Working Paper # 2011-08

Circular Economies and Canada's Forest Sector

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Abstract

The concept of circular economies suggests that optimal flow of goods and services can be represented as a loop. This can be manifest in a process when products are recovered after a period of use and transformed into new goods, and when the last product may be used as the basis for a new iteration of products. The concept is also present in regional geographies, where resources may flow from point to point for processing and use, and where the final leg of the process brings materials back to the starting point. A popular example of the circular economy is the carbon cycle, which sees old products serve as the basis for new growth and eventually new commercial activity. The forest economy has the potential to take the circular approach. This paper describes the current state of Canada's forest sector and identifies barriers to achieving a true circular approach. For example, Ontario is a region where massive disruptions to the existing economy have left the industry in crisis. Opportunities for reinventing the forest sector are discussed, as are the potential impacts on employment and economic returns from this approach.

Presented at the Work in a Warming World (W3) Researchers' Workshop:
"Greening Work in a Chilly Climate", Toronto, Canada, November, 2011

Acknowledgements

This study is part of the Work in a Warming World Project (W3), a SSHRC-CURA research programme

The author appreciates the financial support received for this project through a Social Sciences and Humanities Research Council of Canada, Community-University Research Alliance (SSHRC-CURA) research grant. W3 is a five-year research project to address the challenge of climate change for Canadian employment and work carried out under the direction of Carla Lipsig-Mummé at York University.

Circular economies

The concept of a ‘circular economy’ reflects pre-industrial approaches to almost all forms of agriculture and industry, where residues and products from processes were consistently recycled in order to ensure glean all utility from these materials. In these times, a significant proportion of material inputs were renewable by nature (i.e. wood and plant biomass, animals, and fish), although the management of these inputs might not have been sustainable in practice. The disposal of these products at the end of their useful lifespan provided inputs for the next crop or herd, and thus none of this material was wasted. The use of non-renewable materials (primarily stone and metals) tended to be in long-term applications, and these materials were also reused extensively. It is still not unusual in very old cities to see stone that dates back hundreds or thousands of years reused in relatively modern construction. One of the dominant features of the preindustrial ‘circular’ economy was that human and animal labour provided the primary energy inputs.

The shift from this paradigm into our current, industrial economy robbed us of a system that had the potential to work in harmony with nature, replacing it with a highly mechanized, unbalanced tool that treats the world as both a storehouse for feed-stocks and as a waste-bin for spent product. Our present economy relies heavily on non-renewable materials and fuels, has shifted the focus from labour and service to goods, and operates via processes that generate emissions that have no obvious return path to the ecosystem, which has led to runaway emissions into air, water, and soil and now threatens prosperity and livelihoods in various places around the globe. The threat of climate change, and the impact that it will have on the global population, is serious enough that new alternatives to our industrial economy must be sought.

Mathews (2011) argues that a renewable, ‘green’ economy is already beginning to develop, but that this development is blocked by powerful vested interests, most notably fossil fuel corporations. The emergence of a real alternative to our current economy, as observed in most specifically in China, should be explored. Mathews further points out that the best features of the industrial economy can be retained, particularly the capacity for entrepreneurship and innovation, in a new, circular economy.

The modern definition of circular economies date to a 1976 report prepared by Walter Stahel and Genevieve Reday-Mulvey entitled ‘The Potential for Substituting Manpower for Energy’, later released as a book by the same name (Stahel and Reday-Mulvey 1981). The book draws on pre-industrial systems to explore the benefits of a ‘looping’ economy, where the products and residues of any given process might be designed to act as inputs to a downstream process, and where the final outputs might be returned to the ecosystem at large. This study stresses the importance of certain factors, such as designing products for a long service life, reuse of materials over a series of products, and reducing the amount of ‘waste’ at every stage. Labour is shifted to the core of the concept, transforming the approach from goods - to services-based. Closed-loop systems can be useful in reducing negative environmental outputs including waste, energy consumption, transport processes and packaging (Winkler 2011).

The closed loop approach of the circular economy requires companies to restructure their supply chains, and to consider the impacts of each production decision on downstream characteristics and ultimate ecological recovery (Winkler 2011). This approach is very much at the core of industrial ecology, which focuses on connections between companies and products, and draws parallels between these linkages and natural ecosystem functions (see Ehrenfeld 2004). The circular economy draws upon and encompasses principles from other fields as well, such as biomimicry, which adapts or copies natural processes in designing new industrial approaches or technologies (see Robinson 2004). Cradle-to-cradle views the inputs to industrial processes as nutrients, both renewable and non-renewable, with the latter category limited to materials that have no negative impact on the environment (McDonough and Braungart 2002).

In China, a primary constraint to economic growth is the lack of easy access to materials, due to intense population pressure which reduces local supply (at the per capita level) to minimal levels. This quandary may be seen as a proxy for a ‘carbon constrained’ future, which would see the global population using less material and energy on a per capita basis, due to a combination of scarcity and policy. Effective low-carbon systems have been developed in China to accelerate economic growth, particularly in rural regions such as the northeast, which is not yet fully engaged in the global economy (Zhen et al. 2011).

Dalian, a city in the northeast, has introduced the circular economy to deal with resource scarcity and environmental degradation. A recent study identifies several challenges to implementing a circular economy approach, including a lack of incentives industries, lack of financial support, a need for increased awareness of and participation in the circular economy (Geng et al. 2009). This study suggests pricing and tax reforms to incentivize conservation, allowing a budget to promote the circular economy, and education as responses to these issues. Geng et al. conclude that Dalian is a useful case study but that every city must tailor its own approach for differing contexts and conditions.

From the literature, it seems clear that a circular economy may be characterized by the following features:

a) the use of inputs that can be reused and ultimately returned to nature, to act in turn as the basis for a new series of inputs;
b) the development of long-lasting or persistent products which, at the end of their useful lifespan, can be broken down and used as inputs to a new product, or returned to the natural ecosystem;
c) selection of renewable forms of energy to power systems, including secondary forms of energy such as labour;
d) organization around the needs of human populations at local or regional scales, rather than around sectors producing a class of goods at the regional, national, or global scales; and
e) inclusion of multiple sectors along the circular value chain.

Forestry and the circular economy

Very few have explored the application of circular economy approaches to the forest sector, although the industry has used the circular nature of its business model, including the variety and durability of products generated by the sector, the ability to recycle these materials along the value chain, the benign nature of products for disposal, and finally the capacity of forests to recapture carbon dioxide, offsetting potential emissions associated with forest harvest and biomass use.

Yufang and Yanqing (2011) note that the application circular economy principles build on these strengths, reinforcing the ability of forests to sequester carbon over the long term and increasing their ability to offset greenhouse gas emissions. Importantly, their model suggests that a circular economy approach can extend the wood supply, as the utility of every fibre harvested is maximized, essentially giving broader or longer-term access to the services that forest products provide using the same amount of wood.

For years, the Canadian forest economy employed circular elements in manufacturing, the best example of which is the relation between sawmilling (processing of raw logs for lumber) and pulp milling (processing of chips and/or pulp logs for pulp products). Sawmilling produces large quantities of chips and residues which in the past were taken up by pulp milling operations, often owned by the same vertically integrated company. However, in recent years, demand for pulp has weakened in the face of strong competition from tropical countries and declining markets for products like newsprint. In the past decade, Canadian production has plummeted. For example, only five of sixteen pulp and paper facilities that were operating in Ontario in 2005 remain in operation (see Mabee and Mirck 2011). Similar trends may be seen in British Columbia and Quebec. As pulp and paper production capacity goes offline, there is a corresponding decline in demand for chips and residues from sawmilling operations, reducing the profitability of the overall sector.

Importantly, because the wood and paper industries are often the major employer in remote, resource based communities, the decline observed in the forest sector has a proportionally greater impact on Canada’s rural economies. By the late 1990’s, there were over 300 communities dependent upon the forest sector (Statistics Canada 2006). Statistics Canada reports that from 2000 to 2009, employment in the forest sector has fallen by approximately 50%, from 78,550 to 39,374 employees (Statistics Canada 2006; Statistics Canada 2010), which has dramatically impacted these communities. While some discussion must surely be had about the long-term viability of each and every town, there remains a social imperative for reimagining Canada’s forest sector and for exploring means by which employment might be recaptured or extended.

Forests and the carbon cycle

One important characteristic of the forest sector is that when managed properly, forests are renewable and thus provide a sustainable source of material to the economy.

Increasingly, however, we are coming to be aware of the importance of forests to regulate climate, and to absorb and store carbon from the atmosphere.

In Ontario, the average rotation age for boreal forests varies significantly as one progresses from east to west and north to south across the range of this forest. As a rough rule of thumb, one might anticipate between 60 and 120 years between commercial harvests (as reported in Thibault et al. 2008). Over this period, significant amounts of carbon may be sequestered, although significant amounts of carbon may also be released in natural wildfire events or via the impact of forest pests and disease. A study carried out by Chen et al. (2010) modeled hypothetical carbon stocks in Ontario's managed forests, and in harvested wood products derived from those forests, between 2001 and 2100. This study considered the potential impacts of fire and pests on the forest, carbon releases associated with these disturbances, and the offsetting factor that stored carbon in harvested wood products can play. The study found that forest carbon stocks would increase by about 48 million tonnes over the 100 years of the model forecast, even when fire and other disturbances were factored in (Chen et al. 2010). In other places, where forests are under great threat, the same trend may not be true; one study reported that sequestration of carbon in forests is likely to decrease over a 50 year period, from 274 million tonnes per year in 1990 to 161 million tonnes per year in 2040 (Skog and Nicholson 1998).

In a managed forest, however, the opportunity for carbon sequestration does not end with trees, but includes forest products that appropriately designed and utilized. Skog and Nicholson (1998) reviewed historical estimates of carbon sequestered in wood and paper products across the United States, and generated projections of potential carbon storage attached to different products. Their study estimates that the net sequestration of carbon in U.S. wood and paper products (additions including net imports, minus emissions from decay and burning each year) is projected to increase from 61 million tonnes per year in 1990 to 74 million tonnes per year by 2040 (Skog and Nicholson1998). In Ontario, the total amount of carbon stored in forest products was projected to increase by about 4.2 million tonnes per year 2001 and 2100 (Chen et al. 2010).

Table 1: Storage of carbon in forest products (from Skog and Nicholson 1998)

Product	Half-life in use (years)
Single-family homes	100
Multifamily homes	70
Residential upkeep	50
Mobile homes	20
Nonresidential bldgs.	67
Pallets	6
Manufacturing	12
Furniture	30
Railroad ties	30
Paper (free sheet)	6
Paper (all others)	1

The total amount of carbon sequestered in various forest product applications may be measured fairly accurately using half-lives, which is simply a measure of the length of time required before half of the product is disposed of or otherwise reused (Skog et al. 2004). Skog and Nicholson provide a table of forest product half-lives as estimated in the United States, reproduced here as Table 1. It can be seen that some forest product categories are very long-lasting, particularly homes and nonresidential buildings, while some product categories have significantly shorter lives (particularly paper).

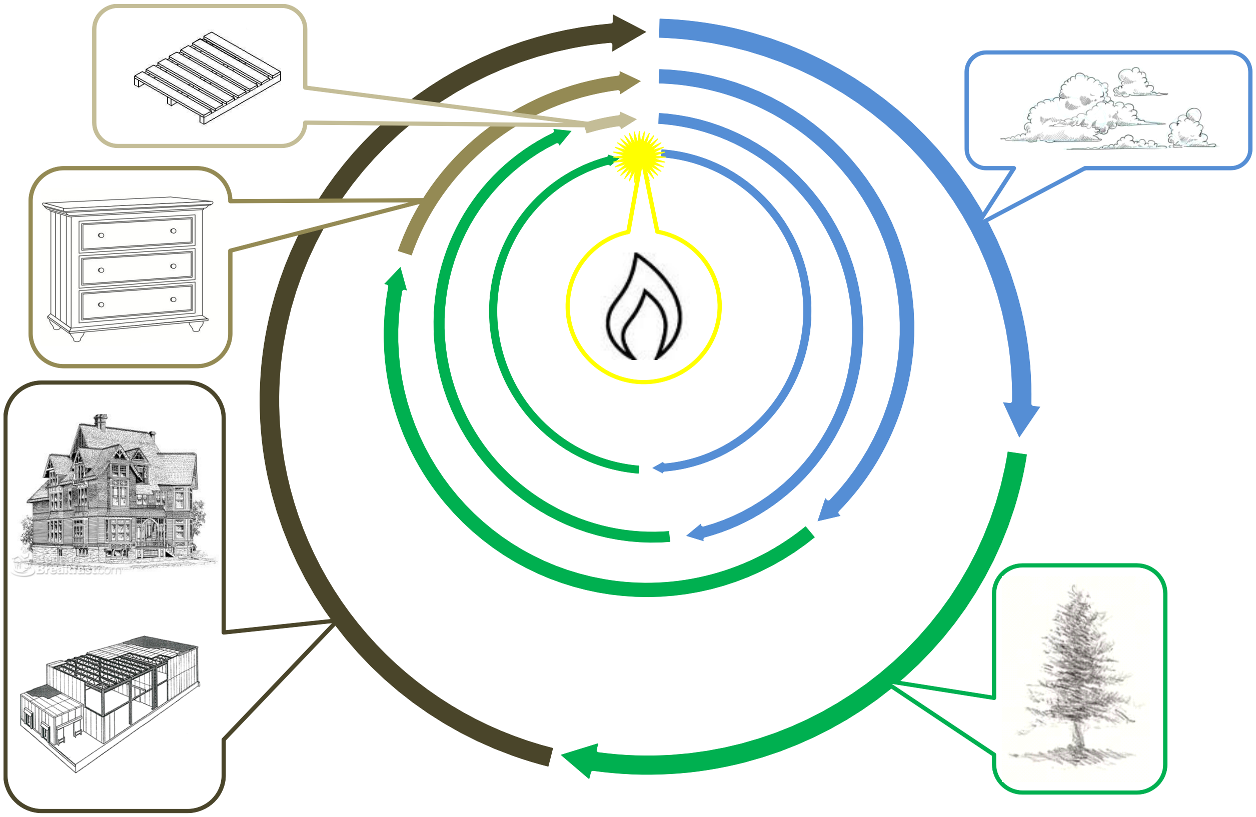
The data presented in Table 1 is instructive in establishing more optimal forms of product use following the principles of the circular economy. It is worth noting that this study made three recommendations for increasing net carbon sequestration, including increasing product use-life, increasing recycling of products, and increasing generation of energy at end-of-life as three ways of increasing net carbon sequestration (Skog and Nicholson 1998). These three principles each support development of the circular economy.

A hypothetical model of the circular forest economy

The typical arrangement of the forest products sector is shown in Figure 1. In this diagram, the industry is described from the perspective of carbon, with arrows representing the subsequent stages of atmospheric residence (blue), uptake and growth (green), and product storage (brown). Theoretically, the product cycle is circular, with carbon ultimately emitted (through combustion or decay) and returned to the atmosphere, although in practice a good proportion of solid forest product end up in landfills and may represent much longer-term sequestration. The sizes of the circles in this diagram represent the approximate half-life of each stage by product, according to data from Skog and Nicholson (1998). The half-lives for atmospheric residence and growth are held consistent at an arbitrary 60 years each, although as mentioned earlier boreal forests may have different growth rates and may be cut on different cycles.

An important message to take home from Figure 1 is the ‘nested’ structure of the forest industry. Carbon spends about the same amount of time in the atmosphere or tied up in growing trees for any product category; however, certain categories (like homes and other buildings, represented by the outer circle) have expected half-lives that are much longer, while other products (including furniture in the second circle, and wood pallets in the third circle) have much lower potential to store carbon. Wood used for energy (represented by the fourth and smallest circle) has virtually no ‘storage’ time associated with product and thus can be seen as an almost instantaneous change from growing trees to atmospheric emission.

Figure 1: The 'nested' structure of the existing forest products sector



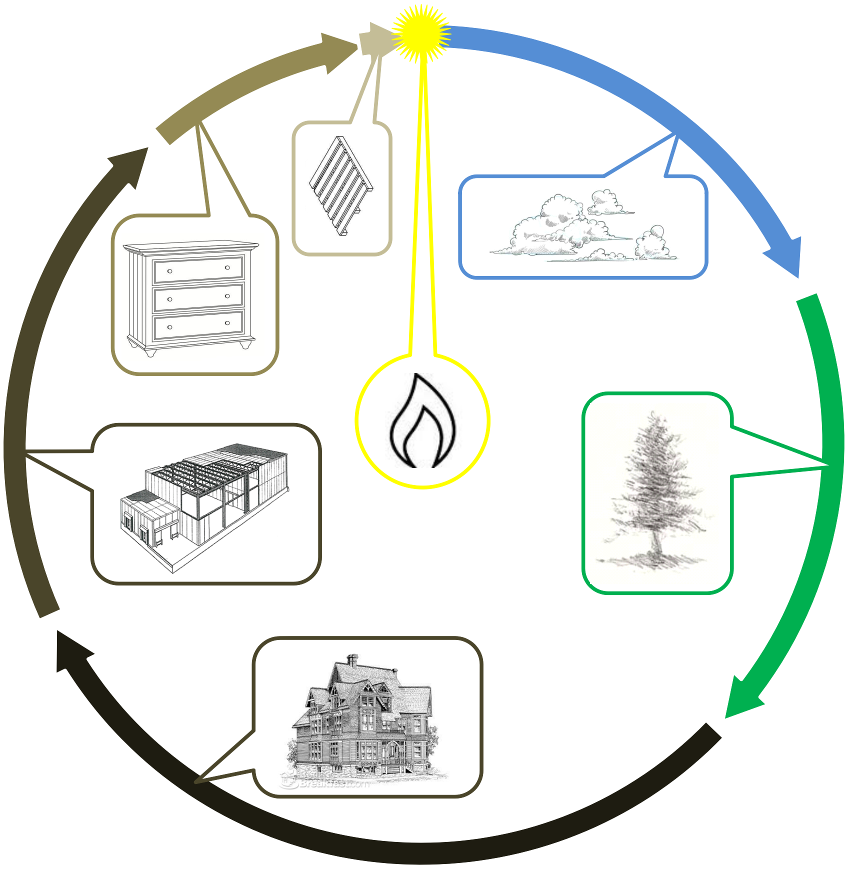
Currently, wood for each of these product categories are typically sourced directly from the forest, and not recycled from previous usage. Even in the case of wood energy, the material used for energy production is taken from sawdust and residues collected at sawmills; this material has not been used in any previous application. This has two important implications for the forest sector.

The use of virgin building materials means that each individual forest industry has optimized their production to utilize clean, homogenous inputs taken directly from the forest (or sawmill) - in essence, blank slates. This allows the generation of these forest products to be carried out with a minimum of labour, and greater reliance upon mechanized systems. Evidence for this abounds. Homebuilding has become more and more dependent upon modular construction or upon 'cookie-cutter' developments where entire subdivisions are built with small, dedicated crews on each task. Furniture manufacture, to a large extent, has grown to rely upon mechanized systems capable of producing large quantities of 'self-assembly' units. Even pallet manufacture, given easy-to-handle raw material inputs, can be done with a minimal labour input.

Secondly, the use of forest fibre in a 'nested' fashion means that society requires different fibre for each application, and that we assume that this fibre will essentially be useless when the lifespan of our application is over. This is certainly not true, and the existence of a significant wood reclamation industry speaks to the value in old wood for any number of applications. At this time, however, our industry is not organized to take advantage of wood biomass when the initial application is complete, with the exception of the paper industry, where recycling (back into paper) has become the norm due to policy. Because forest fibre is not being recycled, we need to cycle more carbon to meet a variety of different needs, and we do not optimize our forest industry for carbon sequestration.

In Figure 2, we suggest a 'series' approach to forest products manufacture. In building this diagram, we recognize that each product can serve as the input for another product downstream, until fibre quality has degraded to the point that disposal becomes necessary. Each product is selected for its ability to sequester carbon; thus, residential housing (arguably the highest value application) is the first choice for fibre. Construction of houses to take advantage of the circular economy would involve better planning for recycling, perhaps by excluding metal fastenings or by favouring cellulose-based insulating and paneling material. Such design might also minimize the use of petroleum-based resins and paints. The advantage of using all wood-based products in a wall section, for example, would be the ease by which this section might be pulled out of service. The emergence of structural insulated panels, a composite building material used in modularized construction, is an example of the type of design philosophy which might be applied here, with the directive that the panels be sourced solely from wood and natural materials.

Figure 2: A ‘series’ approach to forest products manufacture



After use in a residential application (with a 100-year half-life), these panels might find new application in non-residential buildings, including warehouses or utility structures. In these applications (with a 67-year half-life), lower-level finishes are likely to be more acceptable given the relatively high wear-and-tear on the structure. At the end of this use, solid material and panels from within the structure could be recovered and recycled into furniture, which would require significant amounts of labour input. Finally, furniture being recycled at the end of its use might be recycled into pallets or other short-lived wood products, and finally recovered into energy.

At each stage, the key to effective recycling is making the correct decision in previous manufacturing stages. Effectively, each product needs to be designed for its current use as well as for the next potential application. In the paper sector, we have seen this approach in the development of vegetable inks designed specifically for removal in the recycling process (see Mørkbak et al. 1999). The concept of extended producer responsibility, which attempts to integrate real environmental costs into the market price of products (see McKerlie et al. 2006), is one approach which could help drive appropriate decision-making in a circular economy approach.

The advantage of this approach over the ‘nested’ forest products approach is threefold. Firstly, manufacture of new products using recovered goods is far more labour intensive, but should involve lower material costs (as the material would have been considered waste in the nested approach). Secondly, the potential to sequester carbon is vastly increased. In the hypothetical model we present in Figure 2, carbon atoms would spend 265 years in a sequestered form (either growing biomass or a series of forest products), and only 60 years in the atmosphere (on average). In other words, the series approach sequesters forest carbon over 80% of the total cycle, slowing the cycling of carbon through the atmosphere. Finally, each fibre generated through forest growth becomes useful for a longer period of time over multiple applications, and the majority of wood becomes available for energy generation at the end of its lifespan. This reduces the total amount of wood that ultimately needs to be grown, as each fibre is designed to be used multiple times, and thus increases the potential impact of forestry to supply material and energy to a growing population.

The circular economy approach to the forest sector can only be implemented by overcoming a series of challenges. A serious challenge is the timescale involved. It would take literally centuries to achieve all of the benefits of a true circular economy within the forest sector. What financial incentives can be provided to ensure that appropriate decisions are made today about fibre that may be used for hundreds of years? Can we properly anticipate the requirements that our descendants may have for this material? How can we track wood through the circular economy and ensure that it is being used appropriately at each stage, without becoming overly prescriptive with policy and regulation? Finally, and perhaps most importantly, how can we begin to shift to this model of an economy, when we do not have the impetus of resource scarcity and poor economic leverage to drive us forward?

Conclusion

Development of the circular economy in Canada's forest sector could provide significant benefits, as measured by fibre availability and perhaps in terms of employment. A reorganized forest sector meets the basic principles of the circular economy: its products can be reused and ultimately returned to nature, acting as the basis for a new series of inputs. A re-imagined forest industry would focus more upon long-lasting products, shifting the focus from rapid production of goods to more effective use of labour. A modified forest sector could provide more diverse jobs across a range of products; a single fibre could provide multiple jobs over decades, as material is used and reused in various applications. Finally, the redesigned forest sector would ultimately deliver the vast majority of fibre harvested to energy production, but only after centuries of use; this would increase potential energy from the forest while maximizing fibre use.

Our analysis suggests that one of the greatest advantages to the circular economy is the ability to maximize both carbon sequestration and fibre usage, which will reduce the proportion of time that forest carbon will spend in the atmosphere (relative to the total economy), and which will increase the amount of fibre available at any given time for various applications, including bioenergy. Indeed, our analysis suggests that carbon would only spend about 20% of its time as a gaseous emission; this is an improvement over the ratios provided in the typical 'nested' forest products sector. The circular economy approach combines responsible environmental management with better labour stewardship.

Ultimately, adopting the circular economy will require massive change over a long timeframe. Work needs to be done now to establish the appropriate product and designs to allow future generations to take advantage of the circular approach. A transformation of Canada’s forest economy to a circular approach will ultimately require generations of commitment, but that must begin with concrete action now.

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