How cradle to cradle design principles can be implemented into architectural construction methods and designing for the lifecycle of a building.
Table of Contents
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>4</td>
</tr>
<tr>
<td>What Is Cradle to Cradle Design?</td>
<td>8</td>
</tr>
<tr>
<td>Why Adopt Cradle to Cradle Design?</td>
<td>12</td>
</tr>
<tr>
<td>Designing for Disassembly</td>
<td>16</td>
</tr>
<tr>
<td>Supplying a Building as a Service</td>
<td>20</td>
</tr>
<tr>
<td>The Problem With Recycled Materials</td>
<td>24</td>
</tr>
<tr>
<td>Cradle to Cradle Construction Materials</td>
<td>26</td>
</tr>
<tr>
<td>Learning from Vernacular Architecture</td>
<td>34</td>
</tr>
<tr>
<td>Integrating the Cradle to Cradle Principles into Architectural Design</td>
<td>38</td>
</tr>
<tr>
<td>Conclusion</td>
<td>42</td>
</tr>
<tr>
<td>Bibliography</td>
<td>44</td>
</tr>
<tr>
<td>Appendix I :The Hanover Principles</td>
<td>48</td>
</tr>
<tr>
<td>Appendix II :The Cradle to Cradle Certification Criteria</td>
<td>50</td>
</tr>
</tbody>
</table>
Introduction
"In many ways the environmental crisis is a design crisis. It is a consequence of how things are made" (Fletcher, 2001:45).

Designers and architects have a very important role in lessening mankind’s impact on the environment. At present products and buildings are designed and then the environmental impacts are dealt with later, often with end of pipe solutions and quick fixes. Instead the environmental consequences of a design should be considered at the beginning of the design process and not at the end, thus allowing for a more complete sustainable strategy to be implemented into the design. For example, chemicals are often present in the materials of a design that are harmful to humans and to the environment, even though safe alternatives are available. Evidently the design process needs to be changed.

Popular thinking sees this change as being difficult, time consuming and detrimental to economic growth and our quality of life, as increasing pressure is being placed on us to refrain from pursuing the activities and items that give us enjoyment and a sense of well being. Cradle to cradle design provides us with an alternative to this and creates a very good argument as to why it is essential and beneficial for companies to adopt these principles.

Cradle to cradle design has already proven that considerable environmental and economical savings can be achieved by adopting this design philosophy. This dissertation will examine the adoption of cradle to cradle design within architecture and explore its advantages by examining early examples of the principles. Throughout my research, I have found that full examples are still very thin on the ground; however, there are many projects that have begun to make headway towards fulfilling the cradle to cradle principles.
For the purpose of this dissertation I intend to focus on how cradle to cradle principles can be implemented into architecture, primarily during the design and construction phases of a building’s life cycle. This will include how a building could be designed so it can be constructed to allow for disassembly and the extraction of its technical and biological nutrients. An entire cradle to cradle designed building, on a large scale, is still someway off but there are several small-scale buildings that could be certified as cradle to cradle at present. Vernacular architecture has also been incorporating cradle to cradle methods into buildings for centuries and I will discuss this in a later chapter.

In this country the Composting WC in Ecclesall Woods, Sheffield, which was designed and built by 12 MArch students from the University of Sheffield (Bureau of Design Research, 2007), is a good example of a small scale cradle to cradle building that will become a biological nutrient. The toilet is made from locally sourced timber and uses no glues or metal connections in its structure. It sits on a foundation of reclaimed railway sleepers and creates a shelter in the woods for a composting toilet. This careful method of design and construction means that at the end of the buildings life it can be easily disassembled and reused within the biological cycle. I think that this building has been highly successful and shows that by carefully questioning the way in which materials are currently used it is easy to create a very beautiful, cradle to cradle compliant building on a small scale. This way of thinking is gradually proliferating into larger projects and I will look at how some of these projects have begun to use the cradle to cradle principles. I will also discuss how a completely cradle to cradle design might be achieved.
I will also look at how construction materials could be redesigned to make them cradle to cradle certified. As well as looking at the range of alternatives to traditional materials that could more easily become technical and biological nutrients.

I will also investigate how the building can be designed and specified for its intended lifecycle and how this can be integrated into the cradle to cradle cycle. Again this will be backed up by examples of how this is already beginning to happen in architecture.

Throughout my research I have noticed that the majority of texts on cradle to cradle design are written by its advocates William McDonough and Michael Braungart\(^1\) or by authors reviewing or directly referencing McDonough and Braungart’s ideas. I have had to interpret these in a non-biased way and have also referred to several more general texts on sustainability to enable me to present a balanced view on cradle to cradle design.

I have also referred to a range of case studies from product design, construction material design and architecture. This involved consulting the technical data published by the manufacturers and by reading journal articles and books that use the products, materials and buildings as examples. I have used these case studies to illustrate the points that I have made about the possibilities of cradle to cradle design in architecture.

Notes:

\(^1\) Although it is beyond the scope of this dissertation to review it, McDonough and Braungart cite *Small is Beautiful: Economics as if People Mattered*, Schumacher, F (1973) as inspiration for their ideas and this provides good background reading on sustainable economics.
What is Cradle to Cradle Design?
Current industry follows a cradle to grave design. Raw materials are extracted from the Earth, manufactured into a product with a defined life and then disposed of when this is reached. This method exhausts the Earth’s finite resources and then places the waste product back into the ground, in the form of Landfill, where it is of no use to anyone. This is a highly unsustainable industrial model and eventually the Earth will no longer be able to cope with the strain we put on it.

A cradle to cradle industrial system is one that copies natural cyclical systems, allowing for a fully sustainable environment. It utilises a “waste is food” principle meaning that any waste produced goes onto feed another system. For example, a cherry tree produces hundreds of cherries in an attempt to create one other tree, something that would be considered a great waste in our current industrial system, but any cherries that are unsuccessful are eaten by animals or fertilise the soil around the tree. Cradle to cradle design uses this concept² to design products and materials that allow our industrial system to copy this natural model (McDonough & Braungart, 2001).

Cradle to cradle design questions society’s current outlook on materials and products as having a finite lifetime and then disposing of them at the end of the products useful life. Instead its advocates, the architect William McDonough and the chemist Michael Braungart (2002), want products and materials to be part of an endless cycle that replicates nature’s.

This means that products will need to be constructed in a way that makes them easily dismountable; allowing their components to be become either technical or biological nutrients. A technical nutrient means that the material or component will be able to replenish the technologi-
cal cycle, either by being reused in another product, reused in a different way or recycled into something new. A biological nutrient, on the other hand, is able to replenish the biological cycle, usually by being completely compostable and nourishing the soil. To allow this to happen more easily, each component of a product should ideally be made of a single material, especially where a component is likely to be recycled as a technical nutrient. Currently many items, such as aluminium drinks cans, are made of different grades and alloys of a material, meaning that when they are recycled the material produced is of a lower quality due to these alloys being mixed together during the process: something that McDonough and Braungart have termed “downcycling” (2002:56). Instead they believe that products should be designed to be quickly and easily disassembled, so that less durable parts can be replaced to extend the products lifecycle and it also means that when the product reaches the end of its useful life it can be quickly dismantled into technical and biological nutrients. The technical nutrients can then be “upcycled” (2005:72), which means that the resultant products are the same or greater quality than the original. Whilst the biological nutrients can become compost and fertilise the Earth, thus closing the cycle. Designing products or parts of products out of the same material is another strategy that McDonough and Braungart suggest; meaning that it is easier for products to be reused in a technological cycle, as they are free from contaminants. This also makes it more economical for smaller parts to be recycled as there is a higher percentage of a given material to recover from a product. Both of these ideas would be easy to implement into architectural situations as discussed by Solomon in her article Products Made From “Eco-Effective” Components (2005).
Another principle advocated by McDonough and Braungart is that products should be supplied as a service package. Instead of buying a product and throwing it away at the end of its life, a company would supply a product to the consumer as a service. The company would retain ownership of the materials and product and would come and replace the product when it became obsolete or worn out. The company would then take back the product and reuse or sell the components and materials present. This would encourage companies to use materials more efficiently, to create effective return procedures for the products and to recycle the materials more effectively. It would also benefit the consumer as their product would be maintained and updated as part of the service charge; the company providing the service would also have a larger incentive to keep the product working and up-to-date.

Presently, like many of the other cradle to cradle principles, there are no companies that provide products as a service but there are many companies that are heading in the correct direction. For example, Solutia Inc. a carpet fibre manufacturer has established a program called Partners for Renewal, where they have teamed up with entrepreneurs across America to find alternative outlets for post consumer carpet waste. Although Solutia do not retain ownership of their carpet fibre and reuse it at the end of its life, they do help the carpet’s owner to contact members of their scheme to help dispose of their used carpet fibres in a sustainable way. As this scheme becomes better implemented it won’t be long before Solutia begins to provide their carpet fibres as a service (Solomon, 2005:163).

Notes:

2. All the cradle to cradle concepts are detailed in the Hanover Principles which I have included in Appendix I.
Why Adopt Cradle to Cradle Design?
Cradle to cradle design is unique amongst sustainability theories in that it allows us to eliminate or reduce many of the impacts that man has on the planet whilst still allowing for economic growth, enabling humans to become stakeholders of the Earth. On its most basic level cradle to cradle thinking aims to eliminate waste sent to landfill by incorporating all materials into biological and technical cycles. This will result in less of a need for landfill sites to be the final resting place for waste which will take thousands of years to decompose, thus reducing the contamination of the surrounding environment that this causes through the release of harmful chemicals into the earth. By incorporating waste into a cyclical system our consumption of raw materials will be reduced. This allows future generations to continue to use the limited resources that the planet has to offer and will also limit the scarring of the landscape caused by their extraction and the damaging effects that this has, such as increased erosion.

Another aim of cradle to cradle design is to remove harmful substances, such as known carcinogens and toxic materials, from the industrial cycle altogether and to find safe alternatives to them. This creates many advantages both environmental: industrial waste will create less or zero damage to natural ecosystems, and economic: safer materials will mean fewer health and safety regulations in the workplace which results in a healthier and more cost-effective workforce. The materials are also much easier to recycle into the cradle to cradle system after their intended use if they are free from hazardous chemicals, for example, waste is currently burnt to create energy but many harmful chemicals are released in this process making it less environmentally friendly than is currently thought.
Eliminating harmful substances from materials also benefits architecture as fewer harmful emissions will be given off by the materials used, thus eliminating sick building syndrome. As Gallung (1980, cited in Berge 2000:142) states:

“Oil based products, when used in building, can release transitory organic compounds... Many of these pollutants irritate the mucous membranes and can produce traditional symptoms of bad indoor climate such as irritations and increased frequency of respiratory illness. Other more serious emissions... can cause allergy, cancer or embryonic malformation”

More specifically for architecture, cradle to cradle design has tried to make buildings more efficient, more environmentally friendly and better for the workforce. It has currently been more focused on redesigning industrial buildings but these ideas can be applied equally to all other forms of architecture. The cradle to cradle principles build on current sustainable building and servicing methods and implement them in a more integral way to the building and the processes that take place within. A good example of this is Ford’s Rouge Car Plant in Michigan, USA (Ford Motor Company, 2007). The plant was very inefficient and losing money but by redesigning the plant and the processes inside to replicate natural systems Ford has changed the fortunes of its flagship plant. Badly lit production lines were transformed with the introduction of skylights, improving efficiency. Poor rain water management was transformed by adding grass roofs to the site, and the integration of the surrounding vegetation into the production process has eliminated almost all harmful con-
taminants produced. As a result the car plant is now thriving, demonstrating that by applying cradle to cradle principles to architecture, buildings can be designed to be more efficient, reduce running costs, improve the efficiency of workers and have less of an impact on the immediate environment. However the transformation of the plant by Ford is merely a green-wash applied by Ford to improve its image and there seems little point in creating an environmentally friendly production plant that still churns out huge numbers of heavily polluting cars each year. It is definitely a step in the right direction but Ford should have consulted McDonough and Braungart on a cradle to cradle car before they redesigned their factory. This use of green-wash seems typical of heavily polluting multinationals, as they try to create a green public image for themselves, whilst doing very little to actually change the products they manufacture.

The redevelopment of the Rouge Car Plant does show that with a minimum increase in the initial cost of large industrial buildings, they can become far more efficient and sustainable than they currently are. This means that, not only is it attractive to companies to become more environmentally friendly, it should also be very attractive economically to companies and their shareholders. Without this economic advantage it is even harder for companies to be persuaded to incorporate sustainable issues into their business, as they are more focused on short term goals and achieving a return for a shareholders investment. This is why McDonough and Braungart have put a lot of effort into promoting the economic benefits of cradle to cradle design alongside the obvious environmental benefits; this is something that is needed to encourage large companies to adopt this approach.
Designing for Disassembly
Before building materials can be recycled as technical and biological nutrients they must be removed from a building. This will only be done if it is economical for the demolition contractor to remove the materials as Addis (2006: 70) states:

“Building components and equipment are only likely to be re-useable if they can be easily removed from the building without being damaged. This will depend on both the methods for fixing and the sequence in which various components are assembled into a building.”

To enable more materials to be reclaimed and recycled easily there needs to be a change in the way that architects design and detail buildings. Architects will need to take a leaf from environmental guidelines for product designers and begin to design building components from single materials, making it easier for them to be recycled as technical or biological nutrients. It will also make disassembling the component easier, as there will be fewer individual materials to disassemble and sort.

An example of how buildings can be constructed to allow for disassembly has been devised by Patrick Freet in his design for the recent cradle to cradle home competition, which I will discuss later. His idea is to construct the external walls of buildings from panels utilising snap-lock connections (Freet, 2005). These connections allow the house to be easily reconfigured, enabling it to grow with the owner and adapt to changes in fashion or environment. When the owner decides that these panels have reached the end of their life then they can easily be removed from the structure, whilst retaining their second hand value, and newer panels installed to replace them. Freet envisions that the panels could then be sold to a
second-hand building supplies store and that families who cannot afford new materials for their home could purchase the panels. The panel is then resold and passed on to various other owners before being finally sold back to the manufacturer and reprocessed to become the base for new wall panels. I think that Freet has devised a very workable material cycle that brings benefits to the construction industry, the home-owner, charity groups and the environment, however the design of the wall panels need careful consideration to ensure that they can become technical nutrients at the end of their working life. This is a challenge for all aspects of the building industry setting out to create cradle to cradle certified products as, unlike product design, it is hard to construct buildings from a single material that can fulfil the needs of structure, weatherproofing and insulation.

Another difficulty that will need to be overcome is making it economically viable for building products to be salvaged by demolition companies. Currently materials will only be disassembled from a building if there is a significant demand for the material or if the material removed is of a high enough value to be profitable to the demolition company. For example reclaimed roof tiles are highly sought after and antique fireplaces command a high enough value to turn a profit, meaning that both of these components will be salvaged by the demolition company. Conversely structural steel work, which has been successfully reused in several schemes, is not commonly salvaged as there is not an immediate demand for it. Demolition and salvage companies prefer not to have materials in storage awaiting a suitable project as this reduces their profit margins, so they will only salvage materials if they can be passed down the supply chain quickly. This is a problem that will have to be overcome if all the materials in a building are to be reused within technical or biological cycles.

This is a “chicken and egg” scenario as architects are only going to start specifying recycled and reclaimed materials more frequently if it is easy for them to do so and salvage companies are only going to stock more reclaimed materials if there is a significant demand for them. This problem has been dealt with by Patrick Freet’s snap lock external panels mentioned previously and the second hand building supply thrift stores that he proposes. How-
ever in the mean time, the architects of recent buildings that have reused a high percentage of materials from previous projects have had to establish links with local contractors and visit buildings awaiting demolition regularly to source suitable materials for their new building. Once these have been obtained research must be undertaken to ascertain if they are suitable for the intended purpose and finally the detailing and design process needs to remain flexible to accommodate the strengths and weaknesses the material might have developed within its previous use (Addis, 2006:31). Often a practice will need to employ a member of staff specifically for this purpose and this adds both complexity and cost to the design process making it less attractive to firms without a strong sustainable ethos.

This was the case with the C.K. Choi Building at the University of British Columbia, Canada (Addis, 2006:31-34), the architects of which aimed to include at least 50% by weight of reclaimed or recycled materials. The materials used had to be sourced very early on in the design project to ensure that they would be available in time for construction and they had difficulties in getting the materials passed by the local building regulatory authority. These regulatory difficulties were overcome by a close collaboration between the timber graders, the structural engineer and the architects and meant that 100% of the structural timber frame was constructed from reclaimed timber sourced locally.

Other elements of the building that consist of reused materials include the brickwork in the external skin and doors, staircase balustrades and a variety of other internal fittings, all of which enabled the building to exceed its target of 50% reused or recycled components. Whilst this is a high level of recycling, and helps demonstrate to the building industry that more components can consist of recycled materials, it is nowhere near the level of material reuse required for an entire cradle to cradle building. Much of the recycled components used, such as the recycled-content gypsum wallboards for example, are actually downcycled materials. As gypsum wallboards are a common material for internal walls this suggests that an alternative method of internal cladding should be used to allow the wallboards to be reused entirely within the technological or biological cycles. I will discuss how this could be achieved in a later chapter.
Supplying a Building as a Service
The problem of encouraging the disassembly and recycling of buildings could be overcome more easily if developers and contractors began to supply buildings as a service package. Instead of supplying a finished building to the client, a developer would lease the building to the client. The developer would retain ownership of all the materials and would also be responsible for the cost of their disposal. This would encourage the developer to seek out alternative uses for the building’s materials at the end of its lifespan saving them money on landfill taxes and perhaps increasing their profit by selling or reusing the materials they own. It could also persuade them to commission buildings that are easily disassembled and more efficient in their material use as it would be more economically viable to do so. For example developers would be less inclined to use large amounts of concrete in buildings as it is difficult for it to be reused or recycled, depreciating in value significantly at the end of a building’s lifespan. This would be beneficial for the environment as the production of concrete uses a large amount of energy, creating a large amount of carbon dioxide as a result (Berge, 2000:98) This would also mean that a larger percentage of a building could be reintroduced into the technical and biological cycles after use, something which isn’t possible with concrete. However, at present, it would be difficult to eliminate all concrete from the building industry, as it fulfils a structural function that the industry would be reluctant to replace with a different material, even though alternatives already exist and have been used for centuries, wooden piles for foundations being an example. It will be difficult for buildings to become completely cradle to cradle compliant until a method for fully reusing concrete, or a replacement, can be found.

A building as a service package would also be beneficial to the client as the elements and materials of their build-
ing would be replaced as they wore out or became dated, allowing the client to occupy the building for a longer period than normal. Whilst this method of ownership offers many advantages to the client it is unlikely to prove successful at the moment, especially in the domestic sector, with the desire to invest in a building and obtain a foothold on the property ladder. Commercial tenants would also be less keen to pay the slightly increased rents that would be associated with the service charge of a building. They could just move to a more prestigious, new-build development when their current accommodation becomes dated and unsuitable for their needs instead. I will discuss how this could also be prevented, by designing flexible buildings, in a later chapter.

This type of ownership is already being introduced into this country in the form of Private Finance Initiative (PFI) projects which give developers a financial stake in the lifetime costs of public buildings (Bartlett & Howard, 2000:316). The developers become owners of the buildings and in return the public sector pays an operating fee. The scheme was introduced in 1992 and has been successful in encouraging developers to consider the environmental impacts of projects, as it makes economic sense to do so, rather than just responding to tenders. However, the scheme does not take into account the cost of disposing of the building at the end of its lifecycle and this is something that, in my opinion, needs to be changed if developers are to be encouraged to consider the impact of construction waste more carefully. There also needs to be a larger focus on the good design of buildings within the PFI scheme as this lack of ambition is discouraging architects from wanting to design for the scheme (Bullivant, 2005:65). I think that the PFI scheme is a step in the right direction but that it needs to be implemented in a more complete way to encourage cradle to cradle cycles to become inherent in the construction industry.
The Problem with Recycled Materials
Of course the use of reclaimed and recycled building components is only part of the cradle to cradle picture as another aim of McDonough and Braungart’s theory, mentioned previously, is that “materials should be chosen to minimise hazardous chemicals” (McDonough, 1992:8). Often recycled materials are specified as they are thought to be environmentally friendly but sometimes they are merely “less bad (McDonough, 2005, cited in Robins, 2005:2)”. For example the recycled newspaper insulation used in the C.K. Choi building was chosen as it was thought that a recycled material would be best for the environment, however to make recycled newspaper fire retardant enough to be used as insulation it must be sprayed with chemicals, as well as fungicides to limit mould growth. These chemicals, coupled with the ones already present in the inks in the paper, might then be off-gassed within the building contributing to sick building syndrome. This “quality” is common amongst many building materials with a recycled content and is one of the reasons that carpet underlay, containing recycled car tyres, was rejected for use in the C.K. Choi building.

McDonough and Braungart (2002:59) argue that: “Just because a material is recycled does not automatically make it ecologically benign, especially if it was not designed specifically for recycling. Blindly adopting superficial environmental approaches without fully understanding their effects can be no better- and perhaps worse- than doing nothing.”

I agree with this statement in so far as an increase in the use of recycled materials could lead to an increase in the number of harmful chemicals present within the home. This may be detrimental to the health of the occupants but I also think that their argument is highly impractical. They are correct in saying that current sustainable initiatives are only concerned in limiting the damage that we are inflicting on the planet with our industrial systems but I think these initiatives are the only way that we can make the step towards a cradle to cradle model. A cradle to cradle industrial model will work but this will not happen instantly and until this model is fully implemented we still need to take measures to limit the consumption of our planet’s resources.
Cradle to Cradle Construction Materials
Cradle to cradle design has made a slow start in the construction materials industry and at present very few materials can be certified as technological or biological nutrients.

Product designers are leading the way in designing materials and products that can carry the cradle to cradle certification (See Appendix II) with office furniture companies being the first to take up the challenge of creating fully certified products. Herman Miller, a leading American furniture company, has been the driving force in this change with its aim to become the first fully sustainable company, supporting McDonough and Braungart’s vision (Rossi et al. 2006). They have focused a large amount of time and money on the research and development of their products. Evaluating each one in terms of material-chemistry, disassembly and recyclability with the result that many of their products are now cradle to cradle certified forcing their competitors to follow suit.

To design a chair that attained cradle to cradle certification Herman Miller created a new tool to assess a product’s progress towards certification: the Design for Environment Product Assessment Tool. This tool gave the designers a much clearer picture of the overall eco-effectiveness of a product rather than the narrow view offered by traditional tools such as Lifecycle Assessment. This has allowed the designers to make radical changes to the chairs that Herman Miller produces to enable them to gain cradle to cradle certification. Changes that have been made include:

- Changing the material of the chairs spine to improve material safety
- Increased recycled content of the materials
- Eliminating PVC from the chairs components
- Designing the chair for rapid disassembly using common hand tools

(Rossi et al. 2006:4)
All these changes have decreased the level of chemicals off-gassed from the chair and increased the ease of reusing materials within the technological cycles.

I think that it is important for architects to begin to adopt these new tools and this new way of thinking to help buildings to become more integrated into the technological and biological cycles. It is also important that architects begin to specify materials that are cradle to cradle certified as this will put pressure on components manufacturers to begin to implement cradle to cradle strategies and designs within their product range. This will only be possible if the construction industry is open and flexible to new methods of working and new materials to work with. For example recycled content gypsum wallboards are used extensively in buildings to clad internal walls. By specifying recycled content wallboards it is assumed that a sustainable choice has been made but in reality their use is only a slightly more efficient use of materials rather than a truly sustainable choice.

Gypsum wallboard is made by sandwiching plaster between two sheets of specially treated paper and this is the major setback in them achieving cradle to cradle certification, as it is constructed from two chemically different materials (plaster and paper) that are permanently joined together. This makes it impossible for the two materials to be disassembled and recycled. Instead they are generally sent to landfill, or crushed and recycled when they are removed from a building. This recycling is actually downcycling as the gypsum powder becomes contaminated with the paper used to hold it together in its first use, gradually reducing the quality and strength of the plasterboard. Also, as in the gypsum wallboard used in the C.K. Choi building mentioned earlier, the recycled newsprint used to hold the board together is a downcycled material of a lower quality than in its original form. Neither the plaster nor the paper coating are true technical nutrients meaning that this process isn’t truly sustainable in the cradle to cradle sense of the word; instead the materials are only prevented from going to landfill for a couple of generations. This, coupled with the off-gassing that the recycled wallboards create, means that they aren’t a completely sustainable material as they will place a burden, in several ways, on future generations.

The method in which gypsum wallboards are applied to
the internal walls also needs to be reviewed as this currently hampers their ability to be reused, a trait that could make them a more sustainable building material. Often they are attached to internal walls by nailing them into a timber stud-frame and this reduces both the wallboard and the timber’s ability to be reused in another project. The use of nails and glues to join materials is becoming increasingly popular in the construction industry as it seeks to be erect buildings within shorter and shorter time-spans. By using more nails and glues it makes it harder to disassemble building structures quickly, effectively and without damaging the components. This makes demolition companies less likely to remove them from a site and reuse them either entirely or as a technical nutrient, resulting in a higher percentage of construction waste being sent to landfill. For internal wall construction to integrate into the cradle to cradle system the entire process needs to be rethought, both in terms of the materials used and the method in which they are assembled.

One material that could offer an alternative to traditional internal wall construction is cardboard. This technology is being developed and pushed forward rapidly by architects, notably Shigeru Ban who has used cardboard in much of his work, including his Paper Log House, Hyogo. Ban has often used curving walls of cardboard tubes standing on end to create the internal walls of spaces, such as those in his Paper Gallery, Tokyo and he “believes that paper tubes have a strong future as a construction material (Ban, 1997: 54).” The cardboard tubes can be used to create very beautiful walls, whilst providing all the functions of a traditional internal wall, and they are easy to erect. They are also easy to recycle at the end of their life and if they are recycled outside of the main consumer waste stream then there is very little loss in material quality, meaning that they could become a technological nutrient. Ban’s work has shown the great potential of cardboard as a structural material but it has yet to be adopted by more than a handful of architects across the world which is surprising considering that cardboard buildings are cheap, environmentally friendly and easy to construct.

There are many cardboard products that are already on the market that could replace gypsum wallboards for internal partition walls. A British company called Quinton
Kaines, which produced the panels used in The Cardboard School (Cottrell and Vermeulen, 2001) already manufacture honeycomb cardboard panels that are currently used for exhibition display boards, ceiling tiles and furniture. Although this product is not cradle to cradle certified it does provide a highly sustainable alternative to gypsum wallboards that in the future could become a technical or a biological nutrient. The panels, essentially card honeycombs sandwiched between two cardboard sheets, are easy to install, versatile and off-gas very few chemicals. They can be painted on, just like a traditional wall, and can be fully recycled at the end of their useful life as the entire panel is manufactured from the same material (Quinton Kaines, 2006). Alternatively if the glue and the paint used to paint the panels was made from organic compounds then the panel could become a biological nutrient in the form of compost.

For the honeycomb panels to become a complete cradle to cradle nutrient then Quinton Kaines would need to implement a clear product take-back scheme to encourage demolition contractors to salvage the product and to allow the materials present in the panels to be better integrated into the technological cycle. To further increase the ability of internal walls to become a part of the technological cycle the panels could be mounted on a lightweight metal frame, instead of the timber frame that is traditionally used. This frame could then be recycled into the technological cycle and be used to make more lightweight metal frames for internal walls. It is hard to see why the construction industry hasn’t begun to use metal frames on a large scale as they offer many advantages. As Addis (2004) states:

“Galvanised steel studs are cheaper, lighter, straighter, easier to cut and conveniently holed for stringing conduit and pipe. They don’t burn or rot. They stack compactly. They take less skill to work than wood. The steel itself is 60% recycled. And being quickly assembled with wall board screws, steel studs can be quickly taken apart and reused.”

If the construction industry adopted this construction method for all internal wall construction then a large
amount of timber could be prevented from being cut down and sent to landfill. Instead, a large amount of the steel studs could be reused or recycled to make new steelwork. This is a very simple change that could happen immediately and, in my opinion, would be very easy to implement, being of huge benefit to the environment.

Of course paper and card have been used for centuries in Oriental architecture for internal screens and partitions but it is a much underused construction material in this country and if it is to become more popular the construction industry’s opinion of it has to be changed. One such project that has pushed the material to its limits in an effort to highlight the advantages of cardboard architecture is The Cardboard School in Westcliff-on-Sea, Essex. The building which provides an after school club and extra classroom for the school has won several awards, including the RIBA Sustainability Award (Chapman, 2002:41).

Cardboard was chosen as a material for the school due to its green credentials and also due to waste-paper being available in large quantities and at low cost\(^3\). In fact, pupils from the school collected waste paper from the local community, involving them in the construction process (Cripps, 2001a:6). Although the school is not a complete cradle to cradle design it takes a very large step forward in terms of recyclable architecture, and this has been helped by careful choices made by the architects and engineers behind the project. Initially they aimed to use 90% recycled materials, not including the floor slab, and this could have been achieved easily. But due to the requirements of the school to create a robust building more timber than originally planned had to be used (Cripps, 2001b:8). Virgin timber was used for this purpose but reclaimed timber would have been equally suitable. The building’s green credentials are still retained as the timber is easy to disassemble and so can be reused in another project at the end of this building’s life. As a result of this use of timber, the building uses just over 50% recycled materials and this is still an excellent figure. This is especially good considering the fact that the materials used can be recycled at the end of their life and that the off-gassing from them is very low, unlike those in the C.K. Choi building mentioned earlier. The architects decided to use panels that were made entirely of cardboard wherever
possible and they also tried to limit the use of chemicals used to prevent fire and insect infestation. For example, instead of spraying the internal structure of the wall panels with insecticide they used careful detailing to keep water out, thus deterring certain insects and moulds from inhabiting the structure. On top of this they installed insect mesh over all the ventilation gaps to prevent insect ingress. By making these simple design decisions the architects have removed the need for insecticides to be used and prevented harmful chemicals from off gassing, something that is especially important in a building that is going to be used by young children. This, coupled with the architects desire to keep all the detailing, such as the waterproofing, within the panels as simple as possible helps the building to be recycled at the end of its life and by constructing the building from predominately the same material it also makes the disassembly of the structure very easy too. The architects had the intention of making every aspect of the building fully recyclable but this has had to be compromised throughout the design process to take into account structural, water tightness and safety issues. Although these compromises had to be made, this building is still a very good example of many of the cradle to cradle principles and with some more development we could soon see a fully cardboard building that can then become a technological nutrient. At present, a large proportion of the building can be implemented into the biological cycle through the architects’ careful limitation of the chemicals added to the cardboard. This amount could be increased with a little more development in waterproofing technologies and fire prevention methods to enable these functions to be performed by an organic substance, thus imitating nature.

I think that there is still a long way to go before architects will be able to specify building materials that are completely cradle to cradle compliant but it is still important to specify green alternatives wherever possible, and to put pressure on the manufacturers to begin to develop cradle to cradle alternatives. I also think that architects have an important role in deciding how the building will be put together, they must begin to change the traditional methods that the construction industry uses and adopt a more sustainable approach. Lessons could be learnt from The Cardboard School and the simple methods that the architects have used to detail the building to allow for ease of material recycling. Many of the technologies cur-
rently available would allow buildings to be disassembled and recycled more easily but they have yet to be adopted on a large scale and simply by adopting these technologies a large step could be made towards a complete cradle to cradle building.

Notes:

3. This was necessary as the budget for the project was very small.
Learning from Vernacular Architecture
The ideas of designing for disassembly, material reuse and building from organic materials are not new and have been practiced since buildings were first built. For example the Romans would save stone blocks from demolished buildings and reuse them entirely in new projects. This was cheaper and easier than quarrying new stone; whereas nowadays “it is generally considered more economic to extract and convert raw materials than reclaim and recycle waste” (Fletcher, 2001:41). Buildings in many other cultures are still designed with these ideas in mind; traditional Japanese houses, for example, are built without any nails and can be disassembled and reassembled like a puzzle (Fishbein, 1998:80).

It seems that our construction industry has lost this inherent thriftiness and the direct contact with nature that comes from building with materials that are from the earth and close to the construction site. The way that masonry structures are constructed is one example of this, bricks used to be laid using a lime mortar but now, in an effort to increase the speed that brick walls can be constructed, a concrete mortar is used instead. Whilst this has improved the speed of construction it has had many other negative effects, many of which are detrimental to the environment. Lime mortars take several days to initially set and this allows mistakes to be rectified and for the building to settle. Lime mortar never fully sets so the building can adapt to changes in the ground which prevents cracks appearing in the brickwork and would allow for a longer lasting building. The fact that lime render never fully sets also means that at the end of the building’s life the bricks can be carefully removed and reused, something that cannot be done with cement mortars. In fact, these reclaimed bricks are frequently salvaged from a demolition and resold through salvage yards as they are in great demand. Lime mortar, being a natural product is also more environmentally friendly than concrete mortar, needing less energy in its manufacture. Despite its slower construction speed lime mortars offer many advantages over concrete mortars and it is time that it becomes more widely used within the construction industry again.

We have a lot to relearn from other cultures about building in a sustainable way that doesn’t leave a large pile of unusable materials at the end of the building’s life. As different cultures, who fail to have a choice, continue to build in the same way that their ancestors did we
choose to build in an increasingly unsustainable way, constructing buildings rapidly with little care or thought to the environmental conditions offered by the building site; something that happens without a second thought in vernacular buildings. We are also quick to impose this architecture on other countries where it may not be suitable culturally or climatically, and forcing the local people to import expensive foreign materials from wealthy, developed countries (Finch, 2006:42). Maybe we should be trying to replicate the hands-on approach that they take to building, by using local materials and techniques applicable to these materials instead of adopting a one-size fits all approach to architecture.

Stunning, contemporary architecture can still be achieved by using simple, natural material as shown by The Handmade School in Rudrapur, Bangladesh by Heringer and Roswag (2006). They have used local techniques, skills and materials to inform the design of the school and have managed to create a stunning, functional building that presents a sustainable model as to how the local people could build in the future.

The school is built on a brick foundation, on which sits ground floor walls of loam and straw. The first floor is then built using bamboo sticks and boards, with a roof of bamboo. All the materials present (aside from the foundations, damp-proof course and steel pins) can then be integrated into the biological cycle at the end of their life and return to the soil that they came from. The brick foundations have the possibility of being reclaimed and reused in another building. I think that Heringer and Roswag have shown that great architecture can be achieved using simple materials and construction techniques. Their building has given the local people a lasting piece of architecture, entirely fitting to their needs, and one that uses traditional materials that directly benefit their local economy.

I also think that is an excellent example of cradle to cradle design and something that could be emulated by architects looking to build in Western countries. Simply by choosing local, natural materials instead of more industrial, man-made ones and by using the properties that the materials already have, such as the weatherproofing offered by timber shingles, a building can be constructed that can be more easily integrated into the biological cycle at the end of its life. Buildings built from natural materials may not last as long as those built from “bricks and mortar” but maybe they don’t need to. Often buildings
are demolished in this country simply because they no-
longer fit the needs of the owner and not because the fab-
ric and structure of the building have worn out. Instead
buildings could be constructed from natural materials, or
cardboard for that matter, that are designed to last for a
shorter period of time and then at the end of the building
material’s useful life they could be demolished and rein-
roduced into the technological and biological cycles. A
new building could then be built that would fit the func-
tional requirements of the occupier more successfully.
However this is only one strategy in redefining the de-
sign and lifecycle of a building to make them more in line
with the cradle to cradle principles. In the recent cradle
to cradle home competition the winning design featured a
concrete structural frame, a material that has the poten-
tial to last for a long period of time, which creates a large,
flexible space internally (Coates and Meldrum, 2005).
This allows the spaces inside to be easily reconfigured if
the needs of the homeowner change, preventing the
building from being demolished unnecessarily and pre-
venting large amounts of waste from going to landfill,
thus conserving their embodied energy (Brand:
1994:194). I think that flexible spaces offer so many ad-
vantages to the buildings user, as well as allowing the
building to have a longer life, that architects should begin
to move away from using a functionalist approach to de-
sign internal spaces.

However, many highly functional buildings are com-
monly reused for many different purposes; churches for
example are often reused as offices, flats, houses or
sports halls despite their original, very specific use. This
shows that as long as buildings are built with integrity and
to a high standard then the desire to reuse them will be
there and that perhaps we are currently too focused on
putting up buildings cheaply and efficiently. It is hard to
see a modern flour mill, usually made with cheap corru-
gated iron and little architectural care, being turned into a
contemporary art gallery but that is exactly what hap-
pened to the 50 year old Baltic Flour Mill in Gateshead
(Ellis Williams, 2002). This has successfully turned a
large, functional space into a stunning set of galleries for
the display of contemporary art and helped to stimulate
the redevelopment of Gateshead. This is something that
could not have been achieved if the flour mill had not
been built with integrity originally.
Integrating the Cradle to Cradle Principles into Architectural Design
The entrants to the competition to design a cradle to cradle home for a site in Roanoke, Virginia, have designed some imaginative, highly fitting solutions that aptly demonstrate many of the cradle to cradle principles. For example the winning design, by Coates and Meldrum, uses solar power to produce more electricity than it uses and so is able to supply the local grid with power. Its most interesting feature is the integration between the building and its environment, with the house almost becoming a part of the landscape. This allows natural processes to continue to function around the house and even helps some of these to function more easily. This is something that is lacking in the majority of housing in this country with developers using a generic arrangement of rooms for any location, failing to take into account the benefits of integrating passive heating and cooling strategies into the house. Whilst the competition designs were all produced with a specific site in mind many of the competitors produced a strategy for how their design could be integrated into different locations and environmental conditions, something that is important if cradle to cradle housing is to become economically viable on a larger scale.

I also think that this more integrated approach to sustainable design is something that is still missing from current sustainable architecture; the main aim of which is to use energy more efficiently. This is achieved by super insulating and sealing the buildings to limit heat and air loss whilst at the same time using many of the “sustainable” materials that I mentioned previously in the materials section. Sealing all these harmful chemicals into a building may save energy but they can have a detrimental effect on human health. I agree with McDonough and Braungart (2003) where they state: "Where buildings with reduced air-exchange rates are common, so are health problems. In
Germany, where tax credits support the construction of energy efficient buildings, allergies affect 42% of children aged 6-7, largely due to the poor quality of indoor air.”

I think that current sustainable architecture could be accused of being too focused on merely saving energy. It should also take a step back and take a look at the entire sustainable picture, which encompasses materiality, energy and water conservation, the lifecycle of the building and end of life strategies. Whilst there has been much focus on the use of recycled materials, energy conservation and passive heating and cooling strategies there has been less focus on the recyclability of buildings and the reduction of the off-gassing of harmful chemicals within buildings, both of which are very important sustainability considerations. Maybe sustainable architecture needs to strike a balance between reducing the amount of energy we use and sealing harmful chemicals into a building. Instead of removing all possible leaks that contaminated air could escape from, in a bid to reduce energy loss, they could design a house that creates more energy than it needs and then distributes this energy to the local area.

I also think that sustainable design needs to focus more on radically changing consumer culture rather than just making our current lifestyles “less bad.” The cradle to cradle home competition has encouraged architects to do just that by offering the five guiding principles that should inform their design. The first of which states:

“The design decisions that you make as part of your submission for this competition must express what your own personal goals are for the future of building with a full appreciation for how that relates to the needs of the human culture to sustain itself (SmithLewis Architecture, 2004).”

As a result of this the entrants have come up with some designs that really question the way that we live, use and construct our homes, representing an important step towards a fully cradle to cradle certified home.

There is a danger that sustainable buildings will fall into the trap of current housing that quietly churns out large numbers of generic housing solutions, merely making these generic buildings more sustainable. Sustainable buildings are most successful when they really question
current lifestyles and attitudes. Bill Dunster’s BedZed\(^4\) development (2002) is an excellent example of this and by changing the way that the BedZed residents live he has created a highly sustainable community with a very low energy use. Although the BedZed development isn’t a cradle to cradle development it is a good example of the radical changes that need to be made to begin to live in a way that replicates nature’s cycles and more developments of this ilk are needed to really push forward these principles. The cradle to cradle home competition is a good example of this push and with the winning design going to site this year the use of cradle to cradle design in architecture should begin to gain momentum. On completion this should help to demonstrate the advantages of cradle to cradle design on a wider scale and encourage more architects to design in this way. It should also apply more pressure to the manufacturers of construction materials to develop cradle to cradle certified products. The fact that the competition received over 600 entrants from around the world is encouraging, and shows that cradle to cradle design is already beginning to be thought about by architects.

Notes:

\(^4\) The BedZed development is the UK’s largest carbon neutral, mixed use development. The scheme integrates housing, work and community spaces and includes a number of highly innovative sustainable schemes and ideas. More information can be found at: http://www.peabody.org.uk/pages/GetPage.aspx?id=179
Conclusion
Whilst it will be some time until cradle to cradle design becomes fully integrated and accepted into the construction industry it is important that architects begin to adopt its principles and ideas into their work. Many of the important concepts can be addressed at present, such as designing a building to be fully integrated into the surrounding environment, and steps can be taken towards the realisation of some of the other concepts, such as designing for disassembly. It is also important that architects begin to specify the few cradle to cradle materials that are available and put pressure on manufacturers to develop more, thus proving that there is a demand for these products.

It can be said for any sustainable ideals, that there must be economic incentives, and a market, for manufacturers to provide sustainable products and for them to conduct their business in a more sustainable way. Luckily McDonough and Braungart have spent a lot of time promoting the economic benefits of cradle to cradle design and companies are beginning to integrate their business strategies into the cradle to cradle cycles of their own accord. This is why I think that cradle to cradle design is a very real alternative to the way that we currently design and produce as it makes both environmental and economic sense.

Architects have been slow to take up this challenge and really change the way that buildings are put together to enable them to be more sustainable. Architects have an important role in this alternative industrial system and it is important that they begin to take stock of the whole sustainable picture when they are designing buildings, perhaps by following the example that product design has begun to set. It is also important that we design sustainable buildings, not just in a way that benefits humans but that also takes account of the needs of animals, plants and nature as a whole. As William McDonough (1993) said:

"if we understand that design leads to manifestation of human intention, and if what we make with our hands is to be sacred and honour the earth that gives us life, then the things we make must not only rise from the ground but return to it, soil to soil, water to water, so that everything that is received from the Earth can be freely given back without causing harm to any living system. This is ecology. This is good design."


Bullivant, Lucy: (2005) Anglo Files: London, Thames and Hudson


Fletcher, Scott Lawrence: (2001) Developing Disassembly Strategies for Buildings to Reduce the Lifetime Environmental Impacts by Applying a Systems Approach: Thesis (Ph.D), University of Sheffield School of Architecture


(Accessed 21/3/2007)

(Accessed 28/2/2007)


Quinton Kaines: (2006) QK Honeycomb Products Brochure: Suffolk, Quinton Kaines


Appendix I : The Hanover Principles
1. Insist on rights of humanity and nature to co-exist in a healthy, supportive, diverse and sustainable condition.

2. Recognize interdependence. The elements of human design interact with and depend upon the natural world, with broad and diverse implications at every scale. Expand design considerations to recognizing even distant effects.

3. Respect relationships between spirit and matter. Consider all aspects of human settlement including community, dwelling, industry and trade in terms of existing and evolving connections between spiritual and material consciousness.

4. Accept responsibility for the consequences of design decisions upon human well-being, the viability of natural systems and their right to co-exist.

5. Create safe objects of long-term value. Do not burden future generations with requirements for maintenance or vigilant administration of potential danger due to the careless creation of products, processes or standards.

6. Eliminate the concept of waste. Evaluate and optimize the full life-cycle of products and processes, to approach the state of natural systems, in which there is no waste.

7. Rely on natural energy flows. Human designs should, like the living world, derive their creative forces from perpetual solar income. Incorporate this energy efficiently and safely for responsible use.

8. Understand the limitations of design. No human creation lasts forever and design does not solve all problems. Those who create and plan should practice humility in the face of nature. Treat nature as a model and mentor, not as an inconvenience to be evaded or controlled.

9. Seek constant improvement by the sharing of knowledge. Encourage direct and open communication between colleagues, patrons, manufacturers and users to link long term sustainable considerations with ethical responsibility, and re-establish the integral relationship between natural processes and human activity.

The Hanover Principles should be seen as a living document committed to the transformation and growth in the understanding of our interdependence with nature, so that they may adapt as our knowledge of the world evolves.

Appendix II: The Cradle to Cradle Certification Criteria
<table>
<thead>
<tr>
<th>Criteria</th>
<th>Yes</th>
<th>No</th>
<th>1/2</th>
<th>3/4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.2 Raw materials</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All materials (if present) are identified and listed to the 123 step for end use</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All materials are classified as biological or technical hazards</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All materials assessed based on their intended use and impact on human and environmental health</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Human Health:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carcinogenicity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Toxicity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Malignant</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Microbiological toxicity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teratogenicity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acute toxicity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chronic toxicity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other criteria</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.3 Additional credits to achieve certification</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Product formulae, processes, etc.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.4 Additional credits to achieve certification</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.6 Environmental benefits for material design</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Define the appropriate cycle for the product and developing a plan for product recovery and recycling</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Define plans for reducing waste and recycling for developing the desired and recovery systems for this cycle of product</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Products have been designed manufactured for the technical or biological cycle and select the material or recycling process</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Specific material design for recycling and/ or manufacturing process</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.7 Energy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Characterize energy use and sources for product manufacture/assembly</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.8 Water</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Characterize water use and sources for product manufacture/assembly</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Implement water conservation measures</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Implement innovative measures to improve quality of water discharge</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.9 Social Responsibility</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Publicly declare corporate ethics and fair trade statement must be publicized across entire company</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Identify this party assessment system and begin to collect data for that system</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acceptable third party social responsibility assessment, accreditation, or certification</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>