Bamboo in the Circular Economy
The potential of bamboo in a zero-waste, low-carbon future

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Publication date
2019

Document Version
Final published version

Citation (APA)
van der Lugt, P., & King, C. (2019). *Bamboo in the Circular Economy: The potential of bamboo in a zero-waste, low-carbon future*. (Policy Synthesis Report; Vol. 6). International Bamboo and Rattan Organisation (INBAR).

INBAR
INTERNATIONAL BAMBOO AND RATTAN ORGANISATION

Policy Synthesis Report 6

Bamboo in the Circular Economy

The potential of bamboo in a zero-waste, low-carbon future

Cover image: Lior Teitler | MOSO

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International Bamboo and Rattan Organisation

The International Bamboo and Rattan Organisation, INBAR, is an intergovernmental organisation dedicated to the promotion of bamboo and rattan for sustainable development.

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TABLE OF CONTENTS

FOREWORD

When you look for inspiration in addressing the pressing problems of the world, take a moment to observe the marvels of nature. Bamboo will quickly fascinate. It is the fastest growing plant on earth, with a wealth of biodiversity, providing livelihoods to communities in Africa, Asia and South America.

When the German Government invited me in 1996 to present the pioneering cases of "zero emissions" at the World Expo 2000 in Hanover, I decided to showcase bamboo. Linda Garland, who some considered the Queen of Bamboo, had introduced me to the marvels of this grass, that is all too often confused with a tree.

Little did I know at the time how much effort would be required to obtain a German building permit. Quickly, I learned that the only way to convince the authorities to allow millions of visitors to discover the marvels of bamboo was science.

As the engineers discovered and the science demonstrated, bamboo is a vegetal steel that sequesters carbon. It replenishes the soil with nutrients, and regulates the flow of water at times of drought. Bamboo dances to the rhythm of the earth, providing shelter during earthquakes.

When the consortium of universities from Bremen, Stuttgart and Braunschweig agreed that the ZERI Pavilion merited its construction permit, the academics were so impressed with the masterpiece that all Colombian workers were given a master or apprentice diploma. A masterpiece is made by masters, and masters teach their apprentices.

Bamboo forests, enriched with heliconia flowers and home to resting tigers, provide a renewable material with functionality and elegance, performance and beauty. At a time when we face scarcity and struggle to contain emissions, bamboo offers this window of abundance. I—and our team at INBAR—have discovered the marvels of this gift from nature decades ago. It is now high time to inspire policy makers, business and financial leaders to deploy all opportunities of circularity offered by bamboo.

Bamboo's vast potential remains untapped, but I am convinced, after my quarter of a century of admiration for this energising plant, that there will be no real sustainability, lifting people out of poverty, or quality housing, unless we turn bamboo into an integral part of our economy, our agroforestry, our society with arts, and that we must strengthen the science that will unlock its huge potential…

Gunter Pauli

Author of *The Blue Economy* and a series of 365 Fables
Founder of the Zero Emissions Research and Initiatives

EXECUTIVE SUMMARY

In recent years, the idea of a 'circular economy' has been gaining traction. A radical new concept for sustainable growth, the circular economy involves designing products, services and supply chains which are *regenerative*: that is, based on renewable energy and resources. A 'regenerative' system does not generate waste, and keeps products and materials in use, while building economic, natural and social capital.

Bamboo could be a critical component in the transition to a circular economy, by providing a viable, bio-based alternative for non-renewable, carbon-intensive 'techno-cycle' materials. This fast-growing grass plant can be used to create a wide range of both durable and consumer products, which in many cases can substitute those from man-made materials.

Several aspects make bamboo an excellent potential material for use in the circular economy. Bamboo is rapidly self-regenerating: it grows fast, can be harvested without the need to replant, and matures quickly, within 3 to 5 years, to a hard, wood-like material, with a diverse range of uses. Since the 1990s, new processing technologies have enabled the separation of bamboo into strips, slivers, fibres and particles, for use in several different commodity industries, such as pulp, paper, textiles, pellets and building materials.

This report considers a number of bamboo product categories for their 'circularity potential'. According to this report, a 'perfect' bamboo product would: i) have a lifespan long enough to enable the resource to grow back; (ii) be able to substitute abiotic materials; (iii) have 100% bio-based content; (iv) be reusable over multiple product cycles; and (v) at the end of its use, be biodegradable or otherwise safe to burn for energy production.

Durable bamboo products, such as construction materials, long-fibre composites and furniture, perform similarly to other commonly used resources, including stony materials, metals, tropical hardwoods and plastic, but have a lower carbon footprint and are rapidly renewable. Despite the resins, laminates and glues which are used in their creation, many durable bamboo materials are still a preferable, more 'circular' alternative to abiotic materials.

Bamboo can also substitute plastic in a wide range of goods with a shorter lifespan, typically under five years: from single-use bags, straws, crockery, cups and cutlery, to more durable products, including telephone and laptop cases, watches, glasses, kitchen items, sports articles and health and beauty products. Other short- to medium-life products include bamboo textiles, paper and pulp. Although less critical to the circular economy than their durable counterparts, which can replace abiotic materials for a long period of time, a number of these products can still make an important contribution to the circular economy.

Moreover, it is possible for bamboo 'waste' and offcuts from one process to create value-added products in their own right, such as bamboo-based particle / MDF board. And almost every part of the bamboo plant, as well as end-of-life bamboo products, can be processed to form various types of biomass-based energy, including charcoal, pellets and gas, for use in cooking, heating and electricity.

Finally, because bamboo products typically generate numerous valuable by-products, this plant is naturally well-suited to use in 'closed loop' circular value chains, where all parts of the plant are used for value-added applications and minimal waste is generated. In certain parts of southern China, these value chains already exist and have the potential to be replicated elsewhere.

Although these products have important potential to contribute to the circular economy, there are a number of obstacles to integrating bamboo into a circular economy, which this report identifies. The use of non-bio-based resins, glues and artificial preservatives, in particular in engineered bamboo materials and composites, can make products unfit to upcycle; this leaves no other option than burning for energy. Despite this, a number of products are marketed by comparison as a 'green' alternative to materials.

The report provides a number of recommendations:

- The search for bio-based alternatives to synthetic parts in bamboo products, including resins, glues and laminates, will make a critical difference to bamboo products' fit in a circular economy.
- Companies must be transparent and set development goals to reach the 100% bio-based target for their products.
- Policy makers and companies must focus on developing an integrated bamboo industry which adds value to the full bamboo resource.
- There is an important opportunity for the bamboo sector to take advantage of climate crediting schemes. The extra funding and policy support offered by these schemes could spur the development of the sector, and increase the feasibility of establishing even more bamboo plantations and forests worldwide.
- More work must be done to update Harmonized System (HS) codes for bamboo, to incentivise investment and support business development through better understanding of bamboo trade.

In short, bamboo offers an available, scaleable circular solution to current, linear models of production and consumption. This report should provide policy makers, donors and business investors with a greater understanding of bamboo's huge potential in the circular economy.

INTRODUCTION

WHAT IS THE CIRCULAR ECONOMY?

In recent years, the idea of a 'circular economy' has been gaining traction. A radical new concept for sustainable growth, the circular economy involves designing products, services and supply chains which are *regenerative*: that is, based on renewable energy and resources. A 'regenerative' system does not create waste, and keeps products and materials in use, while building economic, natural and social capital.

Calls for a more regenerative, resource-efficient economy stem from concerns about the environmental pressures created by modern-day, 'linear' production and consumption, where finite resources are extracted, used and discarded. This 'take, make, waste' system of economic growth is the cause of most of the environmental problems endangering human society and ecosystems, ranging from plastic pollution and climate change to diminishing reserves of finite materials.

The idea of a circular economy was developed in response to these concerns. The circular economy is best described as "an industrial system which is restorative and regenerative by design, and decouples economic activity from consumption of finite resources" (World Economic Forum et al. 2016). A circular economy is seen as one solution to environmental problems, such as climate change; according to some estimates, a more circular economy which focuses on several of the key industrial material 'offenders'—cement, steel, plastic and aluminium—could help reduce CO_2 emissions by 40% by 2050 (Ellen MacArthur Foundation 2019). According to research by the Ellen MacArthur Foundation and McKinsey Center for Business and Environment (2015) and Accenture (Lacy and Rutqvist 2015), a transition to a circular economy could also bring large economic benefits as high as EUR 1.8 trillion for EU and USD 4.5 trillion for North America by 2030.

"Bamboo could play a significant role in the transition towards a more sustainable, circular economy if the right policy measures and industry adaptations are taken"

Bamboo and other 'nature-based solutions' can integrate well into a circular economy as part of the biological or *bio-cycle*: a process which focuses on using organic materials to create products. These products in general are designed for consumption and can be 'cascaded', or made into new products with as little loss of value as possible, and are ultimately biodegradable. This is separate to the *technical cycle*, where non-renewable industrial materials should be repurposed through different levels of reuse in the so-called R-ladder: reuse, repair, refurbishing, remanufacture, repurposing, and if these options are not available, recycling or use as energy production (Potting and Hanemaaijer 2018). Importantly, durable bio-based products, for example those for use in furniture and construction, should follow the R-ladder as well to extend their useful life, before eventually returning to the bio-cycle. Figure 1 shows a standard visualisation of how these cycles look.

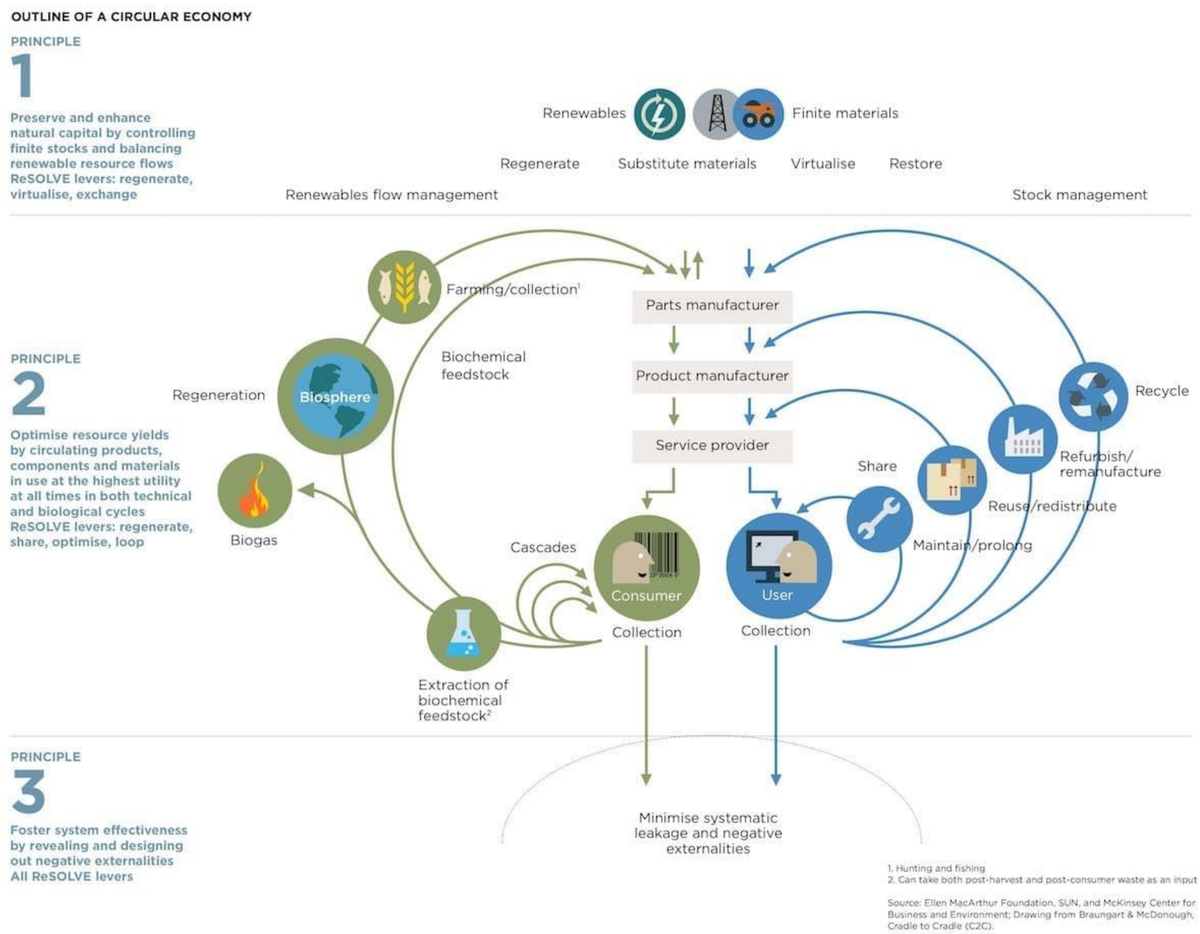

Figure 1. Outline of a circular economy. Credit: Ellen MacArthur Foundation: www.ellenmacarthurfoundation.org/

Where possible, in a circular economy, finite, abiotic materials should be replaced with bio-based renewable alternatives. This is where bamboo can play an important role. Easy to process and very versatile, with a spread of more than 30 million hectares across the tropics and subtropics (FAO 2010), bamboo provides a renewable, sustainable source of durable industrial products, with a lifespan in some cases of over 25 years (especially when used in permanent constructions). These industrial bamboo products include flooring, decking, construction materials and furniture, and can substitute a wide number of traditional manmade or scarce natural resources, such as metals, stony materials, plastics and tropical hardwoods. Durable bamboo products could make an important contribution to the circular economy, and Section 1 of this report considers these different kinds of product in more detail.

As well as durable products, bamboo can be used to create a range of products with a short to medium lifespan, such as textiles, paper and consumer items. Since these products are not always substituting durable, abiotic materials, their environmental impact reduction is less significant. However, these bamboo value chains still merit consideration for their contribution to a circular, bio-based economy. Section 2 of this report considers several short- to medium-life bamboo products.

To extend materials' useful life in a circular economy, products should be consumed and recycled in various product cycles, with as little value loss as possible at each step: a phenomenon also known as 'cascading' (see Figure 1). Section 3 of this report will look specifically at products made using bamboo 'waste', created during processing or after consumer use, including bamboo bioenergy.

The circular economy goes further than the development of new products: it also involves developing processes and supply chains that are fully sustainable and that contribute to a low-carbon economy. Section 4 of this report will look at a few case studies of existing bamboo closed loop value chains in the south of China.

> ***"Although taxonomically a grass plant, mature bamboo is a hard, wood-like material, with a diverse range of uses, including several durable applications"***

Bamboo has huge potential to contribute to the circular economy, but there is work to be done. Section 5 provides recommendations for the development of bamboo products and value chains, to make them as relevant as possible to the needs of a circular economy.

Overall, this report provides a summary of the current status of bamboo products' performance as rapidly regenerative, low-carbon and zero-waste alternative to traditional, often abiotic, fossil-based materials. As the report shows, bamboo could play a significant role in the transition towards a more sustainable, circular economy if the right policy measures and industry adaptations are taken.

WHY BAMBOO?

To be completely compatible with the circular economy, a 'perfect' bamboo product would:

i) have a lifespan long enough to enable the resource to grow back;
ii) be able to substitute abiotic materials;
iii) have 100% bio-based content;
iv) be reusable over multiple product cycles; and
v) at the end of its use, be biodegradable or otherwise safe to burn for energy production.

Several aspects make bamboo an excellent potential material for use in the circular economy. First and foremost, bamboo is rapidly self-regenerating: it grows fast, and can be harvested without the need to replant. Bamboo also matures quickly, within 3 to 5 years, and its selective, annual harvesting makes bamboo plantations relatively resistant to clear-cutting and deforestation. These features, combined with bamboo's global spread and growing area potential (see Figure 2), make bamboo an essentially renewable resource, and one well-suited to the circular economy: it is a classic example of a plant with which "the rate of harvest of forest products shall not exceed levels which can be permanently sustained" (Ellen MacArthur Foundation 2015).

Although taxonomically a grass plant, mature bamboo is a hard, wood-like material, with a diverse range of uses, including several durable applications. These durable bamboo products can last far longer than the harvesting cycle of the mature bamboo stems, providing an excellent example of circularity, as there is a surplus of material regrown.

Many of these durable bamboo products are the result of recent developments, which have vastly expanded the scope of bamboo applications. Since the 1990s, new processing technologies have enabled the separation of bamboo into strips, slivers, fibres and particles, for use in several different commodity industries, such as pulp, paper, textiles, pellets and building materials.

Inevitably, several bamboo products still feature non-renewable, abiotic components, either for their production (e.g. bleaching paper) or in the final product (e.g. adhesive or chemical coating). As such, this report provides several recommendations for improvement within each product group, for the creation of a bamboo product which is perfectly compatible with the circular economy.

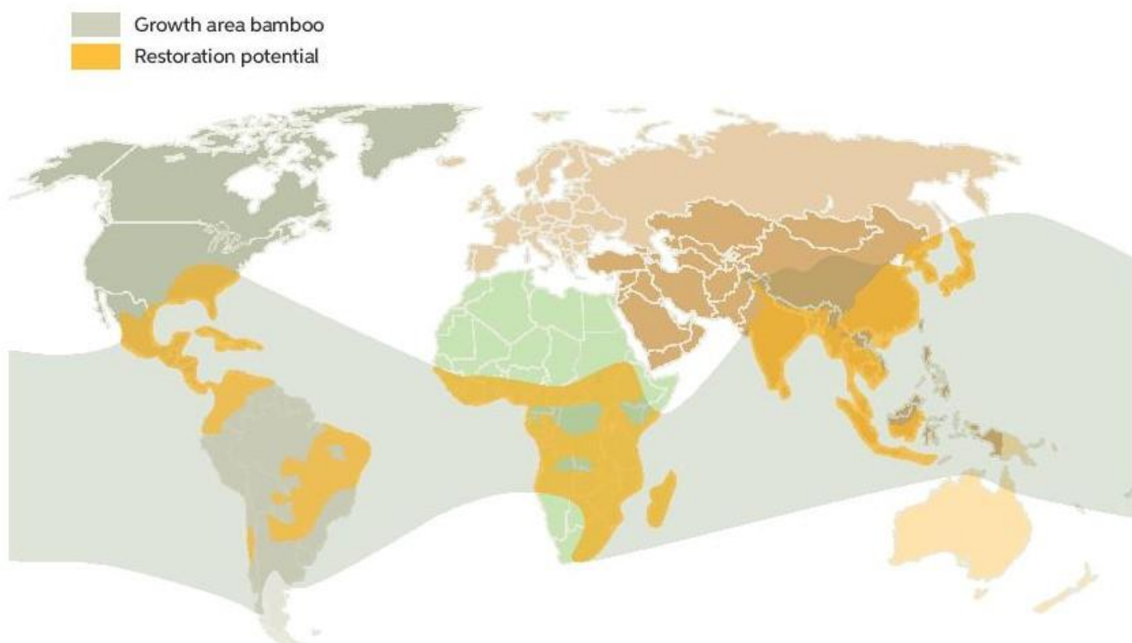

Figure 2. Overlap in natural growing area of bamboo with potential landscape restoration area. Credit: MaterialDistrict.

1. DURABLE BAMBOO PRODUCTS

Durable bamboo products can be defined as those with a lifespan of more than five years; in some cases, these products have a lifespan of over 25 years, especially when used in permanent constructions. This section analyses the potential role of a number of durable bamboo products in the circular economy: bamboo poles and engineered bamboo for construction; bamboo panelling for outdoor use; long-fibre composites; and furniture.

BAMBOO CONSTRUCTION AND FINISHING MATERIALS

The construction sector is a considerable contributor to waste and emissions. Almost half of all materials worldwide are used in housing or construction (Circle Economy 2019). In addition, construction materials are some of the most emissions-intensive to create (Allwood et al. 2010). With huge infrastructure growth predicted over the coming decades, the need for bio-based construction materials is particularly important to the development of a more circular economy.

Bamboo can be used in two different ways in construction: in its natural state, as poles, and as engineered bamboo materials and composites.

Bamboo Poles

Bamboo poles have long been used in the construction of houses, bridges and scaffolding. Bamboo's advantages in construction include its length and light weight, combined with excellent tensile strength and flexibility (Kaminski et al. 2016). Critically, bamboo is also abundantly available and low cost, making it a traditional choice of housing material for many poorer communities: a fact which can strengthen its questionable image as 'poor man's timber' in some countries.

Durable, flexible, low-carbon and self-renewing, bamboo poles are some of the most sustainable building materials available, with a cradle-to-gate carbon footprint of only 0.20 kg CO_2-eq/kg/pole when used locally (van der Lugt and Vogtländer 2015). If not treated or coated using artificial preservatives or lacquers, the poles are also fully biodegradable.

A number of well-known architects, such as Simón Vélez, Elora Hardy and Jörg Stamm, use traditional round-pole bamboo construction techniques to create stylish lightweight structures such as bridges, buildings, schools, eco-resorts and temporary structures, such as pavilions. In Bali, Indonesia, the

Figure 3. A classroom, and the 'Heart of School' at Green School Bali: a six-storey building constructed entirely from round-pole bamboo. Credit: INBAR.

buildings which make up the famous ‘Green School’ are constructed entirely with bamboo poles, and built using traditional Balinese techniques and tools (Figure 3). In certain parts of the world, bamboo scaffolding is a ubiquitous sight and can be used for buildings tens of storeys tall.

Engineered Bamboo Materials

In recent decades, the development of engineered bamboo materials has transformed the potential of bamboo for structural use. A number of processes can be used to transform bamboo poles into woodlike products of standardised stability and shape, such as flattening, laminating or compressing bamboo.

Engineered bamboo products are notable for their impressive performance. In particular, thermally modified and densified bamboo boards can sometimes outperform hardwood in terms of durability for outdoor applications: the outdoor bamboo product Bamboo X-treme has been tested to reach the highest durability class according to European standards (MOSO International, no date). Laminated bamboo has a relatively low stiffness and high flexibility: it famously “bends but does not break”, with greater resilience in earthquakes (Drunen et al. 2015).

Bamboo panels can be treated with biocides to make them more durable for outdoor use. The resulting panels have a wide range of applications: the Netherlands currently uses bamboo road traffic signs, which contain EU-approved biocides, alongside its standard aluminium ones (HR Groep 2019).

LONG-FIBRE COMPOSITES

Bamboo composites created using long fibre segments are particularly strong and can be moulded into different kinds of shape. Products made using bamboo composite technology have similar properties to engineered bamboo products, but are created using a different method and have a far higher synthetic resin content, often in excess of 30%.

A basic bamboo-based composite material is bamboo mat board, which is made by dipping sheets of woven bamboo in resin, after which they are hot-pressed and cured to form rough hard boards suitable for various applications, such as pallets, concrete casting, construction, shipping container flooring, or corrugated boards for roofing. Because of their excellent mechanical performance, bamboo long-fibre composites also have more high-end, mass applications: they are applicable in

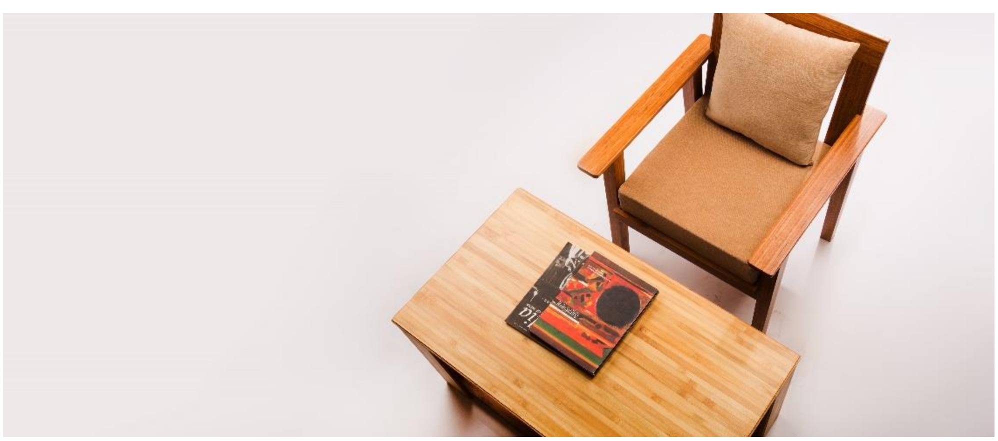

Figure 4. Modern bamboo furniture. Image: Native KONBAC.

industries where light weight, form freedom and strength are key attributes, such as the automotive, aerospace, boating, sports equipment, construction and infrastructure sectors.

FURNITURE

Bamboo furniture is created in a number of different ways (Figure 4). If not combined with synthetic adhesives and/or lacquers, but made using knock-down, biological elements that can be dismantled (for example, bamboo dowels) and reusable techno-cycle components (such as screws and bolts), bamboo furniture can be fully compliant with the circular economy: the bamboo components are able to return to the bio-cycle in the product's end-of-life phase. In this way, bamboo can function as a more sustainable alternative to a number of materials used in furniture: a 2015 report by INBAR, TU Delft and Dutch company MOSO International showed that industrial bamboo products could be a more sustainable substitute for even sustainably sourced hardwoods (van der Lugt and Vogtländer 2015).

Market potential of durable bamboo products

Because they perform similarly to other commonly used construction materials, but have a lower carbon footprint and are rapidly renewable, long-life bamboo materials are already becoming popular across a wide range of sectors. However, assessing their market potential based on existing trade statistics does not present a full picture.

Data from UN Comtrade, based on Harmonized System (HS) codes, shows that international trade in 'industrialised bamboo products', namely bamboo flooring and panels (HS codes 440921 and 441210), was USD 360 million in 2017; 'bamboo and rattan furniture' (HS code 940381) accounted for USD 266 million and the market for bamboo poles ('bamboo raw materials', HS code 140110) increased to USD 101 million (INBAR 2019). However, this data may well be an underestimate, due to the common mislabelling of bamboo products as timber, and the fact that the vast majority of bamboo trade remains domestic, rather than export-oriented (INBAR 2019). A more rounded understanding may come from looking at major Western markets such as the EU and USA: a recent report by the Dutch consultancy firm CREM (2016) estimated that the US and EU markets were each buying 40,000 m^3 engineered bamboo products per year, with an expected growth to 50,000 m^3 within a couple of years.

Given the hardwood-like properties of engineered bamboo materials and the similar properties, the hardwood market in general is a good indicator of the market potential for these materials. In line with the growth of the wood and building industry in general, the hardwood market is growing, albeit slowly, and is expected to keep doing so (ITTO 2017).

In addition, a number of general trends point to opportunities for engineered bamboo industrial products. The increasing importance of using certified timber, combined with supply issues in some major hardwood-producing countries, could put pressure on certified hardwood stocks, thus providing opportunities for engineered bamboo as an alternative, more abundantly available product. The growing attention on green building certification—such as Leadership in Energy and Environmental Design (LEED), Building Research Establishment Environmental Assessment Method (BREEAM), Green Star, and Haute Qualité Environnementale (HQE)—by stakeholders in the Western construction industry offers opportunities for engineered bamboo. This would be particularly important if bamboo's low environmental impact can be proven through internationally recognised methodologies and eco-certifications that feed into these green building certification systems: life-cycle analyses, indoor emissions assessments, and sustainable forestry certification schemes including the Forest Stewardship Council (FSC) or Programme for the Endorsement of Forest Certification (PEFC).

The market for round-pole bamboo construction is likely to remain smaller. Although beautiful, round-pole bamboo construction remains a labour-intensive and time-consuming pursuit; as such, it may be expected to remain relatively small-scale and confined either to upmarket use, or lower-end constructions for domestic markets.

Considerations for durable bamboo products

Although their low-carbon credentials are impeccable, bamboo engineered and composite products are not yet perfectly suited for use in the circular economy.

Firstly, with the exception of round-pole bamboo construction, all engineered bamboo products require resin or laminate to create, and often use the same synthetic glues as those in the wooden panelling industry, including Melamine Urea Formaldehyde, Phenol Formaldehyde (PF) or Emulsion-Polymer-Isocyanate. The dry weight percentage of the glue differs per product, ranging from 2% for laminated bamboo to up to 10% for outdoor bamboo boards and even over 40% for bamboo composites. Because current glues and PF are not bio-based or biodegradable, composting is not feasible. Therefore, until a bio-based or biodegradable adhesive alternative is developed, the best ‘end-of-life’ scenario for such bamboo products is incineration for energy production, provided it is burned in bioenergy facilities that can capture any harmful fumes upon incineration.

Although these are legitimate concerns, it is worth noting that durable bamboo products often have a long lifespan, of 25 years or more, making them a circular alternative to abiotic materials such as PVC for flooring and wood plastic composites for decking. Recent life-cycle analyses executed on engineered bamboo materials show how engineered bamboo materials can be carbon-negative over their full life-cycle (from ‘cradle to grave’), even when transported and used in Western European countries such as the Netherlands (van der Lugt and Vogtländer 2015; see Table 1). This is because of the carbon stored in the bamboo forests, and because the products can be burned as a substitute for fossil fuel-based energy in their end-of-life phase.

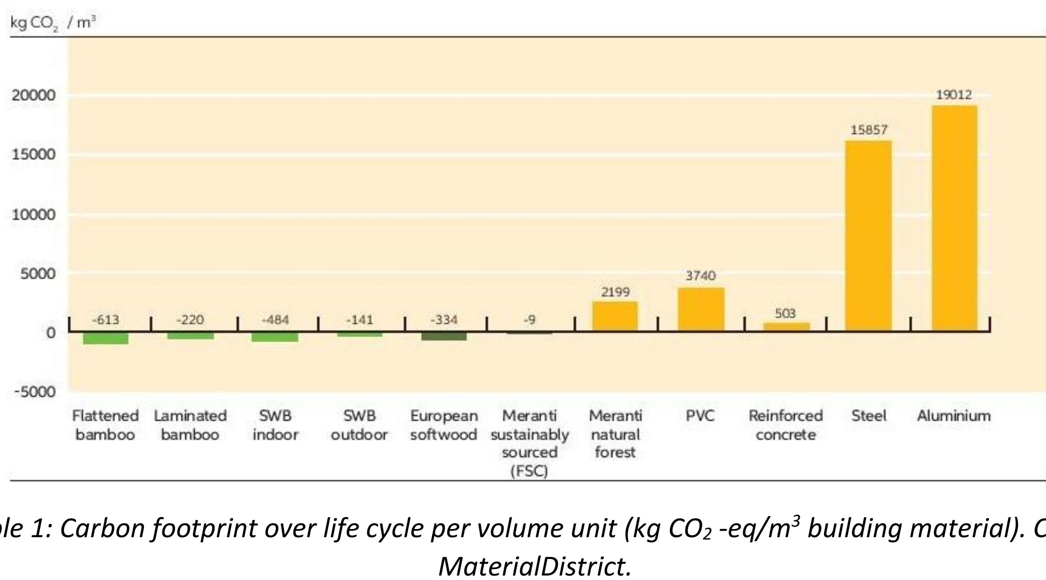

Table 1: Carbon footprint over life cycle per volume unit (kg CO_2 -eq/m^3 building material). Credit: MaterialDistrict.

Outdoor bamboo panels provide one good example of this rule. In addition to the synthetic resin (PF) used, the biocide content in these panels, although EU-approved, limits their end-of-life use to incineration for bioenergy production at best. Despite this, from a sustainability perspective, this kind of bamboo panelling still performs better than traditional aluminium-based traffic signs, as a recent life-cycle analysis study by consultancy firm CE Delft in Netherlands shows (CE Delft 2019).

Currently, much work is being done to develop additives that are also fully compliant with the circular economy, such as non-toxic, bio-based glues and bio-coatings. The search for bio-based additives and chemicals, such as soy, lignin or bagasse, once they can be made in a cost-competitive way, will make a crucial difference to creating fully bio-based bamboo products. There is currently significant investment and research in product development activities by a number of manufacturers (Heinrich 2019).

The situation is far simpler for construction using bamboo poles, which if designed well do not need preservatives and coatings, and can replace abiotic materials in some cases. The main consideration for round-pole construction is the connections, which must be either fully bio-degradable (e.g. wooden props and dowels, inserted without glue), or able to be completely disassembled and recycled at the construction's end-of-life phase. In practice, connections are sometimes made by filling the bamboo cavity with mortar, which cancels out the potential for dismantling and recycling of the individual components, and as such its circularity position.

Perhaps a more pressing issue for round-pole bamboo construction is the lack of international standards and knowledge to support its growth. As a naturally growing material which thrives in a wide range of climates, bamboo's irregular size, shape and properties makes standardisation difficult, and requires construction workers and bamboo farmers with a good deal of knowledge. However, a critical lack of international building codes and classification systems for round-pole bamboo exist, which hampers its uptake in the construction sector. INBAR is currently working the International Organization for Standardization (ISO) to develop and promote new codes for construction with round-pole bamboo, as part of ISO Technical Committee 165, to test the materials and overall construction strength. More generally, temporary bamboo constructions, such as the famous ZERI Pavilion designed by Simón Vélez for the German World Expo in 2000, or more recently the 'Bamboo Eye' Pavilion designed by Mauricio Cárdenas Laverde for INBAR at the International Horticultural Exposition 2019 in Beijing, are helping to raise awareness about the strength and durability of round-pole bamboo structures, while improving bamboo's image as a potential high-end building material.

Case study: Innovative winding technology in China

Due to recent innovations and active government support for research and development in China, several new bamboo composites have been developed in recent years. In particular, the Engineering Research Centre for Bamboo Winding Composites (ERCBWC) is pioneering a new method for making bamboo products. 'Winding' bamboo fibres in meshes, strengthened with synthetic resin (PF), can be used to create resilient products including heavy-duty, long-life drainage pipes—which are already being used in Inner Mongolia (Figure 5)—as well as flooring, walls and train carriage fuselage. ERCBWC is one of a number of companies using bamboo as a low-carbon, often inexpensive replacement for timber, steel, cement and plastic.

Figure 5. These long-life drainage pipes can replace steel. Credit: ERCBWC.

2. SHORT- AND MEDIUM-LIFE BAMBOO PRODUCTS

For bamboo products with a shorter lifespan, typically under five years, it is even more critical to ensure that there is sufficient feedstock recovery during the product's period of use. This makes it important to design products and systems that can safely return to the bio-cycle after its useful life. Fortunately, giant bamboo species enjoy high yields of up to 10m^3/ha/year for engineered bamboo materials; unprocessed bamboo, meanwhile, can have yields of up to 30-40 m^3/ha/year. This means that bamboo short- and medium-life products can still add benefit in a circular economy.

CONSUMER ITEMS

Bamboo can substitute plastic in a wide range of consumer goods: from single-use bags, straws, crockery, cups and cutlery, to more durable products, including telephone and laptop cases, watches, glasses, kitchen items, sports articles (helmets, bikes and skateboards) and health and beauty products (bamboo toothbrushes and cotton buds) (Figure 6).

Indeed, the huge variety of bamboo processing technologies means there are many opportunities to create different products, as a replacement for many traditional abiotic materials. For example, cups and packaging can be made by mixing bamboo fibres and corn starch to form a paste, which may be mixed with a resin. For some kitchenware, melamine is added as a binder, to ensure that the product is durable and suitable for higher temperatures. Another form of production involves using heat-pressing to compress bamboo sheaths, or even discarded bamboo products, into a new shape.

Other, more durable items—which include everything from computer keyboards and laptop covers to skateboards—can be made from laminated bamboo panels or veneer sheets, which are then laser-cut to create a good fit. For the steering wheel of the Lexus GS450, a model which makes extensive use of bamboo for the car interior, bamboo strips are curved and glued in molds to form bended beams, then carved and polished (van der Lugt 2017).

Market potential of bamboo consumer items

Given the multiplicity of materials that bamboo products can replace, it is difficult to assess the potential for growth. A look at the bioplastics industry does offer some idea as to the potential of bamboo consumer items. In 2015, the world produced 381 million tonnes of plastic (Geyer et al. 2017). Although bioplastics at present constitute only a tiny proportion of overall plastic use, their popularity is growing hugely: global bioplastics production capacity is set to increase from around 2.1 million tonnes in 2018 to 2.6 million tonnes in 2023 (European Bioplastics 2018). This is in no small part thanks to a growing international backlash against plastic pollution, and the resultant limitation of single-use

Figure 6. A huge number of consumer items can be created using bamboo. Credit: INBAR.

plastic by bodies such as the European Union, or the ban by China on imports of non-industrial plastic waste (European Commission 2018; Chinese Ministry of Environmental Protection 2017).

In recent years, single-use bamboo cutlery, cups, straws, paper and packaging companies have begun to proliferate, and a number of headline-grabbing transitions to bamboo have taken place, such as the decision by one European airline to replace all plastic cutlery with bamboo (*The Telegraph* 2019). All of this points to an increase in market potential which looks unlikely to change in upcoming decades.

Considerations for bamboo consumer items

Importantly, bamboo consumer items are not always fully compatible with the circular economy. Despite the common perception that bamboo consumer products are inherently sustainable—a misconception which appears to be actively encouraged by some companies—many of these items are actually made by combining bamboo with synthetic materials or processed with chemicals. For example, although the base of a bamboo toothbrush can consist of a solid bamboo strip, which is fully compliant with the bio-cycle, the brush hairs are often still made from plastic and cannot yet be easily separated from the brush at the end of a product's period of use. Some products may even be actively harmful to human health, as several consumer organisations have raised with the case of bamboo cups and tableware featuring melamine binders (Stiftung Warentest 2019). Aside from the health concerns, it is worth noting that these cups are often not fully circular: they permanently fuse ingredients from the bio-cycle and techno-cycle, making the product unrecyclable.

TEXTILES

There are several types of bamboo textile, of which bamboo viscose may well be the most popular on the market. To produce bamboo-based viscose, bamboo pulp is created using traditional pulping technology, during which the bamboo chips are fully saturated under the influence of steam, heat and pressure, in an alkaline solution involving chemicals such as sodium hydroxide and carbon disulphide to remove the lignin and silica. The remaining cellulose pulp is then used to produce viscose for the subsequent production of bamboo textiles. After washing, bleaching and drying, the final fibres can be spun into yarns to eventually produce several kinds of bamboo fabrics. In final garments, bamboo yarn is usually combined with other materials, such as cotton, to make the fabric sturdier.

Bamboo can also be used to create linen. Bamboo stems or strips are mechanically crushed, after which bamboo fibre is extracted through a natural enzyme-based retting and washing process; this fibre is then woven into rough, sturdy textile.

Market potential of bamboo textiles

As with consumer items, bamboo textiles appear to be growing in popularity. Bamboo fabrics are often marketed as a more sustainable alternative to fibres, such as cotton, which are more resource-intensive, or which take more time, to grow. The market potential for bamboo fabric is large: if bamboo viscose were to substitute cotton, it would be able to take part in a sector estimated at around 25 million tonnes, or second only to polyester as the most important fibre used in the textile industry (Textile Exchange 2018).

Due to its slightly rougher texture, bamboo linen is far less commonspread than bamboo rayon, and is unlikely to capture a significant portion of the textiles market.

Considerations for bamboo textiles

Bamboo viscose is an interesting input material for new product chains, especially when substituting techno-cycle fibres often used in the textile industry such as polyester. However, its claims to be eco-friendly, and fitting within a circular economy, require consideration.

Certainly, as a feedstock, bamboo boasts some very favourable properties: it requires fewer inputs than other materials to grow, can thrive on marginal or degraded land, and is self-replenishing. In addition, as with other forms of viscose, bamboo viscose is in essence fully bio-based and bio-degradable, and could therefore safely return to the bio-cycle.

However, as with all materials used to create viscose, the traditional pulping process used to create bamboo viscose is not environmentally friendly, nor are the chemicals involved. Due to its tough, fibrous nature, bamboo viscose may actually require more chemicals to produce than other, more easily processed feedstocks, resulting in a similar and sometimes even higher environmental impact in terms of life-cycle analysis, compared to viscose made from recycled or softwood-based pulp (Schultz and Suresh 2017).

This threat could prove to be become an opportunity if bamboo-based viscose manufacturers lower the environmental impact of their production process by integrating more environmentally friendly bio-refinery processes and closed loop systems. A number of bamboo textile producers have already announced improvements to the production process through nanotechnology, more eco-friendly solvents and/or new cellulose filament production processes. Chief among these is Lyocell, a type of fibre which uses a solvent (N-Methylmorpholine N-oxide) that can be recycled and recovered for reuse, by up to 99% (White 2001). The solvent is toxic and flammable, but these risks are manageable, which is proven by the fact that the fibres are produced commercially. Such processes could further improve the environmental profile of bamboo-based viscose, making it even more compliant with a circular economy.

In circular economy terms, a product's design is only one part of the equation: an equally important factor is how it is used. In terms of emissions, the choice of feedstock actually may not matter much in the overall life cycle of a piece of fabric. This is because its use in the home may account for a significant proportion of emissions from any one piece of clothing or textiles: either because it is discarded shortly after purchase, or is washed many times (Watson and Wiedemann 2019). As such, while bamboo may be a relatively low-input feedstock, its sustainable properties may not have a particularly significant impact on the overall life-cycle analysis of a piece of clothing.

PAPER AND PULP

Because of its high yields, long fibres and good mechanical properties, bamboo can be a good material for use in the paper and cardboard industry. The most common process to produce paper involves mixing and heating bamboo chips with water, sodium sulphide and sodium, to delignify the chips and retrieve cellulose pulp (Figure 7). During this process a considerable amount of harmful waste, known as black liquor, is produced, which needs to be recovered and requires specific waste treatment to prevent pollution of ecosystems. Often the cellulose pulp is then bleached, after which water and additives such as calcium carbonate are added to eventually produce white paper. In this process, large amounts of clean water are required; this water can be almost fully recycled on site if the process is designed well. Unless they are coated with plastic for water resistance, all paper products will be biodegradable.

Market potential of bamboo pulp and paper

Given the considerable amount of illegal logging for paper and pulp still occurring in countries around the world, and the fact that expansion of pulp mills may indirectly lead to deforestation in these countries (Hoare 2014, Environmental Paper Network 2018), bamboo paper and pulp could be a more sustainable alternative. Bamboo is a very suitable substitution for the paper and cardboard industry, and the sector already exists: bamboo pulp and paper-based products had a global export volume of around USD 26 million in 2017 (INBAR 2019).

Figure 7. Bamboo pulp is used to create paper. Credit: INBAR.

In an increasingly digital world, the focus of the paper industry is shifting. Consumption of printing paper is decreasing, but the amount of paper used for packaging—through growing internet purchasing—is on the rise. In total, the amount of paper and cardboard production is still increasing slightly at 1% per year, with most growth and consumption found in Asia. Annually, around 400 million tonnes of paper and paperboard products are consumed, over half of which is recycled paper (Environmental Paper Network 2018). Although they currently hold only a marginal corner of the market, bamboo pulp and paper could play an important role in this industry.

Considerations for bamboo paper and pulp

As fast-growing wood species are typically used to produce paper, replacing these species for bamboo is not a huge step forward in terms of a circular economy, where replacement of abiotic materials with biotic materials is preferred.

As with wood pulp and paper, the various chemicals used in the kraft pulping process, such as chlorine, are environmentally harmful, and in that sense not fully fitting in a bio-based, circular economy. In the future, there lie large opportunities for responsibly produced pulp and paper, based on safer and cleaner bleaching technologies known as Totally Chlorine Free, 'TCF', production. This applies to both wood- and bamboo-based pulp.

3. REPURPOSING WASTE INTO NEW PRODUCTS

Bamboo is a very resource-efficient source of material. All parts of a bamboo plant—culms, leaves, sheaths, roots and rhizomes—can be used to create products. This section analyses some of the products that can be created with bamboo processing and post-consumer 'waste'.

BAMBOO-BASED PARTICLE / MDF BOARD

Bamboo-based particle / MDF boards are produced in a very similar way to their wood-based counterparts, and can be used in furniture construction, flooring underlayment and semi-structural panels. However, instead of using full trunks as input material (as is often the case in the wood industry), more often waste streams of other bamboo industries, both preprocessing or final product manufacturing factories, are used as feedstock to produce these bamboo fragments.

To create these boards, bamboo chips are washed, softened using steam, and then ground and mixed with synthetic resin; once dry, the fibres are pressed into a uniform board.

Market potential of bamboo-based particle boards

Although the competitive mechanical advantages of the long, flexible, strong-fibre bamboo elements are lost in this product, bamboo particle board can provide a value-added alternative compared to burning bamboo waste material during the production of engineered bamboo materials, as a complement to wood-based MDF and particle board panels on the market.

As with most engineered bamboo products above, there is significant uncertainty about the current trade in bamboo-based particle boards, and no separate HS code exists to separate this product from other laminated or engineered bamboo products. However, taking the trade in wood-based panel products as a cue, there is strong potential for bamboo: the overall sector is growing at around 7% per year (FAO 2019; Grand View Research 2019).

An exciting potential avenue for bamboo fibres and sawdust is use as filler in granules suitable for 3D printing or compression moulding. If combined with a bio-based resin, this would allow bamboo to replace a number of materials as an eco-friendly alternative, such as biodegradable packaging or temporary drainage sheets (van der Lugt 2017).

Considerations for bamboo-based particle boards

As with engineered bamboo products, particle-based bamboo boards require synthetic resins to bind the fibres. This means that, although bamboo particle boards can repurpose waste materials to create durable, value-added products, they are still not biodegradable and so not fully compatible in a circular economy. In total, the glue and synthetic additives (such as waxes and pigments) used to create particle board means that the bio-based content is usually lower than 90%, and so cannot be composted; only incineration in special equipped bioenergy plants is possible.

BIOENERGY AND BY-PRODUCTS

Bamboo can be processed in various ways to form many various types of biomass energy, including charcoal, pellets and gas, for use in cooking, heating and electricity (Figure 8).

Firstly, almost every part of bamboo can be used to create charcoal and briquettes, or burned directly as fuelwood. This could be an important, more sustainable substitute for wood biomass in many parts of the world, where people still rely on timber for cooking and heating. Logging for wood biomass remains a major cause of deforestation in certain countries, and bamboo could play an important role to reduce pressure on stressed forest resources: one study even estimates that bamboo charcoal has the potential to replace 64% of sub-Saharan Africa's wood consumption (Partey at el. 2017b).

Bamboo can also be used to generate heat and electricity, through conversion to pellets or gasification. 1.2 kg of bamboo could produce one kilowatt hour of electricity; this is similar to the biomass requirement for wood or timber, and better than other commonly used types of powdered biomass such as sawdust or peanut, coffee and rice husk (Sharma et al. 2018).

In addition, waste bamboo can be converted into a number of important 'by-products' in a biorefinery. In particular, bamboo carbon-based products such as biochar, activated carbon and charcoal are already creating niche markets in the health sector.

Figure 8. Bamboo can be burned as fuelwood, or used to create charcoal (left), pellets, and gas (right). Credit: INBAR.

The market potential of bamboo bioenergy and by-products

Bamboo can have an important impact on many parts of the energy market. Wood pellets offer a good example of bamboo's potential in this field. Because of increasingly ambitious commitments to renewable energy made by countries or country blocs such as the European Union, biomass energy—particularly in the form of pellets, which can be burned for energy in existing power plants—is becoming more popular. The wood pellet industry is growing worldwide, from 21 million tonnes in 2013 to 33 million tonnes in 2017, and is expected to keep growing in coming years (FAO 2019).

Comprehensive data about the use of wood fuel (logs, briquettes or charcoal) more generally is harder to capture. At first glance, the small export statistics for bamboo charcoal, at USD 57 million in 2017, appear discouraging. However, it is more likely that a large proportion of bamboo fuel is not sold on the market, but is cut for domestic use within the home. Indeed, bamboo is already being used by a number of governments as a fast-growing alternative for domestic wood fuel, to reduce stress on existing forest resources (Partey et al. 2017a).

Considerations for bamboo bioenergy and by-products

Burning bamboo is considered 'leakage' in a circular economy, and is the lowest circularity strategy provided on the 'R-ladder' (see Introduction). However, this remains a relatively productive way to use waste streams and lower quality bamboo given the plant's high biomass production. As an alternative to fossil fuel-based energy sources, such as gas, coal and oil, bamboo biomass can make an important contribution to a renewable energy system fuelling a circular economy.

However, care should be taken that bamboo bioenergy products only use bamboo poles which are unsuitable for durable product creation, to stay in line with the cascading principle in the circular economy.

Case study: From waste to resource

Canadian start-up ChopValue is a product engineering and design firm that collects used bamboo chopsticks from local restaurants, and transforms them into high-value engineered products such as home décor, household items and furniture. The chopsticks are sorted, dried and then compressed in a hydraulic press. The result is a dense, uniform material, which is used to create a range of durable new products (see Figure 9). A fully water-based resin binds the chopsticks together, providing a non-toxic final product that has no limitations for recycling in its end-of-life phase. ChopValue is planning to expand with its developed turnkey microfactory concept on a global scale and will be launching their franchise concept in January 2020. ChopValue offers a best case example of how bamboo short-life products can be upcycled in a durable way which is fully compatible with the circular economy.

Figure 9. A pop-up ChopValue installation at Vancouver International Airport, featuring some of their products. Credit: ChopValue.

4. ZERO-WASTE VALUE CHAINS

Circular products do not work in isolation. To be truly circular, bamboo products must be part of connected, circular value chains, which repurpose waste and by-products and ensure the continued sustainability of the bamboo resource base. Bamboo is a particularly useful plant to show the potential of this 'closed loop' system, as many bamboo products also generate numerous valuable by-products: for example, when creating bamboo charcoal it is also possible to extract alcohol, tar and vinegar.

In the south of China, interlinked circular systems show the potential for a closed loop value chain. A number of companies exist solely to repurpose 'waste' from one sector into value-added bamboo products in their own right (Figure 10). China's ability to integrate and add value to all parts of the bamboo resource partially explains why it has risen to become the world leader in bamboo product development and export (INBAR 2019).

In Sanming and Jianou, neighbouring areas in Fujian province, a series of factories create a closed loop system for bamboo use. Fujian is a mountainous southern province of China, and boasts an estimated 1 million hectares of bamboo forest, most of it moso (*Phyllostachys edulis*) bamboo. Within the space of a few kilometres, a number of factories can share the spoils of one bamboo harvest between themselves.

At the 'top' of the chain, a number of companies use bamboo to create a wide variety of high-value products, from bamboo flooring and furniture to construction hard hats. Much of this is marked for export. These companies share their forests with bamboo shoot companies, which exclusively harvest edible shoots in the spring.

Older bamboo poles, which are harvested but subsequently deemed unsuitable for use in these sectors, are sold on to other companies. One bamboo factory buys these poles at a discount to extract lignin, a dispersing and strengthening agent for use in ceramics and dyes. The factory then uses the remaining cellulose to create pulp for paper, as a secondary product. In 2019, this factory processed some one million tonnes of bamboo poles per month.

Offcuts from these industries, including leftover sawdust from the factory floor, find a new use as value-added products. One activated charcoal company buys waste from nearby bamboo businesses, and uses it to create over 30 different types of charcoal product for the food and health industry: from treatment of waste and drinking water, to use as a deodoriser in fridges, wardrobes and cars. As of 2019, the factory processed 40,000 tonnes of activated charcoal a year. It is currently looking into ways to market other by-products created from the charcoal process, including bamboo vinegar.

Any remaining bamboo waste from these companies is combined with crop residue and converted into pellets, which then go on to power the factories in question. Importantly, bamboo waste is generally deemed too important to use for this function, and so does not make up the primary form of biomass in these pellets, but is used as a last option to prevent waste.

The case of Fujian shows the potential of bamboo to create a closed loop system for a large number of products, all from the same crop. Other companies are creating a similar system by themselves. In particular, one bamboo furniture company in Chishui, China, shows the potential of bamboo to be a 100% waste-free enterprise: it uses bamboo poles to create furniture, and the leftover pole tips for creating incense sticks. Even sawdust from the factory floor has a purpose: it is condensed into bamboo briquettes, for burning, or used as a seedbed for bamboo fungus, a delicacy in the area. The factory's 200-hectare bamboo plantation is also used to raise chickens, which eat bamboo leaves for fodder, and as a source of bamboo shoots to be sold as food (INBAR 2016). Although few companies have the capacity or technologies to adopt this kind of process, the case of Chishui does show the potential for bamboo products to create a more circular economy.

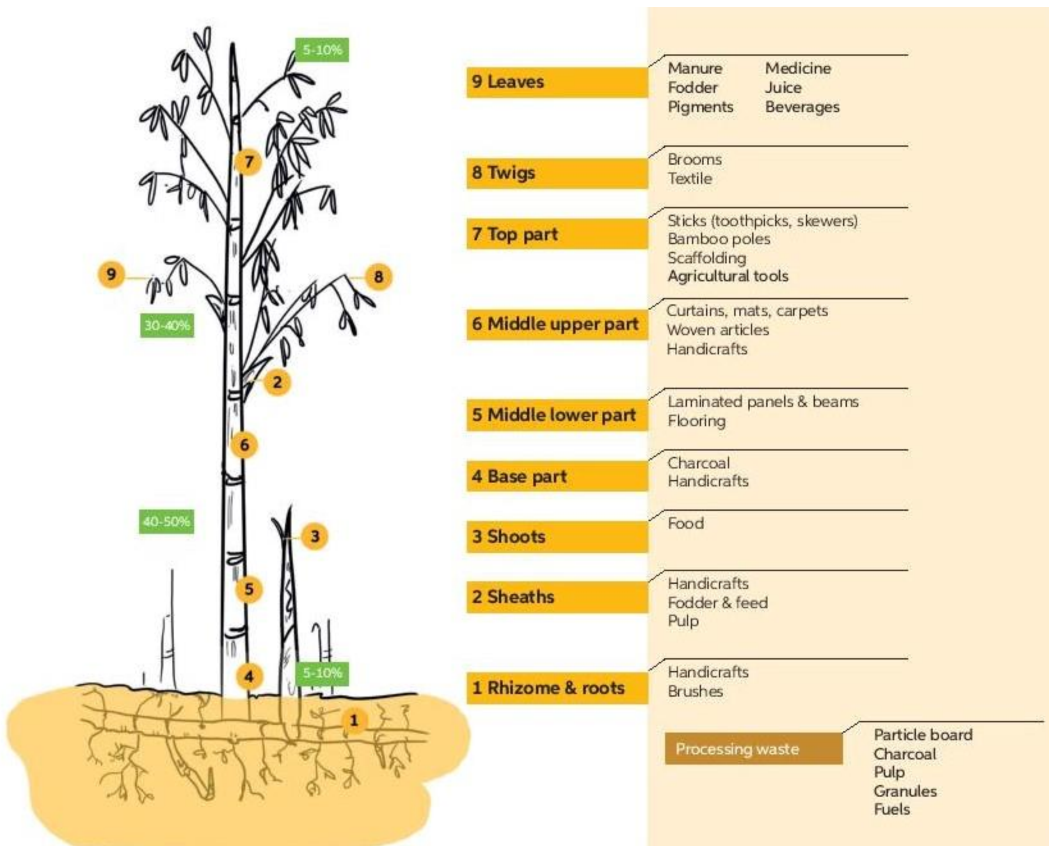

Figure 10. Full utilisation of the bamboo resource: the success factor of the Chinese bamboo industry. Credit: MaterialDistrict.

5. RECOMMENDATIONS FOR THE DEVELOPMENT OF BAMBOO IN THE CIRCULAR ECONOMY

It is clear that there are ample opportunities for bamboo products to assist the transition to a more circular, bio-based economy. This chapter provides recommendations for policy makers and potential investors in bamboo-growing and bamboo-consuming countries, to take advantage of the opportunities that bamboo-based industrialisation offers for the circular economy.

TECHNOLOGY, RESEARCH AND DEVELOPMENT PERSPECTIVE

As has been shown, for bamboo products to take advantage of a circular, bio-based economy, they should be composed and designed in such a way that ideally they:

(1) can substitute abiotic materials;
(2) have a lifespan long enough to enable the resource to grow back;
(3) feature as much bio-based content as possible;
(4) can be re-used or recycled while retaining as much value as possible; and
(5) can ideally return to the biosphere, or at least safely be burned for energy, at their end of life.

To fully comply with a bio-based economy, essential additions to bamboo products must be bio-based as well, or easily separable in the end-of-life phase. Two generic recommendations can be provided to bamboo manufacturers in this regard:

Recommendation 1. Find bio-based alternatives for synthetic parts in bamboo products

The search for bio-based additives and chemicals will make a crucial difference to creating fully bio-based bamboo products. As has been shown above, many bamboo products are made using synthetic additives (e.g. glues, coatings) and/or processing chemicals (e.g. for viscose and pulping processes). These are often toxic and not biodegradable, making the products less compliant with a bio-based economy.

If these additives can also be made from bio-based sources, such as soy, lignin or bagasse, in a price- and cost-competitive way, this might provide additional opportunities and higher adoption of bamboo products in a bio-based economy. However, this will require significant investments in research product development activities of manufacturers. Such developments are possible, as can be seen with improvements in bamboo fabrics: the process used to make Lyocell fibre significantly improves the environmental profile of bamboo-based viscose, making it even more compliant with a circular economy.

Recommendation 2. Be transparent and set development goals to reach the 100% bio-based target

Bamboo is often considered an inherently sustainable material. However, as has been seen above, although bamboo is a fast-growing and renewable feedstock, much depends on the processes and additives used to create bamboo products. It is important that manufacturers are fully transparent with consumers about the content of their product, and that they are clear internally on the required points of improvement for the product to be fully compatible with a bio-based economy.

INDUSTRY PERSPECTIVE

Recommendation 3. Develop an integrated bamboo industry: adding value to the full bamboo resource

Many policy makers and investors think that bamboo, because of its quick growth, is an easy cash crop. However, as with any feedstock, particularly a newly established one, a lot of work is required to ensure a sustainable source of supply, suitable infrastructure for treatment and transport, and supportive suppliers and legislation, to name a few preconditions. In addition, it is worth remembering that bamboo is a hugely varied plant, with more than 1600 species (Vorontsova et al. 2016). Each species has diverse properties and is best suited to different types of product: for example, *Bambusa vulgaris* is best suited for creating paper, while other bamboos, such as *Phyllostachus pubescens* and *D. asper*, are preferred for engineered bamboo products. Those with an interest in developing a bamboo-based product would do well to conduct a value chain analysis, of the sort developed by INBAR for several of its Member States (See e.g. INBAR 2018). Transfer of knowledge and best practices is one way to generate success in new areas; in this regard, INBAR has played an important role as a facilitator of South-South knowledge sharing (INBAR and UNOSSC 2017).

When the above preconditions are met, the most crucial success factor is developing a bamboo industry which is based on several sub-industries, of which each branch adds value to a specific part of the bamboo resource; the examples from China given in Section 4 show how this kind of system might look.

Furthermore, it is recommended not to aim too high from the start. To take one example: experience has shown that it is very difficult to reach the quality required to export engineered bamboo materials such as flooring and decking. As such, it is better to start with more feasible bamboo products useful for local markets such as furniture, household items and charcoal, which make use of the full bamboo resource.

POLICY AND TRADE PERSPECTIVE

Recommendation 4. Take advantage of climate crediting possibilities

Besides possibilities to increase investments through national or regional stimulation programmes and action plans, such as the 2015 Circular Economy Action Plan and 2012 BioEconomy Strategy in Europe, climate-related investments offer great opportunities for the bamboo sector. This is crucial, as a circular economy movement is driven not only by material scarcity but also by the need for climate change mitigation (Ellen MacArthur Foundation 2019).

Bamboo is an important carbon sink. Not only does a well-managed bamboo forest store carbon at a fast rate; as has been seen, over a period of years, one plant can be harvested numerous times, to create a large number of durable products which store carbon. If these products are used to substitute tropical hardwood or man-made materials, or as a source of renewable energy which can replace fossil fuel-based sources, then the CO_2 benefits could be higher than for any other bio-based material (van der Lugt et al. 2018).

Unfortunately, as bamboo is a grass and not a tree, there is a lack of guidelines on how to measure carbon from bamboo forests, and no methodology for quantification of emission reductions from managing bamboo forests. Research is slowly providing more clarity on how to measure the carbon stored in bamboo, and forestry practitioners in a number of countries are now being trained in these techniques (Huy and Thang Long 2019). Over time, these efforts should enable more countries to integrate bamboo into their climate change mitigation efforts, or ‘Nationally Determined Contributions’, under the UN’s Paris Agreement on climate change, as well as national carbon crediting schemes. Recent years have seen a number of important developments in this regard: China’s National Forestry and Grassland Administration has suggested that bamboo afforestation could be part of the new Emissions Trading Scheme; on an international level, one of the most recognised voluntary carbon standards, the Verified Carbon Standard, may soon include methodologies for bamboo afforestation and management.

These developments could all lead to extra carbon funding, and would increase the feasibility of establishing more bamboo plantations and forests worldwide, even outside of the traditional bamboo-growing countries.

Recommendation 5. Update HS codes for bamboo for more accurate trade statistics

Many of the assumptions about the size of bamboo markets in this report are based on existing trade statistics, which follow HS classification. This system, used by the World Customs Organization, UN Comtrade and a number of organisations to track international trade, classifies different groups of products under specific HS codes. However, in reality, the actual trade of bamboo products could be much higher. Firstly, HS codes tell an incomplete story of bamboo trade. Several upcoming bamboo industries, such as bamboo textile and bamboo pellets, have no separate HS codes, and as such are not included in general bamboo trade figures reported by organisations such as INBAR. In addition, due to the resemblance between certain bamboo and hardwood products, many engineered bamboo products are likely reported under HS codes for wood products.

The importance of international trade data, as an incentive for investment and government legislation and as a tool for business development, cannot be overstated. An improved classification and mapping of bamboo products under the HS system is essential to better track the growth and distribution of bamboo markets worldwide.

Work is already underway to provide more suitable HS codes. With the efforts of INBAR, the World Customs Organization and Chinese Customs, 14 new codes for bamboo and rattan have been put into effect since 2007, in which individual codes were given to bamboo and rattan wickerwork, furniture and seats, and bamboo charcoal, flooring, plywood, pulp, paper and preserved bamboo shoots. In 2018, there were 24 HS codes for bamboo and rattan products.

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About INBAR

Established in 1997, the International Bamboo and Rattan Organisation (INBAR) is an intergovernmental development organisation that promotes environmentally sustainable development using bamboo and rattan. It is currently made up of 46 Member States. In addition to its Secretariat Headquarters in China, INBAR has five Regional Offices in Cameroon, Ecuador, Ethiopia, Ghana and India.

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