1. Introduction

“Building art is a synthesis of life in materialised form. We should try to bring it under the same hat, not a splintered way of thinking, but all in harmony together” Alvar Aalto.

This quote from Alvar Aalto, a Finnish architect and designer, touches on a vital aspect of the circular economy: the need for a systems-thinking approach to design, one which takes insights from natural systems where, of course, there is no such thing as waste. In order for manufacturers to repair and remanufacture products in the circular economy, and recover biological and technical materials, products will need to be designed from the outset for disassembly. This requires a radical overhaul of the design process, with consideration paid to how components will separate, how the user will upgrade (if desirable and possible), and what the component pieces could become next.

Typically, little consideration is paid to what becomes of a product when it reaches the end of its first life: designers talk in terms of “End of Life” (EoL) and products are created to last one lifetime upon which they will break or, just as bad, be no longer supported. Try loading a new computer game on a six-year-old laptop, or finding the part you need for your ailing washing machine. This cradle-to-grave approach has been termed ‘planned obsolescence’, indicating the idea all along has been for eventual product failure, rather than defined use periods when the object is withdrawn for replacement. From the designers’ perspective, perhaps the problem has been that they have never before had to consider what happens to their product once it leaves their customers’ hands. This will inevitably change – and is doing so already – as firms move to benefit from the economic advantages of a circular model of production.
2. Some crucial components

In order to upgrade, repair, remanufacture and repurpose materials, it would be sensible to design a product so we can get ‘under the bonnet’ of it. This incurs questions about how the product is assembled and how it may be disassembled. For example, which tools – if any – are required? Are standard fittings used across the device to enable simple disassembly? Can any part of the disassembly process be automated to save time and money?

Dr Joe Chiodo, of Active Disassembly1, has been working in the field of disassembly for three decades, and he has designed a range of smart materials that allows for non-destructive, quick and efficient component separation, under a variety of triggered conditions. Among the innovations that Dr Chiodo has introduced are: biodegradable layers; thermally reversible adhesive sprays; and, shape memory polymers. These adhesives and fittings can be incorporated early in the design process of a product so that when it reaches EoL, it can simply be heated to allow it to ‘open up’ – no schematic drawings or tools for disassembly are required. Should the product be inadvertently heated to the trigger temperature, the process can be reversed if the temperature is lowered again.

Active Disassembly has experimented with its fittings on a whole host of products, from mobile phones, LCDs, plastics dominated goods (such as stereos), laptops, modems and printers. In a typical disassembly session, these devices travel along a conveyor belt that directs them to hot air tumblers. The heat either triggers the shape-changing properties of the smart materials, or it disintegrates the adhesive, and the products simply separate into their constituent parts. The crucial point to note at this juncture is that the products that Active Disassembly has experimented on were not designed from the outset for disassembly, yet the introduction of components and materials made component separation possible.

Continued
Dr Chiodo reports:
Active Disassembly (AD) technology can save time and money at the EoL stage in more ways than one: products could be done in EoL batches of 10s or 1000s at a time, reducing mean time, energy and costs to fractions of a penny per product. I essentially design EoL into the product so that at EoL, it breaks down non-destructively in a controlled hierarchical system. AD also offers clean segregation of liquid crystal in liquid crystal displays (LCDs), small components and contained liquids when designed at the onset.

The purpose of Dr Chiodo’s technology is to provide a solution which works for economies of scale, saving manufacturers money by reuniting them with their component pieces, which additionally generates all the savings associated with extraction and manufacturing from scratch: the embedded energy and material savings are not inconsiderable.

Despite the fact that the products Dr Chiodo has experimented on were not built with disassembly in mind, the use of his technology aided separation of component pieces. This can be seen as the beginning of a wider range of possibilities: imagine what else could be achieved if products are designed from the outset for disassembly.

3. The disassembled computer
While Active Disassembly technology allows for the mass disassembly of products under automated conditions, other products are best left to user upgrade to aid longevity. If you have ever dared open up your computer tower or laptop you will have found a jungle of cables, connectors and components, each attached one way or another to the motherboard. The mere thought of the sight will make some people turn and run, but others are keen to understand, repair and upgrade. Desktop PCs are relatively easy to upgrade due to their near-modular construction, but laptops can be a different story. In order to keep the size of the device down, a compromise is often made over the coherence in the internal workings, which affects the disassembly potential.

Autodesk challenged students from Aalto University, Finland, and Standford University, USA, to research, prototype and user-test product laptops that can be disassembled. They were given three rules: (1) this had to be done in 10 or less easy steps; (2) no tools could be used in the disassembly; and, (3) the user must be able to completely disassemble the product in less than two minutes.

In order to understand the design status quo, the students decided to see how long it would take them to disassemble a popular model of laptop. It took three engineers 45 minutes to disassemble, using three tools and 121 steps. Making disassembly and reuse all the more impossible is the fact that many computers have their parts soldered and glued together (see the 2012 MacBook Pro with Retina Display). Aaron Engel-Hall, one of the students involved in the project, said of existing machines: “In truth, almost everything in your laptop is recyclable material. The issue is that they’re all mixed together and separating all these materials into only their like materials is very difficult.”

Using Autodesk’s design software, the designers experimented with materials, shapes and stylistic considerations. They used a 3D printer to create their prototype laptop, before using the internal circuitry from an existing computer to test their work. Nine months later, the end result was the Bloom laptop. As per the instructions of the challenge, it can be disassembled in 10 easy steps, without tools, in less than two minutes. The materials can be easily separated into material types, such as plastics, metals and circuitry. The laptop is built on a modular basis, making it simple for the user to move the keyboard and trackpad, say, to a more favourable ergonomic position.
The Bloom was never commercially launched, but perhaps its design inspired Hewlett Packard. They released the HP Z1 in 2012, in 2012, calling it “the world’s first all-in-one workstation with a 27” (diagonal) display that snaps open to let you swap out parts and make upgrades. No tools required.”

HP Z1 is basically a monitor that contains all of the machine’s workings. It is opened as simply as a briefcase by pressing the buttons on the front and lifting the lid. Once opened, the user is presented with a schematic diagram of the internal workings to help locate components. HP has placed green indicators over the workstation to indicate the user-friendly areas. All of the major components can be unclipped using simple release tabs – no screwdriver is required. HP calls this ‘Tool-less Design’. For the security-conscious, the machine can be locked to keep out uninvited visitors. Keeping all of the required components inside a 27” display comes with a number of design issues, not least the problem of keeping everything inside cool. Computers use fans to regulate the temperature, but fans tend to be noisy, and noise from fans inside the monitor would reduce the machine’s appeal to users. So HP developed mini-sensors for the fans to regulate temperature quietly.

There is great value in the idea of a computer that can be opened up and easily disassembled. From the customers’ perspective, the disassembled computer allows them to access the inner workings with ease, meaning the life of the product can be extended considerably. For the manufacturer, an upgradable machine helps them to retain customers: rather than the customer ditching an obsolete machine – perhaps for a rival’s model – the customer can upgrade using the manufacturers’ parts, thus maintaining the relationship. When the user no longer has a use for the components, the manufacturer can reuse or remanufacture them for their next product, thus helping the business to save on both material and energy costs.

4. Are you sitting comfortably?
An engineer, an environmentalist and a designer walk into a bar, where they collaboratively designed a seat that is not only comfortable, but simple to disassemble in about five minutes.

Glen Oliver Löw, the designer of the chair, wanted to design a chair which was in tune with the user and the environment, before, during and after its use. The only way to ensure longevity of the Think Chair after its useful life was to design for disassembly, allowing the final user to strip the chair into its component pieces so they can be used again in a new process. The disassembly process takes about five minutes and requires only standard tools. Furthermore, Löw worked closely with McDonough Braungart Design Chemistry (MBDC) (MBDC) to ensure the materials used in the seat are non-toxic, 99 percent recyclable, and carry the lightest environmental impact.

Löw says: “Design isn’t just about style. It’s about integrity of materials, functional integrity, and intent. Think is a truthful chair – the result of open dialogue between engineers, environmentalists, and the designer.” 4
5. Modular construction

Some 20 million tonnes of construction waste was sent to landfill in 2010. Of all industries in the UK, the construction industry is the major consumer of resources, accounting for 90 percent of all non-fuel mineral use. Demolition sites contribute a great deal of that waste, yet it need not be this way. If we deconstruct buildings rather than demolish them, material could be diverted from landfill and put to better use. This approach may aid employment, as deconstruction requires more time and manpower than demolition. However, most buildings are put together without consideration of how the materials could be used in their next life, making the deconstruction job all the more difficult. The situation could be significantly improved if architects were to design buildings with future use in mind.

One way of supporting deconstruction could be building on a modular basis. Yorkon is one of the UK’s leading modular building manufacturers. This off-site manufacturer of buildings pieces together the final building in situ, having done the majority of the work elsewhere. In itself, this can be a money- and time-saver, as there is less disruption than would be the case for an on-site build. Yorkon claims that labour and material efficiency is greater in the factory environment in comparison with a typical on-site construction.

The modular nature of the construction doesn't necessarily restrict the finished design, yet it makes deconstruction a straightforward task.

Refurbishing and reusing modular buildings uses between just 2 and 8.8 per cent of the embodied energy required for the manufacture of new equivalent modular buildings. On top of that, modular buildings have the relocation factor: they can be dismantled and rebuilt wherever they are required. When repurposed for a new client, the buildings are cleaned, redecorated, unnecessary doors and windows are filled in, and new partitions are added as necessary. Modular buildings have an estimated lifespan of between 25 and 60 years. When there is no longer an economic argument for reusing these modular buildings, the design of them makes the extraction of the steel frame for recycling or reuse straightforward. The steel represents the largest single element in the building and accounts for about 65 per cent of the embodied energy.

In the book Sustainable Materials, Dr Julian Allwood makes the point that we can reduce the UK’s CO₂ output by disassembling steel frames and reusing them at high quality, rather than cutting them down and recycling the steel, which is the current practice. As Allwood explains, “there are no fundamental technical barriers to designing steel buildings now, with 40-year old steel”. Cost, as always, is the determining factor. The key to reducing costs is to produce standardised parts (steel frames in this example), and by designing them with mechanised joints, such as nuts and bolts. Allwood speculates that despite the higher cost of deconstruction compared to demolition (and the attendant health and safety concerns), there is a higher profit in reuse over recycling steel frames. Of course, there also needs to be a market for the reusable steel frames. With world demand increasing for steel-framed buildings, and likely to continue as the population grows, the market theoretically exists.

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