A Framework for Incorporating Wood into the Circular Economy

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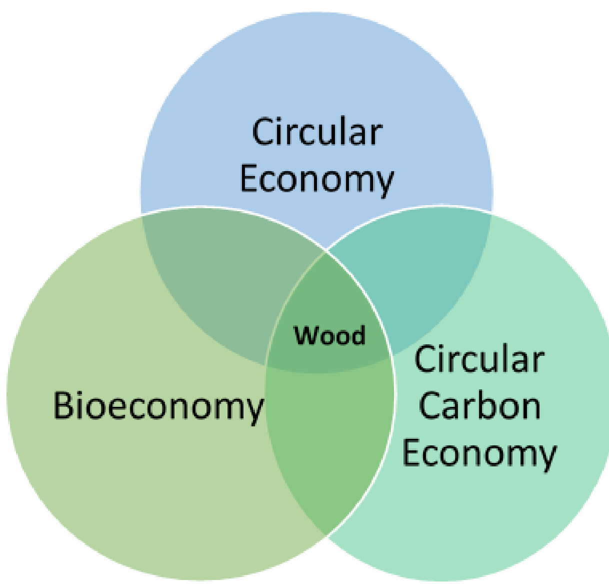
This workshop has been convened to explore methods for incorporating circularity principles into the North American wood economy. There have been numerous workshops on circular economy, bioeconomy, and circular carbon economy across the globe, but none have explicitly explored what research is needed to integrate these concepts and approaches across the lifecycle of structural wood products from forest to frame to end-of-use and end-of-life in North America.



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Background Information

Circular Economy

The circular economy is a framework concept that offers a systematic strategy for minimizing the loss of materials and value, and the negative externalities associated with economic production-consumption systems. The circular economy is grounded in long-standing research themes, including industrial ecology, regenerative design, performance economy, biomimicry, and cradle-to-cradle design. Fundamentally, circular economy principles focus on designing products and materials in a way that minimizes waste across their entire life-cycle. This includes an expanded view of the value-chain, the development of business models that enable an extended 'use phase' of materials and products, potentially over multiple service-lives, as well as planning for alternate re-use options and finally material and/or chemical recycling at end-of-life. The circular economy framework differentiates between cascaded cycling options for *technical* materials and products (e.g. durable goods made of plastic and metal), and those for *biological* materials and products (e.g. agricultural products and bio-based materials).

Bioeconomy

The bioeconomy refers to the production-consumption systems of renewable biological resources and materials, including agriculture, forestry, fisheries, bio-based materials, and bioenergy. Primary emphases of bioeconomy research include technology and innovation to enable the capture and utilization of biomaterials, as well as the development of viable and competitive bio-based substitutes for petrochemically-derived materials and products. Key strategies include the optimization of material and energy extraction from existing biomass streams, and improving yield through the introduction of new or improved species and new and improved extraction and processing activities.[1] An important consideration of the bioeconomy is the assurance of resilience and sustainability: the ability for human, animal, and ecosystem needs to be met and maintained over time; and the balancing of economic interests without compromising environmental and social priorities throughout the value chain.

Circular Carbon Economy

The circular carbon economy extends the concept of circular economy to the elemental basis of carbon, focusing on the capture and using of end-of-life carbon oxides (CO and CO_2) through carbon utilization technology (carbontech or carbon recycling).[2] Carbontech innovations are products that 'use' waste carbon – as production feedstock or fuel – and currently include: construction materials (e.g., cement and aggregate); fuels, chemicals and polymers; and algae-based products (e.g., feeds, fuels, and fertilizers). The utilization of waste carbon in this manner may enable an effective 'circular carbon economy' that works alongside carbon reduction and sequestration efforts. In its work collecting Life Cycle Inventories (LCI) of wood products for the past 20 years, CORRIM has contributed significantly to the understanding of net carbon stores in the forests and products, as well as opportunities for the displacement of fossil carbon emissions.

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[1] European Bureau for Conservation and Development. 2019. "The Role of Bioeconomy in the Circular Economy." Accessed on 12-Dec-2019 from http://ebcd.org/role-bioeconomy-circular-economy/.

[2] Center for Climate and Energy Solutions. 2019. "Charting a Straighter Path to the Circular Carbon Economy". Accessed 12-Dec-2019 from https://www.c2es.org/2019/10/charting-a-straighter-path-to-the-circular-carbon-economy/.

Wood-products (and other biomaterials) present an interesting opportunity at the nexus of these concepts: within the Circular Economy wood can be designed to be cycled through both technical *and* biological cycles; and fundamentally, wood and wood products are central to both the bioeconomy and the circular carbon economy.

A primary opportunity in wood production-consumption systems relates to the minimization of construction and demolition waste are desirable goals as the material is deemed to have no further use. However, with forests and wood products, that circularity is further extended from the waste stream through the uptake of greenhouse gases during new forest growth. Structural wood products have the potential to act as a ***carbon negative technology*** that could contribute to the goals of the circular carbon economy without having to develop entirely new engineered systems to remove carbon from the atmosphere. A substantial amount of data and sophisticated tools exist to address key components of the problem of incorporating wood into the circular economy. Some effort of providing structure, framing, and linkages is required.

The Ellen McArthur Foundation & World Economic Forum Model

Globally, the Ellen McArthur Foundation (hereafter EMF), in collaboration with the World Economic Forum (WEF), has taken the lead on developing and promoting the circular economy. They have developed a model that characterizes material flows into 'green' and 'blue' streams (Figure 1). The green stream consists of renewables (biomaterials) that are consumed with materials returning to the environment as biosphere replenishment nutrients (including animal feed and compost) instead of going to the landfill. The blue stream are the non-renewables (technical materials) that are extracted, mined, and/or processed and then put into use, but not consumed as part of their use.

Key principles of the circular economy are:

- Design out waste and design for circularity
- Reduce, Reuse, Recycle
- Cascading uses and multiple service-lives
- Hierarchy of Value-Retention Processes: Direct Reuse, Repair, Refurbishment, and Remanufacturing
- Preservation of natural capital

Material, product, and system design are critical to the success of the circular economy. A core principle is to design-out waste from our production-consumptions systems, which is a key component of reducing the demand for raw materials. Once products and materials are in-use, effective design ensures that they can be repaired, re-used, refurbished, remanufactured, and ultimately recycled. Cascading use dictates that the inherent and embodied value of materials are cycled into highest-and-best use/value options, and that by-product wastes are incorporated as inputs into other production processes to ensure optimal value retention. Efficient design recognizes the hierarchy of uses, with some options presenting greater benefit or value; these can be measured by specified metrics that include avoided impacts (e.g. emissions, solid waste, virgin material requirement), as well as time-in-use, displacement of less-preferable materials, and employment opportunity.

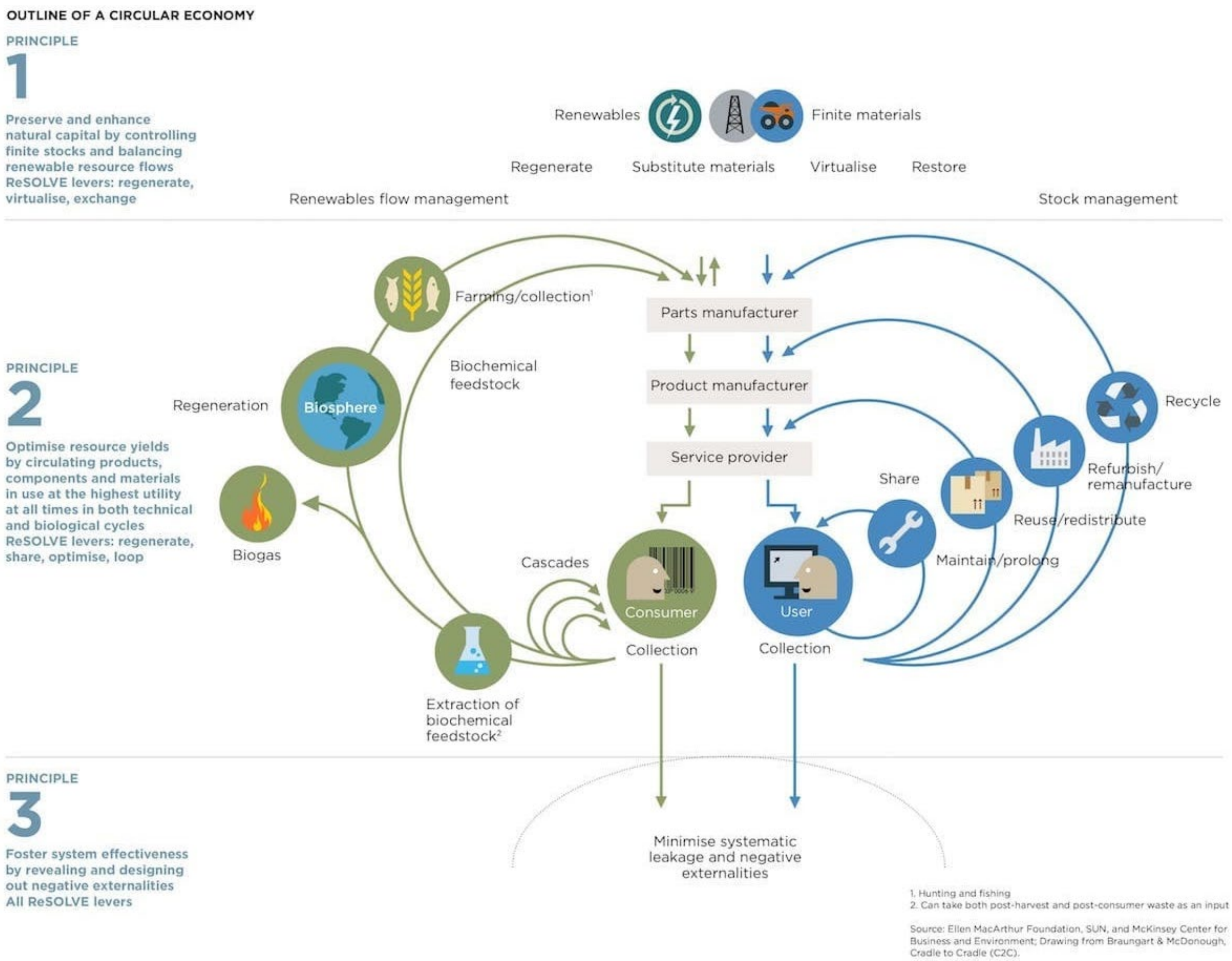

Figure 1: Outline of a Circular Economy (Ellen McArthur Foundation)
https://www.ellenmacarthurfoundation.org/circular-economy/concept/infographic

For technical materials (blue stream), once a product's first service life is complete, cascading use dictates that the product or material, to the extent possible, follows a value-retention process (VRP) hierarchy (Figure 2).

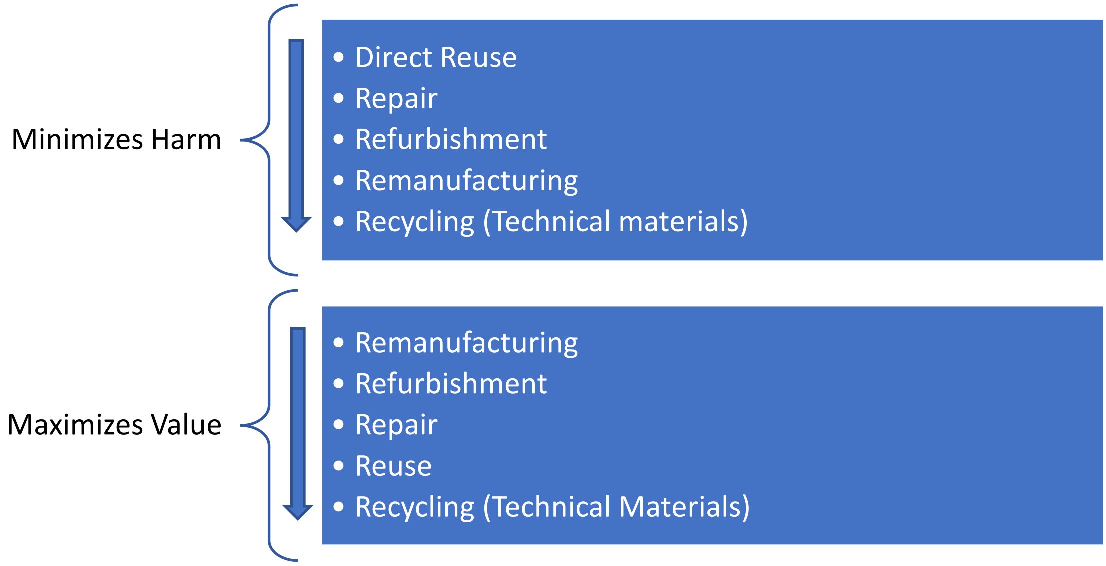

Figure 2 Value Retention Process Hierarchy.

For biomaterials (green stream), goals include the capture of valuable bio-chemical byproducts, bioenergy, and the return of biomass to the biosphere as part of the bioeconomy to ensure that farmland, and particularly the soil resource, is replenished and maintained at its fullest capacity.

Wood within Circular, Bio-, and Circular Carbon Economies

The EMF model and key principles can apply to wood used for bioenergy without modification, as the material is converted and consumed without opportunity for reuse and recycling. For wood used in construction or furniture, the EMF model requires modification, and clarification of the potential for wood as a 'technical nutrient' within technical value-retention cycling processes. That modification acknowledges that wood begins its life cycle as a renewable resource (green stream) and then crosses over into the technical system (blue stream) at the point of manufacturing. At the point of manufacturing wood splits into two distinct streams, with solid wood and engineered wood products continuing within the technical materials system (blue stream), and co-products such as hog fuel, consumable biochemicals, consumable pulp products, and residues, crossing back into the biomaterials system (green stream). In either case the wood will continue its lifecycle through cascading uses and remanufacturing until it is recovered for its energy value at the end of its final useful life. At that point, the core elements of the wood are released back to the atmosphere as carbon dioxide which is available for re-uptake by the regenerating forests to begin the cycle again. We have incorporated this modification as a "brown" stream in Figure 3, which is a modified EMF Figure 1 suitable for evaluating how to fit wood into the EMF/WEF popularized circular economy construct.

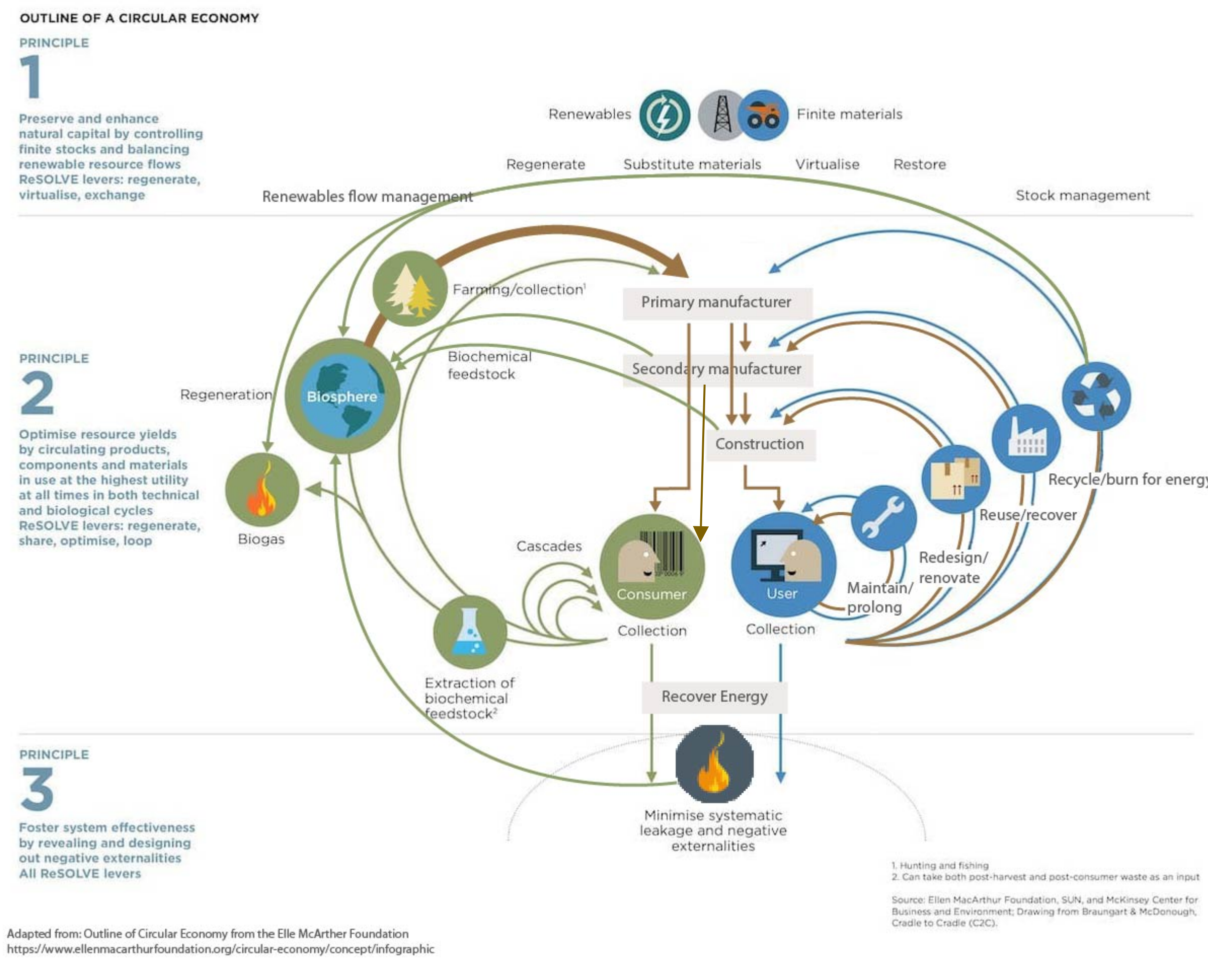

Figure 3: Adaptation of the EMF circular economy model with the addition of solid wood with production steps and cascading uses within both the green and blue streams. Note the separation of the wood material input (thick brown input) into two cascading lines, one following the green stream and the other following the blue stream. In all cases the final collection and disposal can include an energy recovery element that controls GHG emissions.

In addition to the key principles that apply to all parts of the circular economy, wood requires special evaluation of two additional principles that intersect with the bioeconomy:

- Land use and land use change (LULUC) plays a significant role in the efficacy of incorporating wood into the circular economy. Retaining working lands is an integral component of forest sector stability and therefore sustainability. Preservation within the context of forest land has a different meaning than retention of working lands.
- Social License – non-market values, rural economies, ecosystem services, and a host of other social factors influence the potential/feasible pathways for wood in the circular economy.

Figure 4 shows the extended life cycle of wood products coming from working forests and flowing into construction uses. The graphic is color coded to show the cross-over from the green to blue streams and back again, through cascading value-retention processes in the technical stream until end-of-use, and then into the bio-stream at the end of its final useful life. Evaluating wood as part of the circular economy will require a series of nested inquiries as each step in the life cycle will have unique research questions and challenges.

For example, in the first stage of the life cycle (growth), reduce/reuse/recycle considerations are not that prevalent, however questions of land use, land use change, and social license to practice forestry are paramount. Regardless, feedback loops to this part of the lifecycle are required as decisions made at this early stage affect all remaining life cycle stages as tree growth, yield, and marketability, and the markets they are directed toward, drives the allocation of wood products into either the blue or green streams at the outset. Further, wood quality can drive the opportunities for cascaded value-retention processes, and the eventual fate of the wood in the blue stream in particular. This simple example of upstream decisions impacting downstream uses and cascading uses, illustrates the need to develop a framework that can model/track the interactions specific to wood within the context of circular, bio-, and carbon economies, and identify the most critical levers throughout these systems for affecting desired outcomes.

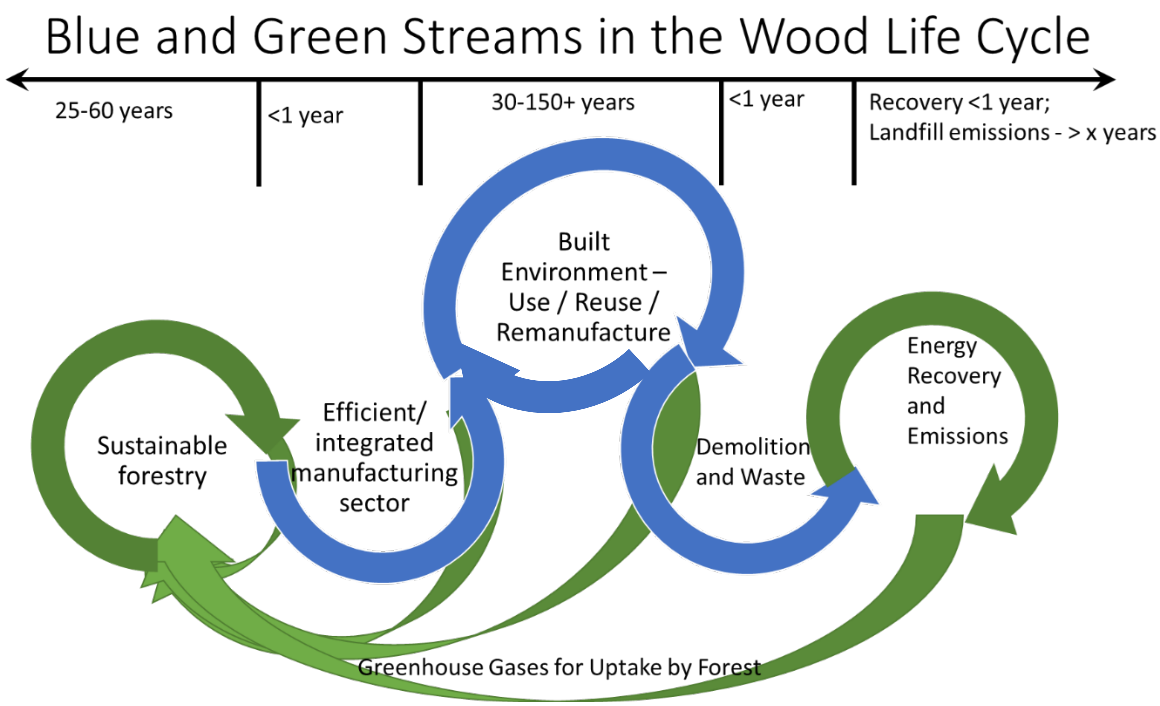

Figure 4 Life cycle of a solid wood product destined for building construction showing the cross-over from green to blue material flows vis a vis EMF circular economy model.

This workshop is designed to build relationships and capacity for integrated cross-disciplinary research. In preparation for the workshop we received input from attendees that identified more than 130 questions that they were interested in pursuing. Those questions were aggregated into generalized themes to be explored as part of the workshop, as outlined below:

1) Characterize how circular economy, bioeconomy, and circular carbon economy frameworks can be integrated and used to frame the research need for integrated problem solving in the wood economy in North America. (a kind of CE 101 for wood within these systems)
2) Develop questions that can direct integrated operational research, with an awareness of systems-level opportunities and implications.
3) Identify data sources and tools, both extant and required.
4) Identify research, development and deployment needs for solid wood (within the blue/technical stream)

5) Identify research, development and deployment needs for wood residues (bioenergy and biochemical uses within the green/bio-stream).
6) Explore linkages to land use and land use change that are integral to circular economy, bioeconomy, and circular carbon economy outcomes.
7) Identify policy, education, outreach, and communication needs that can aggregate and deliver current knowledge to the forest and wood products sector, the design community, land use and city planners and code officials, elected representatives and the public
8) Characterize how non-market concerns influence the adoption and diffusion of these framework principles in the wood economy.

We are set to welcome over 40 of your colleagues from the US, Canada, and Chile to Seattle on January 21 and 22 for the exploration of this material. On behalf of CORRIM, I look forward to hosting you there. Thank you for joining us as we explore this pivotal subject matter.

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