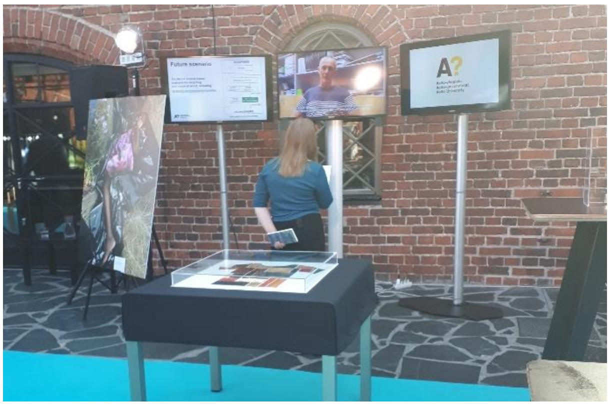
Helsinki Fashion Week (HFW) 2019

Place: Wanha Satama, Helsinki

Date: July 18-22, 2019

Description of the event: International event promoted by the Nordic Fashion Week Association, and aimed at the internationalisation of sustainable fashion between Nordic countries and abroad. The 2019 exhibition 2019 was focused on synergies between bio-based materials and fashion.

Project activity: 1) Presentation of CircWood project in the Bio-Playground exhibition through digital material, including the video “CircWood. Increasing the climate change mitigation potential of wood used in construction”, filmed in collaboration with Destaclean Oy. 2) Podcast by Mark Hughes on the project within Chemicals & Sustainable Fashion Industry. 3) Participation in the TalkTalk panel discussion “Nature, Science and Fashion” by Chiara Piccardo on 21 July 2019.



On the left: TalkTalk (source: http://helsinkifashionweeklive.com/); on the right: exhibition in Wanha Satama.

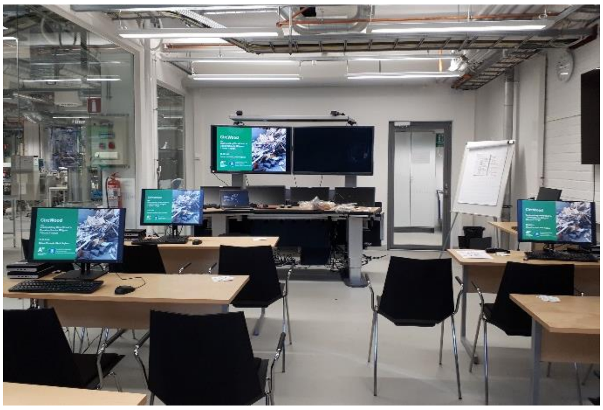
Forest Academy / Metsäakatemia visit

Place: Department of Bioproducts and Biosystems, Espoo

Date: August 22, 2019

Description of the event: Meeting with institutions and companies from forestry and wood industry (mostly Finnish politicians, government agency representatives, business CEOs, media, NGO leaders), organized by the Department of Bioproducts and Biosystems of Aalto University to present the research activities conducted within the department.

Project activity: Demonstration's message from CircWood project through power-point presentation and short discussion.

Forest Academy presentation (on the left, ph. credit Glen Forde).

Helsinki Design Week (HDW) 2019

Place: Väre building, Aalto University, Espoo

Date: September 5-26, 2019

Description of the event: The HDW is the largest design festival in the Nordic countries. The festival aims at developing multidisciplinary events on design, architecture and urban culture, targeted for professionals and the general public.

Project activity: The exhibition project "Circwood: Recirculating Wood within the Built Environment" was selected by Aalto University for at the exhibition "Designs for a Cooler Planet" ,within the Helsinki Design Week 2019. The exhibition project was designed and developed organized by (working group: Chiara Piccardo, Post-doctoral Researcher; Andrea Bandoni, Designer in Residence; Saara Kantele, MA student; Pirjo Kääriäinen, Professor; Mark Hughes, Professor). Our exhibition aimed at sensitizing visitors on the recycling and reuse of wood waste. It included photos, poster and the display of wood waste samples, as well as two piles of wood waste and wood chips, respectively. Wood.be (https://www.wood.be/fr/), a technological centre for wood and furniture in Belgium, learned about our exhibition from HDW website and visited our exhibition on 17 September.

HDW exhibition "Circwood: Recirculating Wood within the Built Environment".

Informal Meeting of Ministers for Economic and Financial Affairs and Eurogroup: The future of Design and Fashion is here

Place: Väre building, Aalto University, Espoo

Date: 13 September 2019 at 10:00-12:30

Description of the event: This event formed part of HDW

Project activity: a verbal presentation of the CircWood project and its aims was made followed by interactive discussion

HDW Exhibition (Images by: Pasi Aalto)

To date, no manuscripts for scientific articles have been finalised, however, as noted above at least two are planned from the results of the project.

6.2 Success of the communication

The project itself has been well publicised through several high-profile events during 2019, as described above. The main value from the project will be the peer-reviewed scientific articles that are planned. We expect (and are planning for) one peer-reviewed article to be published on the topic of the C model completed as part of WP3. This article may also include the results about the substitution effects that are being studied as part of the master's thesis of Fredric Mosley. We are planning for and expect a second article to be published in relation to Design for Disassembly based of the results of the survey of industrial stakeholders and other desk-based research. It is expected that these articles, when published, can be used as the basis of decision making (e.g. policy). It should be noted that one of the prime goals of this project was to develop the scientific evidence to support the development of DfD as a means of combatting climate change.

7. Sustainability and exploitation of results

7.1 Sustainability and concreteness of the results

Climate change, circular economy and wood construction are extremely topical and important subjects. The results from this project help highlight not just the importance of promoting wood construction as a means of combatting climate change, but also helps to substantiate that the cascading of wood, especially if this is enhanced by DfD and smart demolition practices, can help store C in the built environment for a longer period of time. Putting this into practice, will require incentives to help relevant stakeholders alter their practices as well as dialogue with groups such as architects and building developers, so that they might adopt such practices as DfD. The results and knowledge generated in this project help provide the scientific basis for claiming that DfD and other approaches to retaining wood in the technosphere for a longer period of time has benefits in terms of long-term C storage. Further work is still required. This is especially so in terms of practical DfD projects and substantiating the quantity and quality of wood recovered from demolished/deconstructed buildings. More work is also required to raise the awareness of the recycling potential of wood and especially the need to design for the recovery of useable materials.

7.2 Utilization of the results

Importantly, the results have paved the way for further research into the potential for wood cascading to mitigate climate change. Many questions remain unanswered concerning, for example, the quality and quantity of wood material available for reuse from the Finnish building stock or how can we incentivise demolition contractors to recover material for reuse, rather than for energy generation. Moreover, practical examples of wooden buildings designed according to DfD principles are needed to act both as a test-bed and to generate information about the quality and quantity of materials that can be recovered in the future. These kinds of results are needed to refine the model for C storage and for the development of DfD in wood construction in general.

8. Financial report

Please refer to separate attached financial report.

The major part of the original planned budget was related to the hire of a post-doctoral researcher at Aalto University. Additional cost for travel and for some minor materials, external services and other costs were also included. Ideally, the post-doctoral candidate was to have a background in architecture or civil engineering and experience with LCA / sustainability impact assessment. After a competitive recruitment process, Dr Chiara Piccardo (post-doctoral architect with expertise in LCA) was hired for the position. Dr Piccardo began working on the project on 1.1.2019 and was employed until 30.09.2019 when she left to take up a position at another university. As it was deemed unlikely that a suitable replacement post-doc could be recruited to the project for the remaining period of 8 months, it was decided to engage an external expert to conduct work relating to WP3. The budget was accordingly revised as shown below and a proposal sent to the Ministry of Environment.

Type of cost	€
Personnel costs	128321
Costs of equipment and instruments	0
Procurement of expert services	26358
General costs	3276
Costs in Total	157955

The main change to the budget was to transfer €26358 to the "Procurement of expert services" heading to cover the costs relating to the hiring the external expert. Some of the remaining personnel budget was used to hire a master's thesis worker (Fredric Mosley) to carry out part of the work related to WP3. A further researcher (doctoral candidate Bahareh Nasiri) was hired part-time to supplement activities related to WP1 & WP2.

9. Recommendations for future projects and programs

Many of the ideas and recommendation for the future are incorporated in the above. Concrete project ideas might include tangible DfD projects in wood. As there is no better way of learning than by doing, creating a design, construct and deconstruct (and reconstruct!) project for a wooden building would enable ideas to be tested and data generated. It would also act as an exemplar and might well stimulate others to create other DfD wooden buildings. It would also help promote the concept of DfD in wood that would help promote the idea more widely. Engaging all stakeholders is seen to be important to comprehensively understand the problems as well as the opportunities for DfD and, more generally, wood cascading. Recent work conducted in the frame of CircWood and other projects, such as the aforementioned InFutUReWood, have shown that there is a paucity of statistical data about wood use that would be needed to fully support circular wood construction. Much data does exist (such as in municipal archives), but a project that compiles detailed information (e.g. on wood products, their dimensions and quantity) about wood construction would be needed.

10. Conclusions and summary

The overall aim of the CircWood project was model the effect that recirculating wood within the built environment has on carbon storage with wooden buildings, taking into account different wood use scenarios and the implementation of design for disassembly. In the first part of the project, buildings containing the greatest proportion of wood were identified. It was found that wooden buildings account for about 84% and 99% of the permanent and free-time residential buildings respectively and for 58% of non-residential buildings. Demolition and waste management practices were surveyed with the intention of gaining knowledge about the quantity, quality and dimensions of demolition wood as well as a qualitative assessment of attitudes towards wood cascading by these respective industry sectors. Cascading options were investigated through desk research and interviews. In the final phase of the project, a model was created to demonstrate how retaining wood in the technosphere (through cascading) increases the amount of carbon stored. Augmented levels of cascading (i.e. through DfD) increase the level of carbon stored and for a longer period.

This basic research study has demonstrated that cascading wood from buildings can provide a means of increasing C stored in the built environment, helping to mitigate climate change. Further work is ongoing to assess the substitution effects that accrue from the use of cascaded wood. Design for disassembly is seen as a means of increasing the quality and quantity of wood recovered from the demolition of buildings. Modeling suggests that retaining recycled wood in products that last a long time (e.g. as other structural components in buildings), increases the amount of C stored. Nevertheless, the most effective way of increasing C storage is to extend the lifetime of wooden buildings.

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