

Sustainable Hybrid Materials : “where sustainovation meets the Circular Economy”

This publication is rooted in the original thesis with the same title presented by Gerben Eykenaar, at the TSM Business School (Hengelosestraat 583, 7521 AG Enschede) on April 12th 2012 in front of a jury.

Abstract

Innovative Hybrid Materials will have to provide for sustainable solutions in the building market. The building sector in The Netherlands is responsible for 40 % of the total annual waste volume. More than 95% of the all (sheet) materials used in the building sector are in one way or another hybrid. Most building materials are based on two or more integrated components, mainly defined by the requested properties, which basically only these very composites are able to meet. As a lot of “state of the art” solutions do not offer a Design for Disassembly concept, bringing back the separate materials in different loops appears to be impossible or too costly. This paper intends to provide for a rough outline on how to introduce a new process technology for Sustainable Hybrid Materials within existing conservative B2B markets and how to innovate and manage the Closed Loop Supply Chain within a sustainable business model.

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Keywords: Circular Economy; Sustainovation; Keen Company[®]; Sustainable Hybrid Materials; Closed Loop Value Chain[™]; Design for Disassembly; HTL[™]; Clean Tech; Cradle to Cradle[®]; The Natural Step[®]; Sizopreg[®]; M2[™], D2[™], A2[™]

Shifting To a Circular Economy

From the early beginning the industrial revolution was based upon what we call nowadays a **Linear Economic Model** of “ **take – make – dispose** “. Companies used materials just to manufacture and sell them for - hopefully - a fair profit. It is expected that in 2020 82 billion tonnes of raw material will worldwide enter the economic system every year ! The majority of this volume will be disposed of through a landfill or, even worse, through incineration.

Despite the current crisis, for the coming decades millions of new middle-class consumers will enter the market wanting the same satisfaction of needs that already exist for a long(er) time in the western world and upcoming economies (i.e. BRIC countries).

Although our entire mindset is locked into the linear system, more and more experts of different disciplines call for a shift to a **Circular Economy**.

The Building Industry in The Netherlands

In the Dutch building market segment the crisis appears to be persistent and deep. Since the beginning of the crisis (end of 2008) the total turnover in the Netherlands decreased with more than 10 billion Euro, resulting in a total loss of approx 40.00 jobs so far. The total building market in the Netherlands has decreased from 2010 till now with 15 %.

In 2012 the situation will even deteriorate following recent reports of the Economic Institute for Building (EIB). The residential building volume will drop with 5% and the utility building volume even more, with 8%, accounting for both shell and finish.

Despite these rather dramatic figures, the general opinion in the building industry is that sustainability is going to stay one of the major factors for the near future market growth and will not be a disappearing factor.

Sustainovation

The conception of **Sustainovation** (amalgamation of sustainability and innovation) has been introduced by the BSG Group USA ¹ to describe the combination of sustainability and innovation in the B2B environment. It is exactly this combination, which is needed to “bent” the Linear Supply Chain towards a Closed Loop Supply Chain.

Considering the rather conservative building market segments , it should be understood that there are all kinds of vested interests to maintain the Linear Economic Model of wastage and pollution. Innovative new ideas often have to come out of the non-traditional branches, not being influenced by self-interest and protectionism.

Sustainable Hybrid Materials

It is often not realized that more than 95 % of the building materials are eventually hybrids. Even “green” products like e.g. real wooden floors (harvested from FSC forests), need a top layer finishing (lacquer, oil) to meet the very demanding features in the application. By realizing a “wood-hybrid” in this way, we actually have polluted the wood and thus prevent it from becoming part of an infinite Closed Loop Cycle.

The conclusion is that most of the building materials used are based on two or more integrated components, often also part of different loops (e.g. bio- and techno loop).

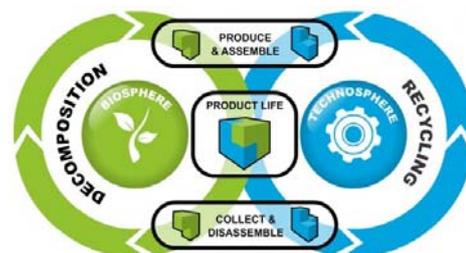


Figure 1. Bio- and Techno Loop

After the useful life of the composite product there is normally no other solution than to landfill or incinerate the non compatible multilayer construction.

Design for Disassembly

Already in 2001 at the respected University of Lund one of the most extensive researches on **Design for Disassembly (DFD²)** has been made by C. Thormark titled *“Recycling Potential and Design for Disassembly in Buildings”³*. In this thesis the DFD component has been extensively analyzed and described.

It is concluded that a decisive factor for recycling is the scope for disassembly. So, one of the main objects has been to formulate guidelines for DFD. The main conclusions are here:

- Adopt a **Life-Cycle Approach**. Consider how the product is produced and how it will be handled during use, renovation and deconstruction, and provide access for this.
- **Design for Disassembly** and recycling. Ensure that there is more multidisciplinary knowledge applied in the design process.
- Provide **Information** on the design to future users.

The combination of these three elements provides us already with a clear picture of which customer problems have to be solved in the B2B environment.

The Customer Challenge

Building up a **Value Proposition** is often based upon a so-called description of the Customer Problem. Facing today's challenges, it is now proposed to speak of the **Customer Challenge**, reflecting better what we would like to achieve with **Sustainovation**.

If we would describe the Customer Challenge in a generic way we could say that hybrid products, being capable of meeting the demands of the **Circular Economy**, should at least fulfill the three elements of being able to be brought back in their respective loops, of being designed to be deconstructed and, of being able to communicate and proof these features in a transparent and easy way to all stakeholders in the loop.

Based upon the assumption that we fulfill the three elements a value proposition could then read as follows:

offering multilayer hybrid products, which will allow for Design for Disassembly features, following strict transparent criteria presented by the rules of the Circular Economy.

Let us now have a look at a new process technology for hybrid multilayer panels, which can be perfectly used for a wide range of applications in the B2B building environment.

An Innovative Breakthrough Process Technology

Till now thermo lamination has been mainly used in the textile industry to convert different textile based layers into strong flexible (decorative) composite materials.

Twente, being originally a very strong textile producing region (from the early start of the industrialization up to the late nineteenth seventies), was forced at the end of the last century to shift over to high tech textiles to survive the effects of globalization. Only a few very high potential companies managed successfully to shift over to the manufacturing of high tech textiles, of which Royal Ten Cate in Nijverdal is one of the most famous manufactures in the Twente region.

In 2012 a unique flat bed laminator (continuous press) became operational in Twente The Netherlands, being able to produce full size multilayer sheets for the interior decoration market. In the first quarter of 2012 major steps have been made to create panels fulfilling all of the major specifications called for in the interior building market (e.g. **Cradle to Cradle⁴** inspired and designed for disassembly).

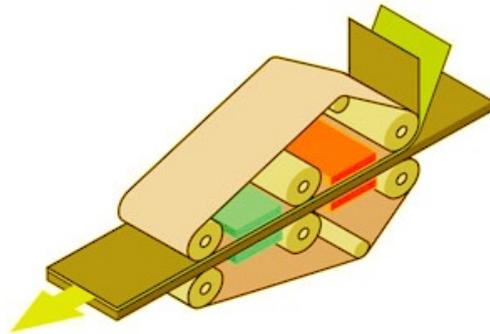


Figure 2. Flatbed lamination

Apart from the stunning properties of the **HTL⁵** panels made, the technology itself can be classified as **CleanTech⁶**. By only using heat, pressure and time the entire production process is completely clean and safe and appears to be fully in line with **TNS, C2C** and **CE** principles⁷.

Curious about one of the 1001 possibilities with this innovative technique? Read more about it in the Appendix *“A Practical Case”*.

KEEN[®] Companies in a Closed Loop Value ChainTM

Because of the fact that the whole Supply Chain should, in the end, take responsibility for closing the technical- and bioloop, it looks evident that the way of cooperation within, what we will refer to from now on as the **“Closed Loop Value ChainTM”⁸** will be an as important **Success Key Factor** as for whatever production, and or marketing techniques to be developed for achieving a Circular Economy.

In this article the **KEEN**® Company®⁹ will be used as a metaphor for a company acting in the Circular Economy.

The **KEEN**® Company is following the well-known **SMART** principles and stands for a sharp, eager, enthusiastic, devoted, intense, strong, competitive, communicative, sound company. Generically a **KEEN**® Company can be characterized as a B2B enterprise, which - being part of the **Closed Loop Value Chain**™ - embraces and intelligently combines the major sustainable (like e.g. CE, TNS and C2C) business principles.

New methods of Communication

In a **Closed Loop Value Chain**™ (**CLVC**™) the B2C and C2B communication is essential to realize reverse logistics on the required level of profitability. The **Greencode**®¹⁰ - being a so-called interactive information platform - shows the potential of the internet to provide solutions towards the need for information (think i.e. of the possibility of a QR "green" code to not only give essential sustainable information about the product / material built-up, but also on how and where to return the goods at what possible refund).

From the **Account Management** and **Procurement** will be asked to communicate in a total different way. The principles of the TNS, C2C and CE must be first understood and then implemented. Knowledge about just product or material properties will not be sufficient to close the technical or biological loop. Only by transferring essential knowledge (i.e. needed to upcycle instead of downcycle) can partners in the **CLVC**™ make a distinctive move towards effectively closing the loop.

Currently the **Social Media** show to be a remarkable asset towards the B2B, B2C and C2B communication. It should be pointed out that "greenwashing" is becoming more and more difficult as a lot of discussions are carried out in the open now. Platforms like "**Cradle to Cradle Supporters** - NL" have become very popular within a very short period of time resulting in a very knowledgeable platform. I.e. companies producing PVC based materials and products often do not realize that upcycling is a complete different story following the C2C movement than recycling: trying to use this platform at the beginning to promote their ideas lead to some sharp discussions as regards to content. In these discussions the (technical) knowledge among the C2C supporters proved to be on a very high level.

A lot can be said about **Authenticity** (being one of the newest buzzwords around in the B2B), but one thing should be clear to any company around the globe. Pretending to be a sustainable company is just not good enough. Information with the speed of light throughout the globe, makes it almost impossible to hide. Being by coincidence "green" does not make a company credible and reliable, nor does it disqualify companies being open in what they think should be done better to become a real "green" company.

It will be no surprise that a **KEEN**® company will be: an **Authentic** company; acting in **Closed Loop Value Chains**™; recruiting communicative and knowledgeable staff; openly transmitting information via various **Social Media** platforms.

How Everybody Will Benefit

If we successfully want to change from a linear approach towards a circular approach, the most important rule of thumb for optimization will prove to be to: "create the tightest circle possible, using the lowest minimum of energy and materials possible". Today's recycling processes are still too long cycles, with almost always effects of material deterioration (**Spiral Loop**¹¹) and high energy consumption rates, due to heavy, powerful machinery.

However, in a Circular Economy improvements in material selection and product design will lead to purer upstream and downstream material flows, and also to improved designs for easier ways of disassembling product compositions. Furthermore using **KEEN**® principles in existing business models will expedite the change from ownership to innovative performance based payment models.

In Table 1. all the benefits are schematically shown for all participants in the **Closed Loop Value Chain**™ involved in the production and consumption of e.g. a bio plastic multilayer hybrid sheet material made with the patented thermo lamination technique.

- The entire **CLVC**™ benefits from the fact that the cooperating chains, although being primarily interested in their own profits, gain from considerable short cuts in the loop and Clean Tech production methods.
- All the companies benefit first of all from reduced materials bills, and warranty risks. Apart from that, they will gain momentum by getting a far better customer interaction and loyalty. Last but not least will the product complexity of hybrid materials be less by the **DFD** component of the innovative thermo lamination technique.
- The consumer benefits from safe and sound materials and the optimized transparency in the entire chain, enforced by effective and efficient intra-communication. The consumer has become a partner in the Value Chain, which also implies that the other partners will value the end-user in an entirely different way than they did before in a Linear Economic model.

A well-known saying is: "*the proof of the pudding is in the eating*". Having pointed out all of the above benefits it would be nice to bring them to life in practice. Please read "*A Practical Case*" and "*Today's Future*", in which The Export Office shows more than a glance of the possibilities of implementing the basics of these a.m. **KEEN**® principles into the practice of a Circular Economy.

It should be noted that the chosen example (a PLA based bio plastic hybrid sheet material called **Sizopreg**®¹²) is just one of the amazing possibilities of the thermo lamination technique.

Type	Chain Link	Cost advantage	Effectiveness & Efficiency	Sustainability
CLVC™	Entire chain	Bio loop material which can be in an economic way, be locally produced and maintained.	Short cut loops resulting in tight cycles. Less spillage due to transparent communication.	Highly reduced emissions and energy consumption. No interference in food chain.
	Farmers	High yield, cane sugar, based crop.	Worldwide homogeneous and simple cultivation, which can be processed more than once a year.	GMO free plant and renewable feedstock.
KEEN® Company	Compounders	Less processing costs due to non hazardous materials.	Very simple master batches C2C basis of compounds.	Very low CO2 footprint Clean & safe additives. C2C approved granulates.
	Extruders	High recuperation yield. Less cleaning costs. Cheaper compound composition.	High ease and quality of production Lower portfolio complexity	Clean basic built up Clean Tech process.
	Laminators	High recuperation yield. No cleaning and extraction costs.	Lower portfolio complexity. Very flexible production process.	No emissions during production. Clean Tech process.
	Thermoformers	High recuperation yield. No cleaning and extraction costs. Low or no molding costs.	Lower portfolio complexity. Ease of thermoforming and bending. Quick and effective processing.	No emissions during production. Clean Tech process.
	Resellers	Lower working capital. Superior shelf life regarding thermoforming properties.	Lower portfolio complexity. Improved design freedom for participating designers and users.	Green product line and certified C2C approval of basic bio plastic material.
	Installers	Ease of installment Low weight composite material.	Less product complexity. Increased added value by welding and 3D-printing .	Compatible bonding and sealing techniques.
	Recyclers	High value of returned materials by disassembly. Lower upcycling costs.	Less production and product complexity.	Clean product separation for (different) loops. Industrial composting or recycling.
Consumer	End-users	Performance based products Possible attractive refunds. Optimized price/quality value.	Improved customer loyalty, influence transparency and interaction in the entire Value Chain	Closed Loop product. Safe, halogen free and low smoke flame retardant versions.

Table 1. Benefits of PLA based Bio Plastics to the Circular Economy

Today's Future

It is the beginning of December 2012. John Keen Sr. smiles when entering with his son the impressive Green building via the main entrance hall. John Keen Sr. was an important member of the building combination erecting this revolutionary Green building totally based upon Cradle to Cradle principles.

The **KEEN® Building** company, being specialized in installing partition walls, accepted early 2012 the challenge to install the first C2C inspired composite wall panel ever in this breathtaking building.

*“Look dad, the 12 years old John Keen Jr. is shouting. I scanned the **Greencode®** at the entrance for the entire building and its materials and just passed on the link to all my friends. They think it is really cool to have a dad working on a safe and sound future !”*

Looking up from his smart phone John Keen Jr. identifies the **Greencode®** label of one of the laminated wall panels and just for fun he “scans” the full composition of the wall. It appears to be a C2C certified laminated **M2™**¹³ wall panel entirely made of PLA based layer material, being put into a C2C certified Aluminium framework. The DFD partition wall in total can be very easily deconstructed in its individual parts and thus brought back in their respective loops. Looking around more closely John Jr. sees a funny furniture and is flabbergasted by the design of it.

*“What’s that dad ? “ It is a **Wibble®**¹⁴ son, just have some fun with it !”*



John Keen Jr. is excited, playing with the chair with marbles inside and is really enjoying his “ride”.

*“What is it made of dad ? Check by yourself son, by scanning the imprinted **Greencode®** on the inner surface..... Wow, That’s Cool !”*

John Keen Jr. again uses his smart phone to check the C2C properties of the chair.

*“Can I please have such a chair at home ? Perhaps, John Keen Sr. replies, if you are a good boy now. Dad look, you can just put an immediate order online for this chair through the same **Greencode®** system. Please let me have one.....please !”*

John Keen Sr. is not responding to his sons request as he is struck by the appearance of the very funny window shields, made out of a thermoplastic C2C core material and laminated with a thermoplastic C2C finishing wall paper. The total infrastructure of the building is just so inspiring to experience that John Keen Sr. feels proud to have been part of the building team .

Walking back with his son through the entrance hall to the car, John Keen Sr. is really impressed by the efforts made by the entire Value Chain to have created such a beautiful and revolutionary Life Cycle Design building.

Driving home John Keen Sr. is already imaging the cheerful face of his son when finding a brand new -online ordered **Wibble®** in his bedroom

Figure 3. The Wibble

Appendix A Practical Case

“A New Keen Standard for Sustainable Hybrid Materials “

As we have already shortly introduced the thermo lamination technique, we will now have a closer look at the possibilities of this break through process technology.

Early 2012 **The Export Office** approached **Synbra Technology BV** and **Houthandel Blok** to start up a unique project. **The Export Office** - representing the patent for this new revolutionary lamination technology - had just started up the collaboration with **SI Zwartz BV**, to implement this technology on their brand new (and modified for this very purpose) flat bed laminator.

SI Zwartz had already developed a PLA based material with jute reinforcement ¹³ and wanted to commercialize this in the interior building market. The Export Office - being a specialist and pioneer in this market segment and the Circular Economy - offered to improve on the quality and composition of the base material; the dimensions of the sheet material; C2C inspired hybrid **D2TM** ¹³ and **M2TM** ¹³ combinations with such materials and the flame retardant properties of these kind of materials.



Figure 4. The Synterra® Loop

In May 2102 in an amazing four weeks time schedule a complete collection of prototypes **Sizopreg**® was established, inclusive an excellent basic quality, the right sizes and flame retardant (FR) properties. Due the fact that **Synbra Technology bv**, produces both the granulates and foam particles, hence an entire **Cradle to Cradle** inspired sandwich panel (based upon C2C certified granulate and foam material) was being realized in less than one month !

First market tests on the multilayer hybrid product made clear that all participating Value Chain partners where on the right track.

As **Synbra Technology bv** already holds longer experience with the so-called **Synterra**® and **BioFoam**® materials, it appeared evident that the product built up would provide for some excellent features.

If we take a closer look on what we from now on will refer to as **Heat Transformable Laminates (HTLTM5)** materials we can tentatively make already the following observations:

- Synterra PLLA and PDLA grades are perfectly suited for use in decorative based multilayer (hybrid) panels, offering attractive and interesting properties towards this market segment.
- The lamination technology adds a revolutionary thermo formable dimension towards the design possibilities of designers and architects in the interior building segment.
- The PLA based - jute reinforced - bio plastic in itself offers stunning properties and benefits to all Value Chain partners (see previous Table 1).
- The hybrid multilayer sandwich panel offers unique possibilities and benefits to all Value Chain partners, especially due to it's DFD feature.
- Although the base price of the bio based granulate is still considerably above the base prices of comparable polyolefin (mineral oil) based granulates, the total cost of ownership perspectives look very promising.
- Starting off with interior applications the material shows an interesting extra potential in future – more demanding - exterior applications.
- Using jute reinforced PLA inner core layers to strengthen hybrid constructions looks very challenging and will be explored more in depth through field- and desk research in the coming years.
- In combination with PLA based wall coverings new installation techniques like welding joints and printing in 3D may be used, offering unique possibilities of “C2C-ness” added value in the application and upcycling.



Figure 5. Sandwichpanel with Sizopreg® decking and BioFoam® core

Last but not least it should not be forgotten that the discussed thermo lamination process technology has just started up and keeps the promise of more surprising product- and material combinations in the (near) future.

To be continued

Notes

- 1 *BSG group USA. Sustainovation* was firstly introduced by the BSG Group USA to describe the combination of sustainability and innovation in the B2B environment.
- 2 *DFD*. Often used as abbreviation for Design for Disassembly
- 3 *C. Thormark*. Recycling Potential and Design for Disassembly in Buildings. Thesis 2001. University of Lund Sweden.
- 4 *Cradle to Cradle*. Sustainable business model described in “Remaking The Way We Make Things”. William McDonough & Michael Braungart. First edition 2002.
- 5 *HTL™*. For the first time used in this publication of 2012 by The Export Office to describe a new generation of so-called *Heat Transformable Laminates*.
- 6 *Clean Tech*. Has been described by the company Clean Edge (clean technology research firm) as “a diverse range of products, services, and processes that harness renewable materials and energy sources, dramatically reduce the use of natural resources, and cut or eliminate emissions and wastes”
- 7 *Abbreviations*. TNS for The Natural Step, C2C for Cradle to Cradle and CE for Circular Economy
- 8 *Closed Loop Value Chain™*. Firstly described by The Export Office in 2008 to illustrate a closed loop supply chain adopting the upcycling - / marketing principles of the Circular Economy.
- 9 *The KEEN® company*. Firstly introduced by The Export Office in this thesis to describe a company acting in a Closed Loop Value Chain™.
- 10 *Greencode®*. QR based system developed by Marco Dees, which identifies “green spots” within a building.
- 11 *Spiral Loop™*. Firstly introduced by the Export Office in the thesis of 2012 to describe the standard recycling process of “downcycling”. Although the timeline has been extended by recycling, in the end recycling is still embedded in the linear economy, leading eventually to downcycling.
- 12 *Sizopreg®*. In 2001 the first ideas about a thermoplastic materials with natural fibers (jute) were developed by Zwart. The material called Biopreg® was based on a standard pressed PLA with jute inlay and should become a sustainable alternative to resin based materials. Sizopreg® being diverted from this idea, is referring to a complete collection of decorative thermo laminated panels for the interior building industry.
- 13 *A2™, D2™, M2™ Hybrids*. Firstly introduced by The Export Office in the thesis of 2102 to describe hybrid materials as a function of their product built up in a closed loop system .
- 14 *The Wibble®*. Designed by the designer collective SensId, being the first furniture to adopt the Design for Disassembly (DFD) principle.

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* *Gerben Eykenaar*. The author Gerben Eykenaar started up his own operation - *The Export Office* - end of 2011, kicking off with the representation of a patented thermo lamination process technology and a part-time study at the TSM Business Schools : *Industrial Business Marketing & Innovation Programme*. In April 2102 the Innovation Case : Sustainable Hybrid Materials - “where sustainovation meets the Circular Economy “ – has been published by Gerben Eykenaar, describing the innovative thermo lamination technology and the way this technology has to be implemented in a Circular Economy.

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