FUTURE PERSPECTIVE:
DESIGN PROCESS OF PERFUME PACKAGING

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Muotoilu- ja taideinstituutti
Muotoilun koulutusohjelma
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Abstract

In a world where technology develops at a rapid speed a packaging designer should have the ability to adapt to the challenges in a world where the packaging landscape might look far more different from today. This thesis will look at possible future scenarios relating to resources, infrastructure and consumer behaviour in the year 2050. It will then go on to discuss the emergence of new packaging materials pitted to replace plastic, as well as take a look at printed electronics in packaging and the potential of additive manufacturing. Through the research the outcome will take a previous completed design of perfume packaging and project it into the future landscape. The design solution will be 3D renderings accompanied by a drawn scenario based on the scenario research to demonstrate how a consumer might interact with packaging in the middle of the 21st century.

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1.0 Introduction

The stone age, the bronze age, the iron age, the history of man's anthropological development has been referenced through it's advancement in material technology. In several hundreds of years from now our descendants may very well look back on our time as 'the plastic age'. Plastic is undoubtedly a remarkable material; durable, lightweight, able to be formed into a myriad of shapes and sizes in a variety of colours. It's implementation in packaging has allowed us to ship and receive products all over the world with less weight, at less cost and with less product damage than preceding materials such as glass and tin. But plastic is derived from oil and oil is for fact a finite source. Plastic has also become a devastating menace to our environment and especially to our oceans, causing a detrimental effect to our marine ecosystems and consequently our own health. The next age will have to replace conventional plastic as we know it and reduce or eliminate the harm that it causes.

As well as developments in material technology we are also living in an exhilarating era of packaging design with the emergence of printable electronics. With the ability to print low grade organic electronics on mass scale at low cost brings countless application opportunities to the packaging market. This can enhance brand identity, product authenticity and safety, packaging functionality and push packaging into a whole new realm of modern living.

Advancements in 3D printing might also herald a new era of how things are manufactured in the future. This paper will take a look at what is happening today and what it could mean for packaging tomorrow.

The outcome will be a design for perfume packaging based an a previous paperboard packaging designed by myself. It will use the technology research as well as future scenarios presented by SPREAD to build a concept of what eco-luxury might look like in the future and how consumer and packaging might interact with each other.

2.0 Recreate Packaging

2.1 Recreate Packaging Overview

Recreate Packaging was a competition hosted by Stora Enso in 2016. The brief was to design packaging for a luxury product in any of the following categories: perfume & cosmetics, champagne & fine spirits or chocolate & confectionery. The key point for the brief was ‘luxury is tactile’, meaning that a focus should be placed on the feel of the packaging in the luxury market. They were looking for new and innovative ways in which their material could be formed and promote renewable luxury packaging. Although graphic and primary packaging design could be developed, the main criteria was to focus on the structure and functionality of the secondary packaging. The contestants were given a choice of three of their paperboard materials in varying grammage to use: Performa Brilliance, CKB and Ensocoat. (Recreate Packaging, 2016).

2.2 Inspiration

The inspiration for my project came in two parts. Firstly from a previous structural design which I created as part of coursework to design a goody-bag for the Muotsikka fashion show (Image 1). The design wasn’t chosen to be used for the fashion show but I liked the design and wanted to utilise it for another project. The original inspiration was from a clock but it developed organically to take on more of an insect-like form. The second part was a visit to a butterfly sanctuary in Laos during the summer of 2015. There I saw for the first time a Chrysalis (Image 2). Chrysalis is defined in the dictionary as “the hard-shelled pupa of a moth or butterfly” (Dictionary, 2016). I thought it a perfect example of packaging found in nature and also a reflection of renewable material.

Image 1: Goody-bag Concept - Duncan Anderson - 2015

Image 2: Chrysalis and Newly Hatched Butterfly - Duncan Anderson - 2015

2.3 Concept Prototyping

To begin with I took the structure from the goody bag and made it smaller and widened the base a little to make it more stable. I then completed the structure so it was fully encased and investigated different kinds of openings as I wanted to create a feeling of emergence when the packaging was opened, much like a butterfly emerging from it's chrysalis.

Image 3 & 4:

Shows experimenting using ribbon to connect the front flaps. Although the opening was smooth I wanted to only focus on the given materials and make the design without using any extra fastenings like ribbon.

Image 5 & 6:

Shows the flaps connected by the material and the opening flap has a tab which connects at the top eliminating the need for any extra fastenings. However, the front was not really secure when closed (image 5) and all of the small folds were too much of a strain on the material.

Image 7 & 8:

Shows the same kind of design as before but with the flap on the outside. This made it more secure when closed and it had an interesting pop opening effect when the flap was pulled down. However I felt that the essence of the inspiration was a bit lost and it didn't re-close properly due to the resilience of the material.

Image 3: Prototype 1 Closed - Duncan Anderson - 2016

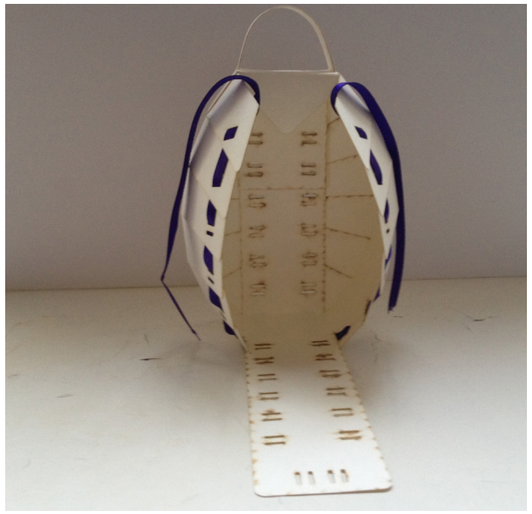

Image 4: Prototype 1 Open - Duncan Anderson - 2016

Image 5: Prototype 2 Closed - Duncan Anderson - 2016

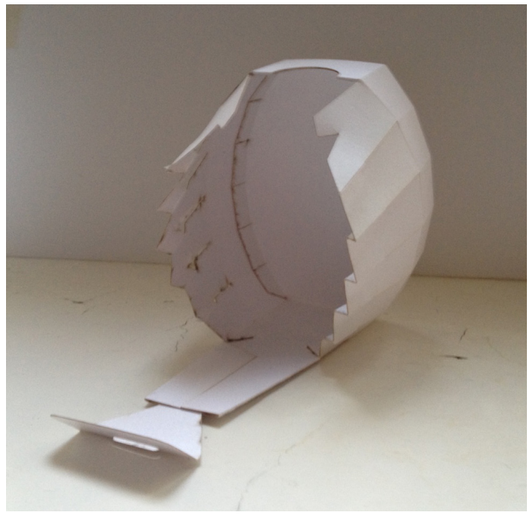

Image 6: Prototype 2 Open - Duncan Anderson - 2016

Image 7: Prototype 3 Closed - Duncan Anderson - 2016

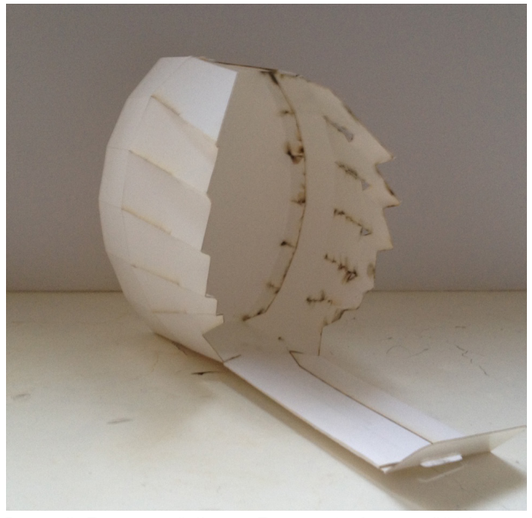

Image 8: Prototype 3 Open - Duncan Anderson - 2016

2.4 Final Design

In the end I settled on turning it into a flip box (image 9) to make the design more secure, simpler and easier to understand. I also wanted to simplify the design to show the potential of it being brought to a production ready level. The flaps were glued overlapping each other to create the tactile feeling. The primary design of the bottle was made to be the exact shape of the secondary packaging in order to give the feeling of the packaging completely encasing what is inside, to reflect how it is in nature of the chrysalis completely encasing the growing butterfly. To keep to the inspiration there are two versions, the butterfly or day version (image 9) and the moth or night version (image 10). The design won first place in the student category of the competition.

2.5 Evaluation and Moving Forward

The design was successful in the competition but I wanted to look at ways the inspiration and ideas behind it could be implemented from a future perspective. This concept draws more upon inspiration from nature than biomimicry and I wanted to see how new materials, technologies and future scenarios could elevate it more towards mimicking the inspirational source of the chrysalis.

Image 9: Chrysalis Perfume, Day Version - Photograph: Ninni Vidgren - 2016

Image 10: Chrysalis Perfume, Night Version - Photograph: Ninni Vidgren - 2016

3.0 SPREAD

3.1 Overview

SPREAD Sustainable Lifestyles 2050 is a European social platform project running from January 2011 to December 2012 including different societal stakeholders from business, research, policy and civil society. The outcome of the project was not to produce predictions of the future but to present extreme scenarios of how a fully sustainable society might live so as to help decision makers plan for the future. (SPREAD, 2012)

Sustainable living exists today at niche level in a society of overconsumption and over-industrialisation. They looked at these pockets of sustainable living and devised a strategy on how they could be scaled up and conglomerated to fit a fully sustainable society (Image 11). To do this they established four future landscapes based on research through which the scenarios would be constructed. The landscapes were defined as; technology is either pandemic or endemic and society's governing principle is either human-centric or meritocratic. They then devised four future scenarios of sustainable living fitting to this landscape which were Singular Super Champions, Governing the Commons, Local Loops and Empathetic Communities (Image 12). Using their research they created scenarios for each way of living and then used a method known as backcasting, which is working back to present day to configure what events may have led up to the future scenario. In this way they avoid the risk that starting from the beginning might focus on problems which are prevalent today but irrelevant in the future.

The outcome is a roadmap of events which could lead us into one of the four determined scenarios for a sustainable lifestyle in 2050. The scenarios are centred around moving, living, consuming and society.

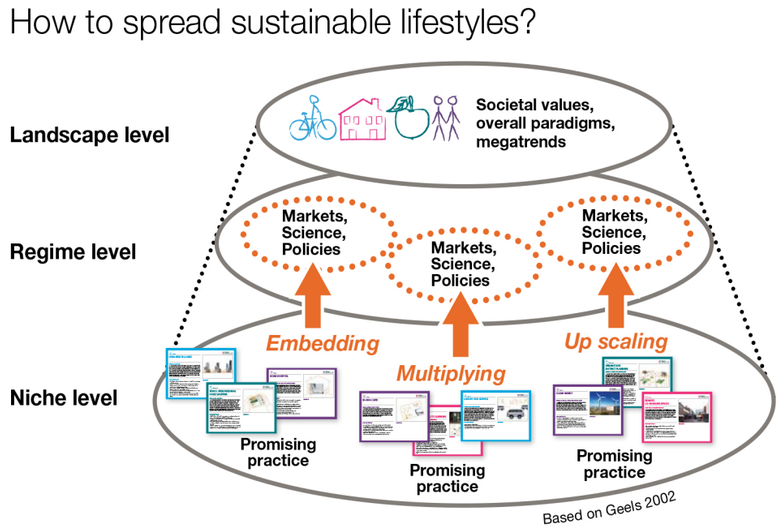

Image 11: How to spread sustainable lifestyles - SPREAD - 2012

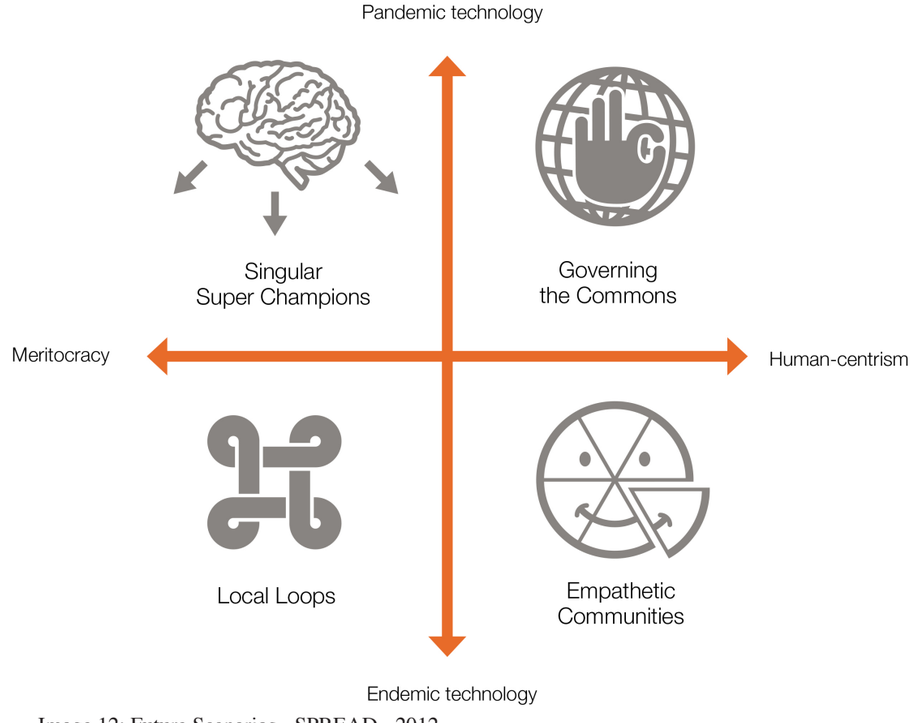

Image 12: Future Scenarios - SPREAD - 2012

3.2 Chosen Topics

For my thesis project I chose some examples related to resources, production, product, packaging and consumer behaviour. Rather than focus on one of the scenarios put forward by SPREAD I chose to take different elements from each as I felt this would be less limited in scope and it could potentially create a solution that could be easily adjusted to fit each one. Opposite are the topics chosen to focus on.

"The dramatic rise of resource prices and the scarcity of oil finally arrives in late 2010s, though it comes as a great surprise to many. Several companies, politicians and citizens were ill-prepared for an era of radical rise of resource prices and oil scarcity. The rise of logistics costs meant a shift towards local production. This makes people view local resources, like soil, in a new light."

"Transparent product data allows people to understand the environmental cost of their personal consumer choices and their overall lifestyle. Comparing the sustainability of choices of food, housing, mobility and consumer goods in 2050 is as easy as comparing prices was in 2012."

"Most of the major economic papers acknowledge that cradle-to-cradle is the most efficient production method regardless of production sector or materials required. It quickly reaches all parts of production systems. As a significant proportion of usable resources is owned by users, they also become part of these networks."

"Home waste-management opportunities allow households to turn into suppliers of raw materials for local companies."

"All around Europe, technological breakthroughs allow information to circulate without barriers. The development of stocks of natural resources can be tracked in real time by everyone."

"A price mechanism includes and quantifies everything: resource use, pollution, health, biodiversity, etc. It is a top motivator of behaviour and influences lifestyles."

"The entire built environment can be seen through two separate layers, a digital and an actual, physical one. Billions of microchips embedded in machines, walls and pavement bring a new type of data to users and create new opportunities to live smart, sustainable lifestyles through powerful feedback mechanisms."

"Meanings and symbols get consumed more than products."

"Intelligent and smart packaging of food for transparency, awareness and less waste."

(SPREAD, 2012)

4.0 Plastic Alternatives

4.1 Polylactide (PLA)

4.1.1 Terminology

The implementation of biodegradable packaging into mainstream packaging has been highly controversial and difficult to implement for the reasons that will be discussed. First it's important to define the terminology behind biodegradable.

Biodegradable plastic is not only limited to plastic derived from biomass but can also be derived from fossil fuel based plastic, conversely not all plastic derived from biomass is biodegradable. Biodegradation is the breaking down of a material by microorganisms (bacteria of fungi) into biomass, CO2/methane and energy. Compostable means the ability to be biodegraded under soil with elevated temperature and certain conditions (usually those found in industrial composter). For packaging to be labelled as biodegradable or compostable it must adhere to certain standards. The European standard for compostable is EN 13432 and maintains that the industrial composter will reach temperatures of 70°C and at least 90% of organic matter is converted into Co2 within 6 months and after 3 months no more than 30% of the residue is able to be retained by a 2mm mesh sieve. (Biodegradable Plastic & Marine Litter, 2015)

The common compostable plastic that has been used in packaging is Polylactide (PLA) which is a polyester produced from lactic acid most commonly derived from corn (Image 13). PLA may be more widely known today for it's use in 3D printing.

4.1.2 Disposal and Environmental Impact

Compostable plastics do pose an interesting solution if they are managed correctly but the problem is how they effect the environment and recycling systems when they are not.

Compostable PLA packaging in most cases must be processed in an industrial composter and it varies a lot by country and council whether or not they have these facilities. PLA is capable of being recycled but it's not possible to recycle it along with petroleum based plastic and there simply is not enough demand for PLA recycling to make widespread recycling systems an economical option. Furthermore packaging made from PLA looks identical to conventional plastic so it is understandable that people would place them into conventional plastic recycling bins. This creates a problem since if biodegradable plastic makes its way into plastic recycling streams then it becomes a contaminant and can reduce the usability and lifespan of the recycled products. (osof.org, 2016)

If PLA packaging is sent to landfill then it makes absolutely no difference if it's compostable or not. Landfills are entombed structures sealed from oxygen and not temperature controlled, meaning that compostable plastic sent to landfill will essentially take as long as conventional plastic to decompose, anywhere from 100 to 1000 years. In-fact, if biodegradation takes place in landfill this can lead to serious environmental and human health concerns including ground water pollution, methane gas emissions, and unstable sub-soil conditions. (greenlivingonline.com, 2016)

Similarly PLA poses the same threat as fossil fuel based plastics in the environment. The plastic pollution of the ocean is one of the biggest threats to marine animals and ecosystems and human health of modern times. The

Image 13: PLA Cup - Creative Mechanisms - 2016

conditions of the ocean are highly varied but unlikely to reach conditions similar to an industrial composter, therefore the rate of biodegradation is incredibly slow and research into the comparisons is difficult since it is region specific. Exposure to UV, temperature, oxygen and the presence of suitable microorganisms are all factors. Plastics on the shoreline are more exposed to UV and oxygen and so are more prone to fragmentation. Large and fragmented pieces buried in sediment or entered into the water column will fragment at a slower rate. Fragmented pieces pose a threat to marine animals who mistake them for food and die because of blocked internal systems. (Biodegradable Plastic & Marine Litter, 2015)

One relevant study comparing conventional and compostable plastic in marine environment took the gastrointestinal fluids of two recently deceased sea turtles (Green and Loggerhead) and exposed them to different polymers. They used a sample of conventional high density polyethylene (HDPE) and biodegradable PBAT/Starch blend (Mater-Bi™) shopping bag and the remaining weight was examined after a 49 day period exposed to the fluids. It found that the weight difference of HDPE was negligible while the biodegradable plastic had reduced by 8.5% with the Green turtle sample and 4.5% with the Loggerhead turtle sample. In short, biodegradable plastics are unlikely to break down significantly in marine environments and pose as much of a potent threat to the oceans ecosystems as conventional plastic. (Biodegradable Plastic & Marine Litter, 2015)

Other environmental problems arise as the result of vast monocultures used to grow the corn for production such as high volume water usage, soil erosion and pollution from fertilisers, pesticides and soil run off.

4.1.3 Social Impact

Sceptics of PLA have heavily criticised the use of arable land for the growing of corn for product rather than food and for good reason. The diversion of corn into products such as ethanol and PLA raises the price of the food, especially during times of adverse weather effecting harvest. For example in 2012 after a drought in the US caused a reduced harvest corn prices raised by 21% while ethanol consumed 40% of the total harvest. This has a devastating effect on global food security since the US is the largest exporter of corn and many developing countries depend on foreign food imports. It also has a knock on effect into other sectors, since corn is the main feed used for livestock it also raises the prices of meat, dairy and eggs. (aljazeera.com, 2012)

4.1.4 Consumer & Corporate Behaviour

There is a common misconception among consumers that however a biodegradable product is disposed of, be it in landfill or in the environment, it will simply disappear. For this reason it has been argued that biodegradable plastics have led to more littering and pollution. This is backed up by a survey of young people in Los Angeles that found that labelling a product as biodegradable would be one factor that would make them more likely to litter. (Biodegradable Plastic & Marine Litter, 2015)

Labelling packaging as biodegradable or compostable reduces the guilt factor to consumers of buying a product as well as heighten a brands green credentials. In 2006 Innocent Smoothie started selling their products in a bottle made entirely of PLA (Image 14 & 15) with the claim that it could be composted in your home composting bin. It couldn't. Furthermore they made the claim that the bottle was carbon neutral, owing to the fact that the company in the US who made the PLA from

Image 14 & 15: Innocent Smoothie PLA Bottle - MoDiP - 2007

corn starch used corn that was grown using only wind power. However this didn't bring into account the fact that they use large amount of fertilisers based on fossil fuels and transportation of the grain uses vehicles also running on fossil fuels (independent.co.uk, 2007). This led them to eventually withdrawing the bottle and converting back to their conventional PET bottle. Innocent is a progressive company and I'm sure they had the best intentions, but this highlights the complexity in introducing new materials to market and the necessity to understand consumer behaviour

4.1.5 Thoughts

A plastic that's made from plants that can be broken down into compost is a wonderful thing. However it seems from this research that it's potentially more harmful than petroleum based plastic. This is due to consumer behaviour with plastics labelled as compostable and disruption to established waste streams. As well as the growth of large monocultures for raw material and the divergence of food into product. Perhaps in a sustainable society there might be more weight put on composting and potentially it could become more easily integrated into waste streams. However the use of food crop for products is likely to be unpopular in a sustainable society where food receives higher value as it has to be grown locally.

4.2 Bio-PE & Bio-PET

4.2.1 Introduction

Due to the expected rise in oil prices, consumer demand and marketing potential, companies have been seeking to find renewable alternatives to petroleum based plastics for a sustainable future. In the last few years there has been dramatic breakthroughs in bioplastics engineered to have the same technical profile as their petroleum based counterparts which have since found their way into mainstream packaging. Presented as a "green" alternative, these bioplastics such as plant based polyethylene terephthalate (PET), polypropylene (PP) and polyethylene (PE) are derived mainly from sugarcane grown in Brazil. Brazil is the ideal place for production of bioplastics due to it's booming ethanol production, a biofuel produced from plants that is the key ingredient in the production of bioplastic. Sounds great but as packaging designers we have to be able to look beyond the green marketing presented by companies promoting renewable plastic and find out what are the true costs of the materials we have the option to work with.

Tetra-Pak created it's first carton made entirely from renewable materials in 2014 and it was successfully launched by Valio in Finland in January of 2015. The pack was successful with the company and consumers and has since been rolled out to other companies worldwide. The pack replaces the traditional petroleum based PE with PE derived from sugar cane by the petrochemicals company Braskem. The carton consists of a layer of paperboard with a layer of bio-LDPE either side and a gable top closure made of bio-HDPE (Image 16) (tetrapak.com, 2015).

Coca-Cola first released it's PlantBottle in 2009 with up to 30% containing PET made from sugar cane (Image 17). In 2015 they unveiled a PlantBottle made entirely from the bio-PET and aim to produce only PlantBottles by 2020. (mashable.com, 2015)

In the following pages I will look at the environment and social impacts of sugarcane plantation in Brazil from where Tetra-Pak and Coca-Cola source their bioplastic.

Image 16: Tetra-Pak's Tetra-Rex - Plant Vending - 2015

Image 17: Coca-Cola's PlantBottle - Plant Vending - 2015

4.2.2 Environmental Impact

Brazil is the largest producer of sugarcane in the world with around 90% being grown in the centre-south region, mostly in the state of Sao Paulo which represents 60% and the rest being grown in the Northeast region. (Braskem 2016). (Image 18) shows a map commonly used by mills in Brazil to distance themselves from the Amazon and quell foreign concern about deforestation in the area. This is further backed up by the statement that the Amazon area is an undesirable location for sugarcane plantation due to its climate. However the Amazon is not the only biome in Brazil of immense natural importance. The statistics of sugarcane land use show the majority happening in Brazil's Cerrado, also known as Brazil's Savannah region which is favoured for its large water basins which are important in production. The region is home to 160,000 species of plants and animals, of which many are endangered, yet it's one of the least protected regions in Brazil with less than 3% under legal protection (wwf.panda.org, 2016). Statistics from the Laboratory for the Processing of Images and Geoprocessing at the Federal University of Goiás indicate that the current rate of deforestation in the area may raise the biome destruction from 39% in 2009 to 47% by 2050. They also warn about the potentially dangerous knock on effect this may have on rainfall patterns and water levels in the Pantal and Amazon regions as the biomes are all interconnected (A Monopoly in Ethanol Production in Brazil, 2011). Another area where plantations occur are areas previously covered by the Atlantic Forest. The Atlantic forest has suffered the most deforestation of any tropical rainforest, with only around 7% of its original cover remaining. The main causes of deforestation being agriculture (primarily sugarcane and coffee), urban development, cattle ranching and eucalyptus plantation. The Atlantic Forest is considered one of the most diverse ecosystems in the world, second only to the Amazon, with only 23.8% under legal protection which is about 2% of its original footprint (rainforests.mongabay.com, 2016).

Many of the responsible mills, including Braskem who supply Tetra-Pack, now comply with Brazil's new Forest Code (Law no. 12.651) which grants them access to international markets as well as government grants. The law which has been in force since 2012 implements better monitoring of land use to combat deforestation and is a step forward in working to eliminate deforestation as well as ensure Brazilian commodities in the supply chain have been legally and sustainably managed. However, if you look closely at the law it still permits for 880,000 km2 of legal deforestation of native habitats according to clause Soares-Filho et al. (2014) (deforestation is defined as the conversion or removal of vegetation and vegetation in medium or advanced stages of recovery which may or may not include forest area). To put it into perspective that's the equivalent land area of the U.K. and France combined.

Mills such as Braskem claim to be planting only on degraded pastures to offset international suspicion on deforestation for agriculture and comply with the Sugarcane Agro-ecological Zoning Policy (ZAE) in force since 2009, a regulatory body enforced by the government that prohibits growing in areas of high biodiversity and excludes any area in the Amazon region. The WWF have stated in their guide to the Forest Code that 70% of the 152 million hectares of pasture land in Brazil are degraded including 50% in the Cerrado region. They suggest that economic and environmental gains can be obtained by better land management and the utilisation of one crop for another, which Braskem claim to be doing with sugarcane production, which would offset the need for further deforestation. However, it's suggested that increased productivity and utilisation of degraded pastures could potentially offset deforestation only until

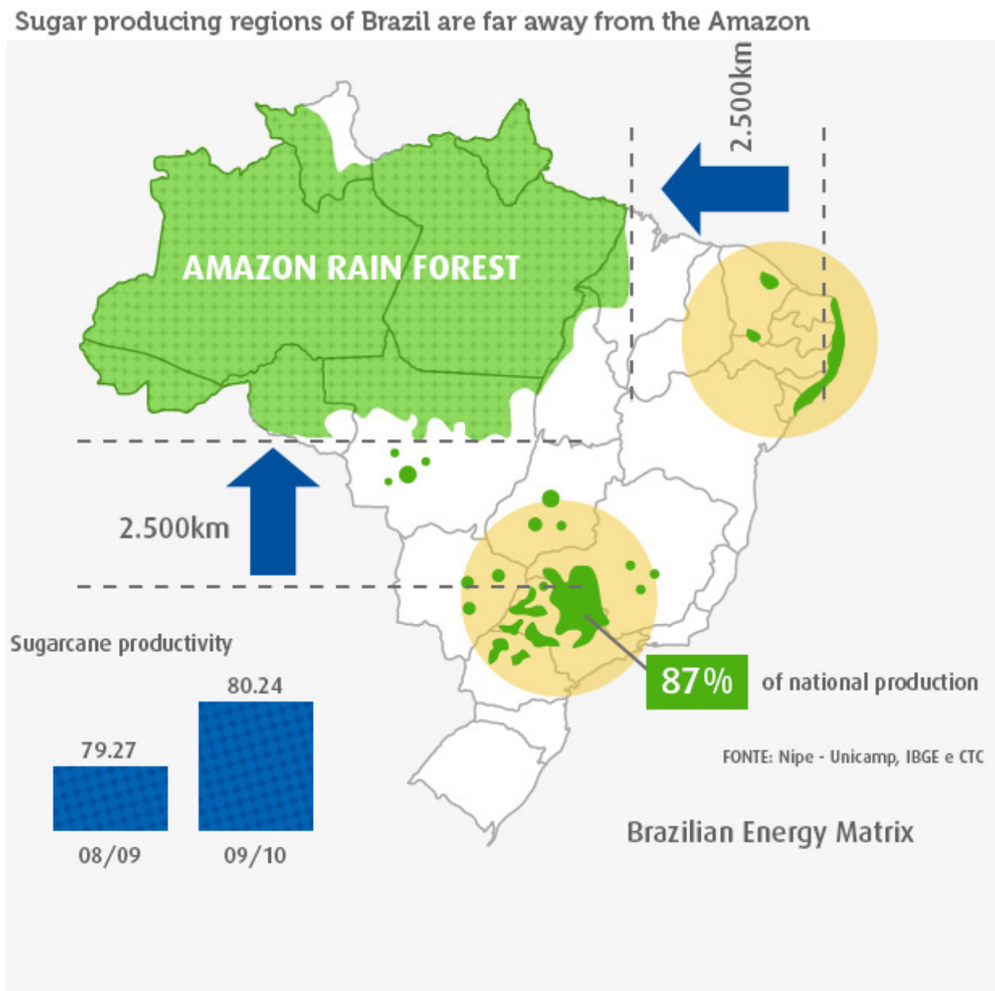

Image 18: Sugarcane Zoning Map - Braskem - 2016

2040 at the earliest (Brazil's New Forest Code, 2016). This means that degraded pastures are a finite source of land. As the worlds demand and dependence for biofuel and biopolymers as well as food shortages increase this may lead to increased rates of deforestation and changes in the Forestry Code to allow for further legal limits of deforestation. Furthermore a report by Friends of the Earth Netherlands (Milieudefensie) and The Transnational Institute (TNI) states an increase in land prices in the Cerrado from leasing of land for sugarcane is pushing other agricultural sectors further into Cerrado, Pantanal and Amazon nature reserves creating an indirect effect on sensitive ecosystems (A Monopoly in Ethanol Production in Brazil, 2011). A separate report by TNI states that the ZAE has been criticised for not taking into account indirect land use change, areas of biodiversity put forward by the Ministry of Environment and not establishing restrictions for existing plants and new projects that have already obtained environmental license in the excluded areas. They state that such regulatory bodies are extremely problematic since they simplify complex land relations and ignore traditional farming practices (The Politics of Sugarcane Flexing in Brazil and Beyond, 2014).

Sugarcane has been a problem for water pollution created by silt from eroded soil and applied fertilisers. Braskem have cited on their website that many of their mills use vinasse (a by-product of sugarcane processing) as on 'organic fertiliser' which reduces carbon emissions. The report from TNI however cites that these can be more detrimental to the environment compared to petrochemical equivalents. This is due to its large amount of organic matter, low PH, high corrosiveness and high BOD (biochemical oxygen demand) index. They explain that soils in Brazil are predominately acidic and adding a low PH fertiliser increases the amount of liming needed; liming is the process of adding an alkaline mineral such as calcium or magnesium carbonate to acidic soil to increase fertility and oxygen levels. These carbonates contain fixed carbon from the lithosphere that when reacting with the hydrogen ions responsible for the acidity release carbon dioxide into the atmosphere. In a reaction efficiency of 100% for every 100g of carbonate used this could release 44g of carbon into the atmosphere. (A Monopoly in Ethanol Production in Brazil, 2011)

Another characteristic of vinasse fertiliser that is damaging to the environment is the high BOD (biochemical oxygen demand) index. The BOD is the amount of oxygen that would be consumed if all the organic material in one litre of fluid were oxidised by bacteria. When the fertiliser gets into natural water the bacteria needed to consume it effectively robs other aquatic organisms of oxygen. This has a knock on effect up the food chain meaning that fish and other aquatic organisms may not survive. There is also a greater release of nitrates and phosphates into the water which creates more algae and plant life, more plant life means more plant waste from dead plants which again raises the BOD index of the water. This all contributes to polluted water which can be detrimental to humans and animals that rely on the water as a source of food. (A Monopoly in Ethanol Production in Brazil, 2011)

Braskem statement on their website of using an 'organic fertiliser' is misleading, the natural societal conclusion is that organic means natural and therefore must be good for the environment but it is not always the case.

One of the big selling points companies point out and use in their marketing for using bioplastics is the reduction in carbon emissions compared to petroleum plastics. The sugarcane traps CO2 as it grows and Brazil has replaced 42% of it's gasoline needs with ethanol (sugarcane.com, 2016). This is meant to be greener than fossil fuel because even though CO2 is emitted when ethanol is burned it is theoretically trapped by the regrowing of sugarcane therefore emissions from industrial machinery used in cutting, harvesting, transporting and processing as well as logistical infrastructure are often considered negligible. The process is also expected to create fewer carbon emissions with the increased production of cellulosic ethanol created from the sugarcane bagasse (the waste parts of the plant). Furthermore, mills such as Braskem are often self sufficient due to the burning of bagasse as a raw material to create steam which turns the turbines and any surplus is fed back into the grid. However claims on carbon emissions can be misleading as they are dependant on the factors that are included in the studies. Coca-Cola stated that their PlantBottle can reduce carbon emissions by 12-19 percent compared with traditional PET which it backs up with a life cycle analysis carried out by Imperial College London. Coca-Cola stated that in 2010, the year after the release of their PlantBottle, they eliminated the equivalent of 30,000 tonnes of CO2. However Coca-Cola are inherently secretive about the studies carried out on the LCA of PlantBottle and withholding them from public access means they can't be examined by regulators and environmental groups. In an interview with International Business Times the general manager of PlantBottle packaging programme Scott Viters said "the company is still working to strike a balance that keeps customers well-informed without bogging them down with esoteric scientific information that few people understand" after being accused of embellishing the environmental attributes of the product by the Danish environmental group Forests of the World (ibtimes.com, 2013). This statement would suggest there is something to hide and that my be because LCAs are very dependant on the factors that are included in the analysis. For example one study of the LCA of shopping bags concluded that HDPE was a better environmental option compared to paper, LDPE, non-woven PP and cotton (in order of least to highest) but purely on the basis of carbon footprint. Conversely, an LCA of textiles that included factors of social and environmental impact put cotton as having a smaller footprint than acrylic fibres. However environmental impact is a broad term and a separate LCA concluded that cotton had a greater footprint than fabrics made with PP or PET and much greater than those made from man made cellulose based fibres. This was because this analysis included factors of ecotoxicity, eutrophication, water use and land use (Biodegradable Plastic & Marine Litter, 2015). In another interview with Plastics Recycling Update a Coca-Cola spokesperson revealed that the LCA studies by Imperial College London were carried out in 2008 before the supply chain was fully established and that the current figure is more like a 7.5-11% reduction in carbon emissions (resource-recycling.com, 2013).

4.2.3 Social Impact

The expansion of agriculture and large scale monoculture crops in Brazil have always been fraught with human rights violations and land rights issues. In 2013 Oxfam published a report that implicated one of Coca-Cola's suppliers Bunge in a major land grab scandal. The report showed that sugarcane sourced by Bunge had been grown on land illegally stolen from the ancestral land of the Guarani-Kaiowá (forest people) in the state of Mato Grosso do Sul (Sugar Rush, 2013). The Guarani have suffered harassment, assault, rape and assassinations of tribal leaders as well as the loss of forest which they depend upon for food and medicine, forcing them onto small patches of land surrounded by plantations or to live by the roadside (Image 19). Further detrimental living conditions are imposed upon the Guarani by contamination of water supplies and exposure to harmful pesticides and smoke from burning which is especially damaging in children causing them to vomit and have headaches. This has been driving the Guarani into impoverishment, starvation, malnutrition, loss of livelihood and depression. The Guarani have a suicide rate 34 times the Brazil national average with most victims aged between 15 and 29 years old and the youngest recorded being just 9 years old (survivalinternational.org, 2013).

This is not just an isolated incident. In 1998 in the north-eastern state of Pernambuco a sugar and ethanol producer Usina Trapiche expelled 53 fishing families who had lived there since 1914. Trapiche claimed they were living in sub-human conditions and destroying the mangroves which was disputed by social organisations CPT (Pastoral Land Commission) and Fishermen's Pastorate. Trapiche drove them from their land by destroying their homes, farms, polluting water supplies and killing fish that they need to survive. As recently as 2012 they have been accused of burning huts and threatening further violence. Trapiche relocated the families to the town of Sirinhaém giving them access to sanitation, electricity and schooling however forcing them to live in slum like conditions. Unable to fish or grow food as they had done for over a century they are forced to search for wage labour, paradoxically often working as cutters in the sugarcane plantations. Coca-Cola admitted to purchasing from Usina Trapiche. (ejatlas.org, 2016)

After the Oxfam report Coca-Cola declared a zero tolerance policy on land grabs. However this is set to be a long and difficult process for a company with established supply chains in 207 countries with complicated legality surrounding land rights and missing or incomplete documentation. Companies like Coca-Cola share part of the responsibility but ultimately you would think the welfare of people should come down to their government. However reports suggest that the Brazilian government is often putting big business before the rights of its indigenous tribes and traditional communities. The Guarani are served legally appointed eviction notices on lands they own and are evicted by armed police. Reports suggest there are around 200 Guarani in prison serving disproportionately long sentences for minor offences with little or no access to legal advice. Any attempt to retake their land is met by gunmen protecting plantations (Image 20) who have been accused of murder and rape but receive no repercussion for their actions (survivalinternational.org, 2016). The fishing families of the Pernambuco initially were given the right to live in the estuary but this decision was overturned by the courts in 2002. In 2009 the estuary was designated as a reserve by the Chico Mendes Institute for Conservation of Biodiversity (ICMBio) but it was not upheld by the state. These points highlight an incredible amount of corruption

Image 19: Living Conditions for The Guarani - Survival - 2016

Image 20: Gunmen Caught on Camera Shoot at The Guarani - Survival - 2016

and shows that the Brazilian government is most likely putting big business before the rights of it's indigenous tribes. Trapiche has continued to be fined for illegal dumping of chemical and organic waste, deforestation and pollution but it seems to be of little detrimental effect since it continues to happen (ejatlas.org, 2016). So in places like Brazil it really does comes down to the big corporations to ensure that their supply chain is strictly monitored and transparent. Coca-Cola is understandably highly secretive about their supply chain. Tetra-Pak do state on their website that they source their bio-PE from Braskem but it's unclear from Braskem's website exactly which lands they source their sugarcane from.

Being the worlds largest producer of sugarcane ethanol, the sugarcane industry is one of the largest industries and thus one of the biggest employers of the country. The entire sugarcane industry employs around one million people or one quarter of the rural population (SugarCane, 2016). The number of workers has been in decline with the increased mechanisation of the cutting, in Sao Paulo alone the average number of workers dropped by 14,468 between 2010 and 2011 (The Sugarcane Industry and The Global Economic Crisis, 2013). The sugarcane mills promote that this is a positive advancement since cutting is highly strenuous and it eliminates the need for burning (done to drive away poisonous animals and make it easier to cut) which is both detrimental to the environment and the health of workers and people living nearby.

However social groups argue that the mechanisation of sugarcane plantations has led to further exploitation of workers. The decrease in jobs has made the harvesting more competitive and since workers are paid not by the hour but by the amount they harvest the mills exploit this for increased productivity. The amount of money cutters receive has dropped considerably with mechanisation, in 1970 the average worker would receive R$ 2.00 per tonne of cane cut which had dropped to R$ 0.86 by 2005. Meaning that increased efficiency is not reflected in the salary of the workers. Workers are expected to cut between 10 and 15 tonnes per day and if they don't reach targets they are not re-hired. For these reasons cases of deaths from overexertion and injuries have not ceased to exist, 17 instances of death on sugarcane plantations in Sao Paulo were recorded between the harvests of 2004-07 when the state was predominately mechanised. (The Sugarcane Industry and The Global Economic Crisis, 2013)

Some positive steps have been taken however. In 2009 in response to the reduction in jobs needed UNICO (Brazilian Sugarcane Industry Association) along with key players in the sugarcane industry created the RenovAção Project, the largest retraining project for sugarcane workers in the world. Between the years of 2010 and 2013 they retrained 5,730 workers in fields such as the operation and maintenance of harvesting equipment, training for other skills required by the community and training programmes for different production areas. (unica.com.br, 2016)

In 2005 WWF founded The Better Sugar Cane Foundation. The aim was to promote and monitor environmentally and socially responsible sugarcane practices. The initiative is now a multi-stakeholder, non-profit organisation called Bonsucro which comprises over 200 members including The Coca-Cola Company and Braskem. In 2010 the Bonsucro Standard was launched which compares practices against key indicators such as energy consumption, greenhouse gas emissions, and water consumption. Members must adhere to strict standards in order for their products to be Bonsucro certified. (worldwildlife.org, 2016)

4.2.4 Thoughts

The production of plant based plastic is an incredible innovation in itself. I think it's also admirable that corporations are seeking to find alternatives to petroleum based plastic. It also makes sense for a company like Coca-Cola to produce packaging in a country where they already source a lot of their raw material, sugar. However, I don't agree with it being labelled as green or more ecological. The points expressed here have shown that the growth of large scale sugarcane monoculture in Brazil is a complex issue and the effect on the environment and people of Brazil may be more damaging than we realise. Furthermore standards may not be as transparent as they seem in a country that is often experiencing corruption scandals. I'm not implying that companies such as Braskem or Coca-Cola would be intentionally disregarding environmental or social etiquette, but in places like Brazil they may include 3rd party companies in their supply chain that don't adhere to a strict code of ethics.

The material itself is intended to be a drop-in solution to petroleum plastic as it shares the same mechanical properties. This means it can be recycled in the same waste streams, however it still poses the same threat to the ocean as conventional plastic. If we look at look at the future scenario of production becoming localised after peak oil then it's unlikely to take pride of place. Sugarcane is only grown in certain regions which requires shipping to location. It's also possible to make the bio-plastic from crops such as corn but this is unpopular due to the diversion of food crop. This is unlikely to happen in a sustainable society where food is more localised and valuable unless cellulosic ethanol allows substantial production from waste plant material.

4.3 Nano-Cellulose

4.3.1 Cellulose

First discovered in 1838 by French chemist Anselme Payen, cellulose is the most abundant organic compound derived from biomass. It's the main building material of wood but is present in a wide variety of sources such as plant fibres, marine animals, algae, fungi, invertebrates and bacteria. In plant sources cellulose can be present in the leaf, the fruit or in the stalk or rigid structures of plants (e.g. the tree trunk) (Microfibrillated Cellulose, 2012). The cellulose content of the source varies, in cotton fibre it's about 90%, in wood it's 40-50% and in dried hemp about 57%. In industrial use cellulose is mainly obtained from wood pulp and cotton and is mainly used to make paperboard and paper (wikipedia.org, 2016). As discussed earlier in this paper, cellulose from energy crops such as cellulosic ethanol is being explored to increase efficiency of ethanol production by producing it from the plant waste.

4.3.2 Nano-Cellulose

The production of nano-cellulose material is in its infancy and so exact standards are not precisely defined, therefore terminology can be confusing. Broadly speaking nano-cellulose is an umbrella term for different kinds of nano and micro sized cellulosic particles which can be grouped within three categories; microfibrillated cellulose, cellulose nanocrystals and bacterial cellulose.

Microfibrillated Cellulose (MFC) is the area of most interest to this paper. MFC was first studied in the late 1970s as part of research at the ITT Ryonier labs in the US (Microfibrillated Cellulose at a Glance, 2016). Due to the high energy input needed for production it has only recently been developed for commercialisation facilitated by technological advancement, research into pretreatments and the increased demand for alternatives to fossil fuel based materials.

Cellulose fibres are made up of smaller particles called microfibrils, the MFC process breaks those fibres down into smaller microfibrillar structures resulting in a viscous gel (Image 21). MFC can be created through various mechanical treatments. Initially it was created when wood pulp was passed through a homogeniser, essentially passing the pulp at high pressure through a small hole followed by sheering and a rapid deceleration in pressure. Further subsequent technologies have become available for production including a microfluidiser which passes the pulp through thin z-shape chambers at high pressure and a grinder which passes the pulp between a static grindstone and a grind stone rotating at high speed. The drawback to mechanical processing is the high energy input required but pretreatments have been developed to obtain fibres that are less stiff and cohesive therefore decreasing the energy needed for fibrillation. Different factors can produce different properties in MFC materials such as the raw material used (e.g. trees, vegetables, sugar beet pulp and citrus pulp), the mechanical treatment and type of pretreatment used (Microfibrillated Cellulose, 2012). MFC has been found to have great potential for a range of applications from improving rheology in spray cosmetics to improving wood adhesives to replacing fossil fuel based plastics.

MFC has a great potential in a multitude of packaging applications. It can be used to create a film, for example the tear off film on food packaging. It's barrier properties make it possible for use in replacing the plastic layer in carton liquid containers. It can be

Image 21: MFC - Stora Enso - 2016

used to coat paperboard to create excellent printability with low absorption, meaning less ink can be used during printing which is more ecological. It can be formed into solid objects using conventional means such as injection moulding but it's also possible to use it in 3D printing and when formed it's said to have strength comparable to steel.

4.3.3 Raw Material

Although wood can be sustainably procured by responsible forest management, a growing amount is coming from eucalyptus plantations in problematic markets and this may rise with the increased demand for biomass. Eucalyptus is favoured for its fast growth (reaching maturity in 7-8 years) but is best suited to warmer climates such as Brazil. Strict land use policies in Europe as well as growing of slow growth species means supplies are often supplemented with stock grown in plantations in developing or newly industrialised nations. Eucalyptus monoculture in developing or newly industrialised countries poses social and environmental problems akin to those discussed for sugarcane plantations for bioplastics.

One area of land use science which could provide a better future solution is agroforestry. Agroforestry is a model whereby the same land is integrated for the use of forestry, crops and/or livestock (Image 22). It's already widely used around the world in small and large land holdings and has been the focus of a lot of recent research. The growth of different trees and plants together creates a synergy of elements which has substantial sustainable, environmental and social benefits over monocultures, such as:

- They can be employed to reclaim degraded or eroded land.
- The breeding of different species of plants together creates more biodiversity. This creates a habitat for birds and insects that feed on crop pests which reduces the spread of disease and the need for pesticides.
- Decomposition of tree matter can substantially improve the fertility of the soil. The addition of high quality tree prunings (e.g high nitrate fast decomposition varieties) during crop planting can enhance the nutrients available reducing the need for fertilisers and increasing crop yields.
- Well thought out tree planting designs can create a windbreak to protect crops and stabilise soil preventing soil runoff and reducing the risk of pollution and landslides as well as containing soil nutrients.
- Plants of different heights, leaf shapes and alignments utilise solar energy more efficiently than monocultures.
- Trees can control the water table of the land. They can reduce water run off through soil stabilisation and conversely reduce water logging by removal and evaporation. However in dry regions trees and crops may compete for scarce water.
- Trees provide shelter which reduces the stress of livestock during hot seasons.
- They can stimulate rural economies leading to more stable farms and communities.
- They offer farmers the ability to maintain better control of land despite climate change.

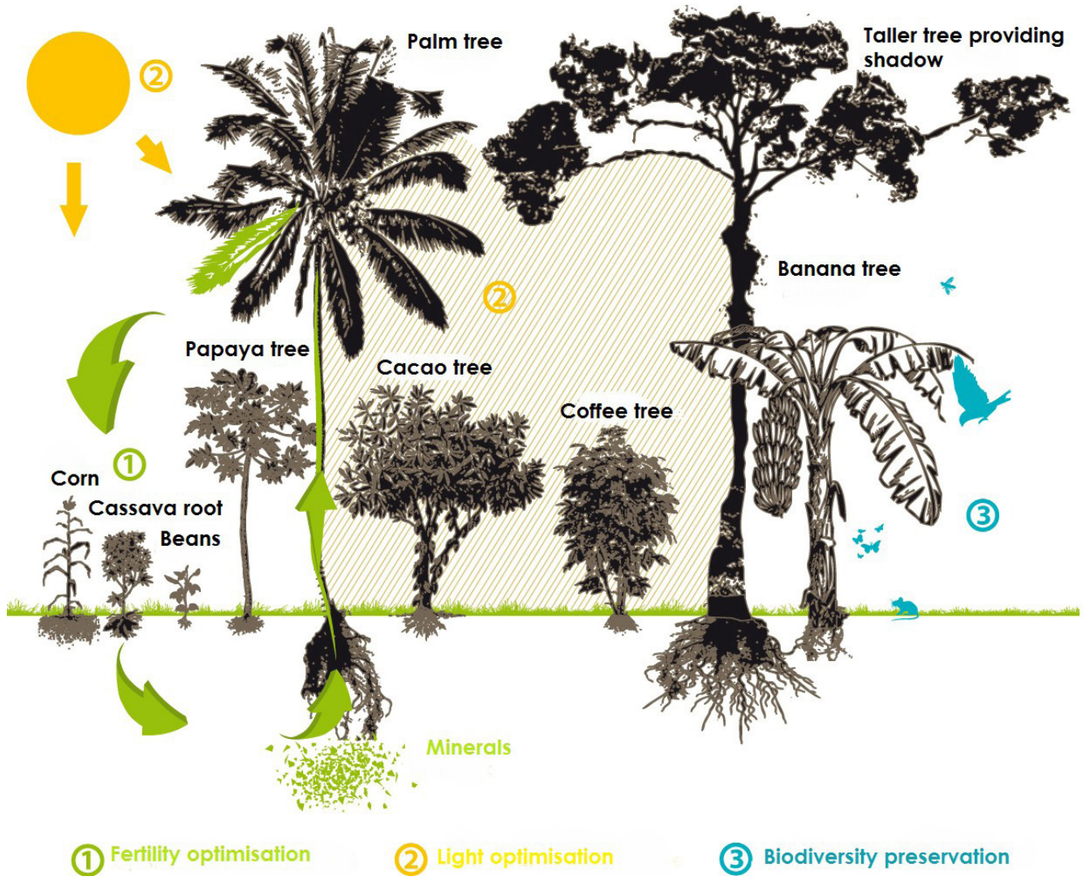

Image 22: Agroforestry Model - Discovery Organics - 2016

The greater spacing of trees has been found to accelerate their growth. In a study conducted in Laos by the Australian Centre for International Agricultural Research (ACIAR) they found that the planting of 650 - 900 teak trees per hectare produced trees of logging maturity in 10 - 12 years (Image 23). Compared to the planting of 2000 trees per hectare which were found to not have reached maturity by 15 years (Image 24). Greater spacing also means crops can continue to be grown as the trees grow whereas with more dense tree cover crops can only be grown during the first few years. The research also looked into the prospect of growing broom grass which creates jobs for woman who collect it and make it into products that can be sold locally and into neighbouring countries like Vietnam and Thailand. (aciarblog.blogspot.ch, 2016)

Another ten year study of agroforestry in Laos by Stora Enso planted trees of 9 metre spacing in-between which local farmers could grow crops of rice, cassava and corn. The outcome of the study was found to be supported by local communities. The system can utilise degraded land that was cleared by previous deforestation and bombing during the Vietnam War. This creates a carbon sink as well as reduce pressure on protected forest and reduce the amount of travel farmers have to make to fertile lands. Such schemes can improve food security of developing nations and stimulate local economies by the creation of jobs. In places like Laos large corporations can also invest in the removal of unexploded bombs leftover from intense bombing campaigns during the Vietnam War, improving the safety of farmers and local communities. (outreach.stakeholderforum.org, 2016)

4.3.4 Thoughts

Nanocellulose shows huge potential in packaging applications but since it has not yet been launched for mass manufacture it's hard to gauge the impact it will have. It is compostable but it's difficult at the moment to get information on what conditions biodegradability will take place. If it's limited to industrial composters then it may face the same difficulties as PLA and it's also unknown what it will mean for recycling streams.

In terms of this paper I think it's the best possible solution for packaging material in a sustainable future. It can be produced from local organic material and doesn't need to be sourced from food crops, it can even use waste materials from forestry. It's possible to be 3D printed which could be the future of mass manufacture as will be discussed in the following pages. These points make it suitable for a sustainable society with localised production.

Image 23: 7.5 Year Old Wide Spaced Teak - ACIAR - 2016

Image 24: 15 Year Old Narrow Spaced Teak - ACIAR - 2016

5.0 Active and Intelligent Packaging

5.1 Overview

Smart packaging, also known as intelligent, interactive or active packaging is the term for packaging utilising new developments in printed electronics to add functionality, safety or extend shelf life in a variety of packaging ranging from food to pharmaceuticals to luxury products. They are defined in two models. The first interacts with the product, for example to control the growth of bacteria, this is termed as active packaging. The second enhances functionality, user interaction or product information (often with the use of sensors and communication) and is defined more as intelligent or interactive packaging. Intelligent and active packaging is expected to grow rapidly, for example, in the U.S they predict an 8% annual increase with a predicted 3.5 billion in 2017. The largest product segment in 2012 was food and beverage but the fastest growth market is expected to be pharmaceuticals with the increase in high value, temperature sensitive biotechnology drugs. (packagingdigest.com, 2014)

5.2 Printed Electronics

The ability to integrate electronics into packaging has been facilitated by the development of organic (carbon based) electronics. Organic electronics have been developed in the field of organic and polymer chemistry to utilise organic small molecules or polymers to have electronic properties such as conductivity. The benefit of this compared to inorganic electronics is the low cost point, mechanical flexibility and high thermal stability. This facilitates the printing of electronics on a variety of flexible substrates including plastic, foil and paper and allows for the high volume, very low cost production of electronics for applications that don't require high performance. Besides packaging, potential applications include flexible displays, animated posters and active clothing. The widespread, low cost point has also been facilitated by the ability to print electronics at fast, high volume using common printing equipment such as screen printing, flexography, gravure, offset lithography and inkjet. (wikipedia.com, 2016)

Another implementation of printed electronics is OLED (organic light emitting diode) which is an LED in which the emissive electroluminescent layer is a film of organic compound that emits light in response to an electric circuit. The ability to implement this into packaging is allowed by the low cost, ability to print it onto flexible substrates and the ability to print roll to roll since packaging applications are low performance. This can be especially effective in promoting brand identity, enhancing shelf presence and developing unique consumer packaging experiences.

5.3 Electronic Communications Technology

Two communications technologies that are becoming increasingly prevalent in packaging are RFID (Radio Frequency Identification) and NFC (Near Field Communication). RFID is a means by which items are uniquely identified and transmit information by using radio waves. RFID systems consist of a tag, a reader, an antenna and can be grouped into two categories active and passive. An active tag requires its own power source and can broadcast at ranges up to 100 metres. A passive tag (also known as an RFID inlay) doesn't require its own power source as it draws power through its antenna from a reader when it comes into range. Unlike active tags the passive tags require only an antenna and integrated circuit. The advantages of this are that the tags are smaller, cheaper, thinner and can last a lifetime but the range is reduced to 25 metres. NFC is a specialised development of RFID technology and creates secure contactless exchange of data over a short distance of only a few centimetres. Most modern smartphones and tablets are NFC enabled and are capable of communicating between each other for easy exchange of data and can also read NFC tags which can be easily and affordably implemented into packaging. (blog.atlasrfidstore.com, 2013)

The implementation of these technologies has many benefits to businesses and consumers. Throughout the supply chain the condition and environment of the product can be tracked and monitored and relay information if the product has been stored in unsuitable conditions or if the condition of the product has deteriorated, this can be especially important for food and pharmaceuticals increasing product safety and reducing waste. This information can be relayed to supply chain management and can also be displayed to the customer ensuring that the product they are buying has been kept in desirable conditions. The tags will also relay information if a seal has been broken or tampered with and since the unique identifier cannot be copied this means that high end products, such as perfume, which are prone to counterfeiting can be identified as legitimate products.

Specifically looking at perfume and cosmetics the technology can increase customer engagement and brand loyalty. At the point of purchase a customer can use their smartphone to guarantee authenticity and view product information. After purchase and the product is opened the customer can then use their smartphone to view specialised information such as information on complementary products, product lifespan and can furthermore receive customised offers and suggestions of additional products.

5.4 Most Interesting

Images 25 & 26:

Show a concept for pharmaceutical packaging utilising communications technology. The packaging can communicate to a doctor that a patient has taken their medication and can alert them if they have missed a dose. It also has a four button selection where the patient can select how they are feeling (image 2), notifying the doctor if the medication is working or not or perhaps indicating side effects.

Images 27 & 28:

A concept for perfume packaging utilising OLED lighting. The tab on the top flap breaks a connection and when opened the connection is established causing the inside to light up (image 4) (due to overuse this model didn't work as intended any longer so connection had to be established by squeezing the sides).

Images 29 & 30:

A concept for champagne packaging. The packaging can be used as an ice bucket and is lit up when the circuitry on the base and top come into contact with each other.

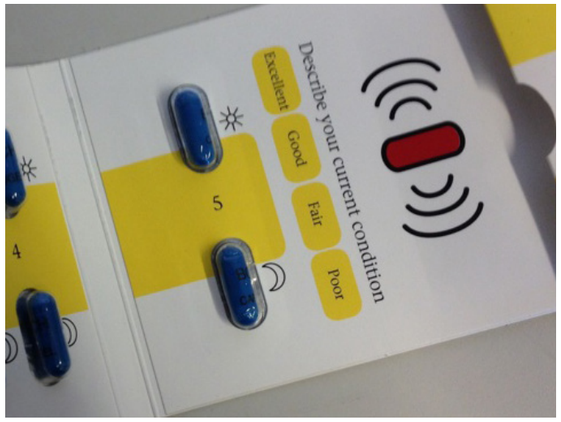

Image 25 & 26: Pharmaceutical Packaging - Duncan Anderson - 2016

Image 27 & 28: Perfume Packaging - Duncan Anderson - 2016

Image 29 & 30: Champagne Packaging - Duncan Anderson - 2016

Image 31:

Smart shelf detects the packages that's sitting on the shelf. The consumer can be alerted to food that's soon going to expire, the consumer can also check via smartphone or tablet what they have in the kitchen. Handy if you're out at the supermarket and forget what you have at home. On display but not pictured was a refrigerator which performed the same interaction with the packages inside it.

Image 31: Smart Shelf - Duncan Anderson - 2016

6.0 Additive Manufacturing

6.1 How it Works

Additive manufacturing starts with a model created with computer-aided design (CAD) or through reverse engineering techniques, such as scanning an object using lasers. Next the CAD file is converted to a standard additive manufacturing file format, most commonly a StereoLithography (STL) and the object is sliced into layers before being sent to print. The 3D printer then prints the object layer by layer, then depending on the requirements the object may require further cleaning, polishing, painting and finishing (Image 32). Three types of materials can be used in AM; polymers, metals and ceramics. (lboro.ac.uk, 2016)

6.2 Categories of AM

AM processes vary depending on the material and machine technology. The American Society for Testing and Materials (ASTM) have classified the range of AM processes into seven categories:

VAT Photopolymerisation

The object is created in a vat of liquid photopolymer resin. A UV light is used to cure or harden the required layer of the object after which the platform where the object sits moves down in order to create the next layer.

Material Jetting

Objects are created using a print head similar to that of an inkjet printer. The print head deposits drops of material onto a build platform where it solidifies and then the next layer is applied with a UV lamp being used to cure the material.

Binder Jetting

A roller applies a layer of powder material over the print platform. The print head then applies a binder adhesive to the required area of the object layer. After this the build platform is lowered and the process repeated until the object is completed.

Material Extrusion

The printing material is drawn through a nozzle where it is heated and then deposited on the print platform. The print platform moves to accommodate the necessary position of the object layer.

Image 32: AM Process - Deloitte - 2014

Powder Bed Fusion

A thin layer of material is spread across the build platform using different methods such as a roller or a blade. After this a laser or electron beam is used to melt and fuse together the material in the required area of the object layer. Next the build platform is lowered, a new layer of powder is applied and the process repeated until the object is finished.

Sheet Lamination

Process using sheet material such as metal or paper. The material is either bonded in place over the previous material then cut using a knife or laser or cut before being bonded in place. The process is repeated until the object is created.

Direct Energy Deposition

Similar to material extrusion but the nozzle is not fixed to an exact position but can move in multiple axes. The nozzle heats the material then it is deposited to the required area upon which a laser melts the material. Typically used for repairing or maintaining structural parts.

(lboro.ac.uk, 2016)

6. 3 Advantages and the Future

Although once considered more as a hobby or for rapid prototyping, additive manufacturing is quickly gaining traction in manufacturing. Although at the moment it's more limited to high end production for industries such as medical implants (Image 33), dental restorations, automotive, aeronautics and spacecraft (Image 34). It offers a glimpse to its potential in mainstream mass manufacturing and the possibility that it may be used for packaging in the future. Additive manufacturing could offer great benefits for production in a sustainable society including:

- Complex cavity structures can be created which reduces the weight of the object.

- Unlike techniques such as injection moulding, no tooling is required reducing cost and risk to manufacture. Alterations can be made quickly to suit changing consumer demand.

- More localised manufacturing, designs can be sent digitally and produced anywhere there is a printer available. Lessens environmental impact since objects don't need to be transported over long distances.

- Objects can be printed to demand rather than stockpiling for expected demand, meaning more efficient material usage.

- Efficient use of material. Objects can be produced without any waste, support material can often be recycled and put back into the system.

- Lessens constraints of traditional manufacture, more organic shapes can be produced.

Image 33: AM Titanium Hip Implant - E-Manufacturing Solutions - 2016

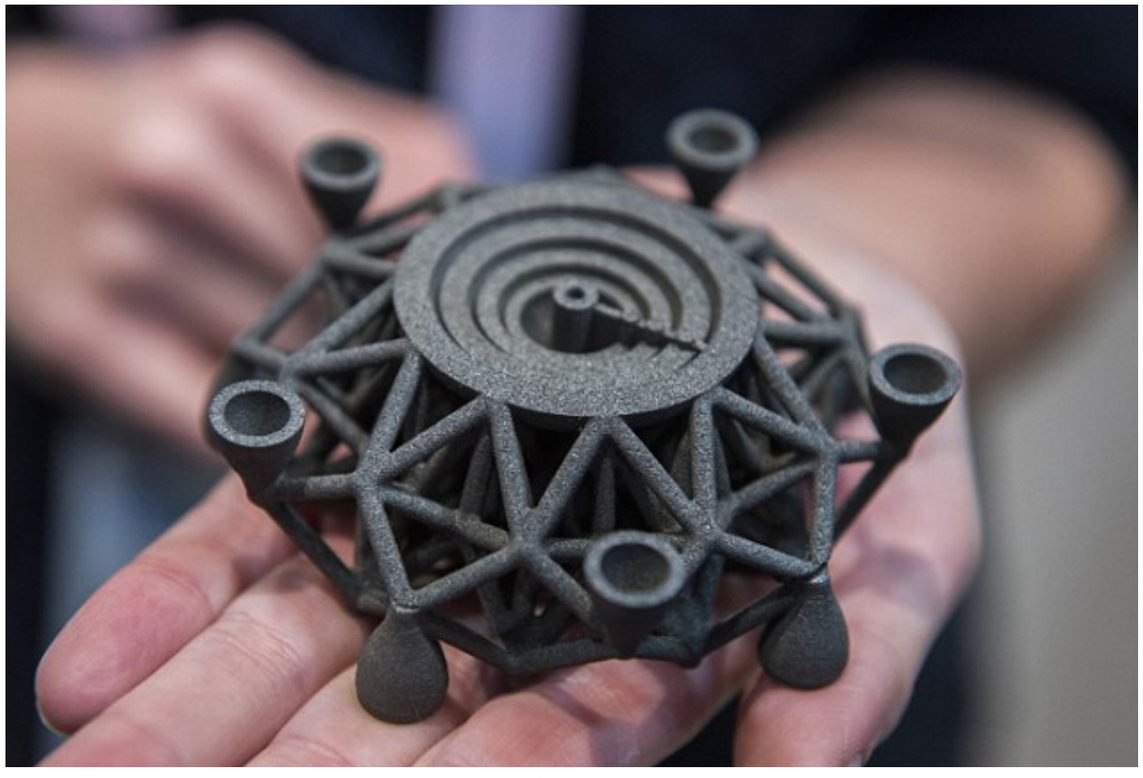

Image 34: AM Model of Part of a Spacecraft - Daily Mail - 2016

7.0 3D Printed Circuitry

One evolution in 3D printing now is the addition of 3D printing circuitry with the product. This was initially achievable by retrofitting existing 3D printers but now companies are producing dedicated machines capable of printing objects with integrated circuitry. A company called Voxel8 created what it says to be the first printer capable of producing objects with integrated circuitry. It prints using PLA (polylactic acid) for the body and specially formulated conductive silver ink for the integrated circuitry (Image 35). Standalone chips can be inserted during the process and then the printer lays down silver ink to make the connections. (Image 36) shows a drone printed by the machine, although standalone chips and extra components had to be added, the body and internal circuitry was 3D printed as one. (mashable.com, 2015)

Autodesk got behind Voxel8 and offered to build them software for 3D electronic printing design. They envisage manufacturing moving more towards integration. Where now multiple components are made and then pieced together to form the product, in the future it might be possible to completely manufacture products as one complete with all circuitry. If this is the case the future could be the same for packaging with integrated circuitry.

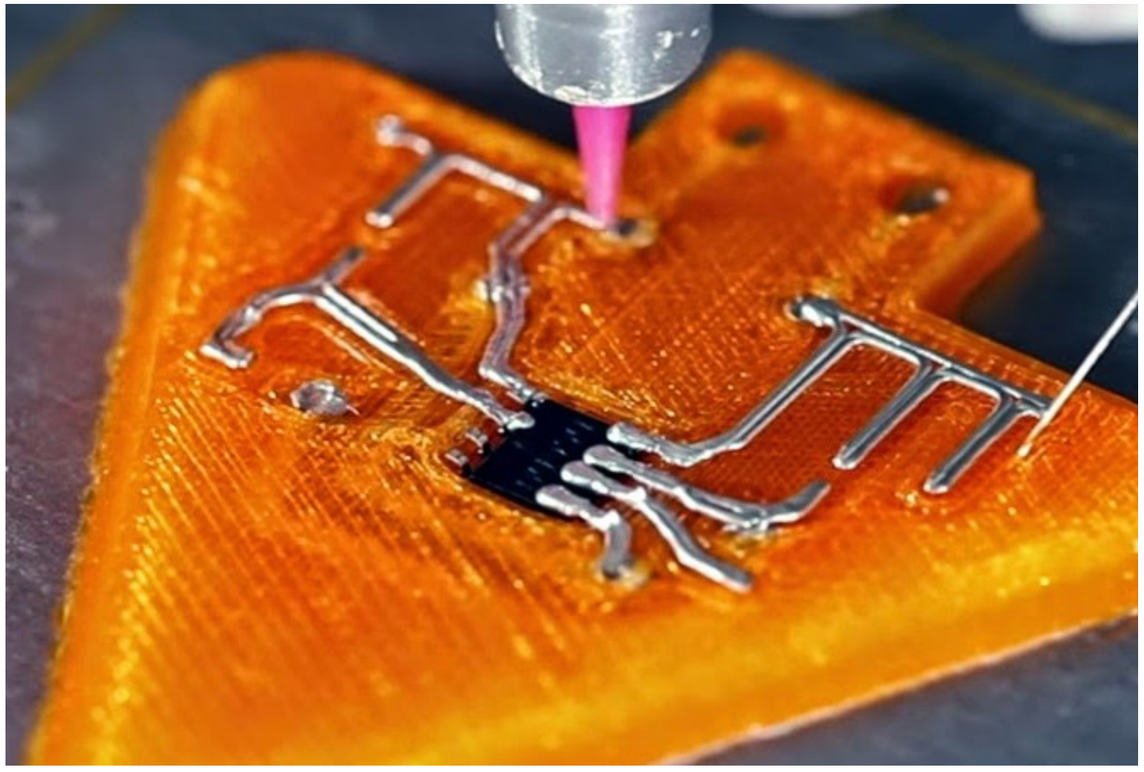

Image 35: 3D Silver Ink Being Printed to Create Circuitry - Earthtron Blog - 2015

Image 36: 3D Printed Drone Printed on Voxel8's 3D Electronics Printer - Mashable - 2016

8.0 Design Solution

8.1 Design Brief

WHO: A young consumer of 20 to 35 that is conscious about the environmental impact of their buying decisions. Still they want to buy luxurious products that make them feel good. They like to dress up and feel glamorous in a glitzy city setting, but they also like to spontaneously put on old functional clothing and go camping with friends to get away from it all and get in touch with nature.

WHAT: Eco-Luxury packaging for perfume that draws on natural inspiration, reflecting it's intent to be a sustainable luxury product.

WHERE: The year 2050 in a sustainable society with attributes identified from SPREAD.

WHY: Luxury can often equate to wasteful or flashy packaging. Eco packaging is not often glamorous as it is intended to look basic. Some people want to feel that they are getting both in their buying decisions. To create a vision of how luxury might be perceived in a fully sustainable society.

HOW: 3D-Modelling design and concept based on the research. Accompanied by a scenario (descriptive visualisation) of how the consumer would interact with the packaging. Based on the research the packaging would be made using MFC with raw material sourced from agroforestry. It would be locally produced using additive manufacturing and 3D printing of circuitry allows for packaging and electronics to be printed as one.

8.2 Moodboard

The butterfly chrysalis is the base of the inspiration for the concept. This fits well with a society that values meanings or symbols more than brands as identified by SPREAD. The cocoon is emblematic of a material that comes from nature and can be recycled after use.

The good thing about the use of MFC and additive manufacturing is the ability to incorporate features from the chrysalis that were difficult or couldn't be implement with paperboard. Producing more organic smooth lines such as the paper kite chrysalis (Image 37) is one thing that I wanted to achieve with the technology. The diagonal split opening (Image 40) is also something that I wanted to carry through to the final concept. With precision manufacturing it could be possible to manufacture complex packaging opening mechanisms.

As I had used in the initial concept I decided to keep with the theme of having a day and night version reflecting the butterfly (Image 39) and moth (Image 38). I think this is a good aspect as often perfumes come in different versions and the scent of each would be more suited to the time of day it is meant to be used.

Image 37: Paper Kite Chrysalis - Animal Photos - 2016

Image 38: Moth - Audubon - 2016

Image 39: Butterfly - Duncan Anderson - 2015

Image 40: Opening Monarch Chrysalis - All of Nature - 2016

This feature of the chrysalis changing from opaque to transparent (Image 41) was of great interest to me. I think that carrying this feature through to concept could make the product feel more alive and interactive to the consumer. I think that with the implementation of printed electronics it could be possible to achieve in the year 2050. This would bring the concept closer to biomimicry than inspired by nature.

Image 41: Changing Monarch Chrysalis - Marty Nevil Davis - 2016

8.3 Sketching

I began sketching how the paper kite chrysalis and monarch chrysalis might look as a package (Image 42).

Left: I liked the curves of the paper kite chrysalis and thought the ribbed texture might be interesting.

Middle: I didn't feel like the shape of the monarch chrysalis was very elegant and looked more like a roll-on deodorant, but I liked how the pattern of the wing shows through.

Right: I decided to combine the two using the elegant curves of the paper kite chrysalis with the pattern of the monarch. I decided to make it smooth rather than ribbed to make it more minimal, elegant and luxurious.

Image 42: Chrysalis Packaging Sketches - Duncan Anderson - 2016

I then drew different patterns of the wing using Illustrator (Image 43). I decided to go with the simplest one to make it clear and minimal. I then went on to 3D modelling the design from the sketch and the pattern of the wing.

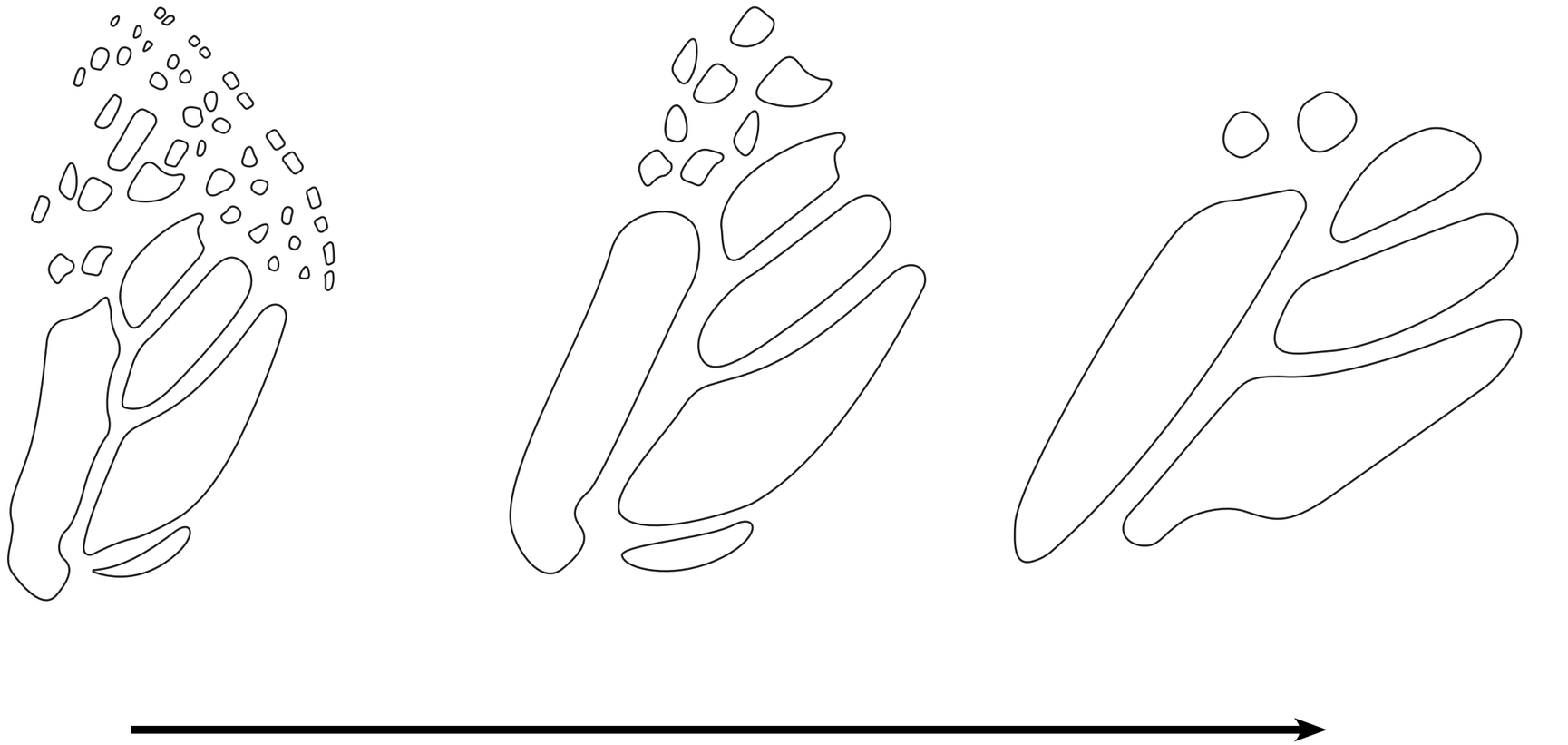

Image 43: Butterfly Wing Illustration - Duncan Anderson - 2016

8.4 Concept

Inspired by the smart shelf discussed earlier in this paper, I considered that they may also become part of the retail environment. This could add extra functionality and development of unique shelf appeal features to packaging and products.

In this concept the packaging could change from opaque to transparent when it comes into contact with the shelf, slowly revealing the product inside in a seductive manner. The liquid would be illuminated by OLED lighting which would shine with increasing brightness as the packaging turns more transparent. This would add the effect of the contents being mysterious and valuable. The level of transparency could be relative to the position on the shelf so that the ones at the front would change faster and thus be ready to take home by the customer (Images 44 & 45). Or perhaps they could oscillate between opaque and transparent and stay at the level of transparency when they are picked from the shelf.

Image 44: 3D Render 1 - Duncan Anderson - 2016

Image 45: 3D Render 2 - Duncan Anderson - 2016

With the use of additive manufacturing the packaging would be precision printed giving the advantage of an intricate opening mechanism. The integrated electronics allow for an electronic seal that can be opened by the consumer after purchase. At the consumers command the packaging opens with a smooth action (Images 46 & 47).

Image 46: 3D Render 3 - Duncan Anderson - 2016

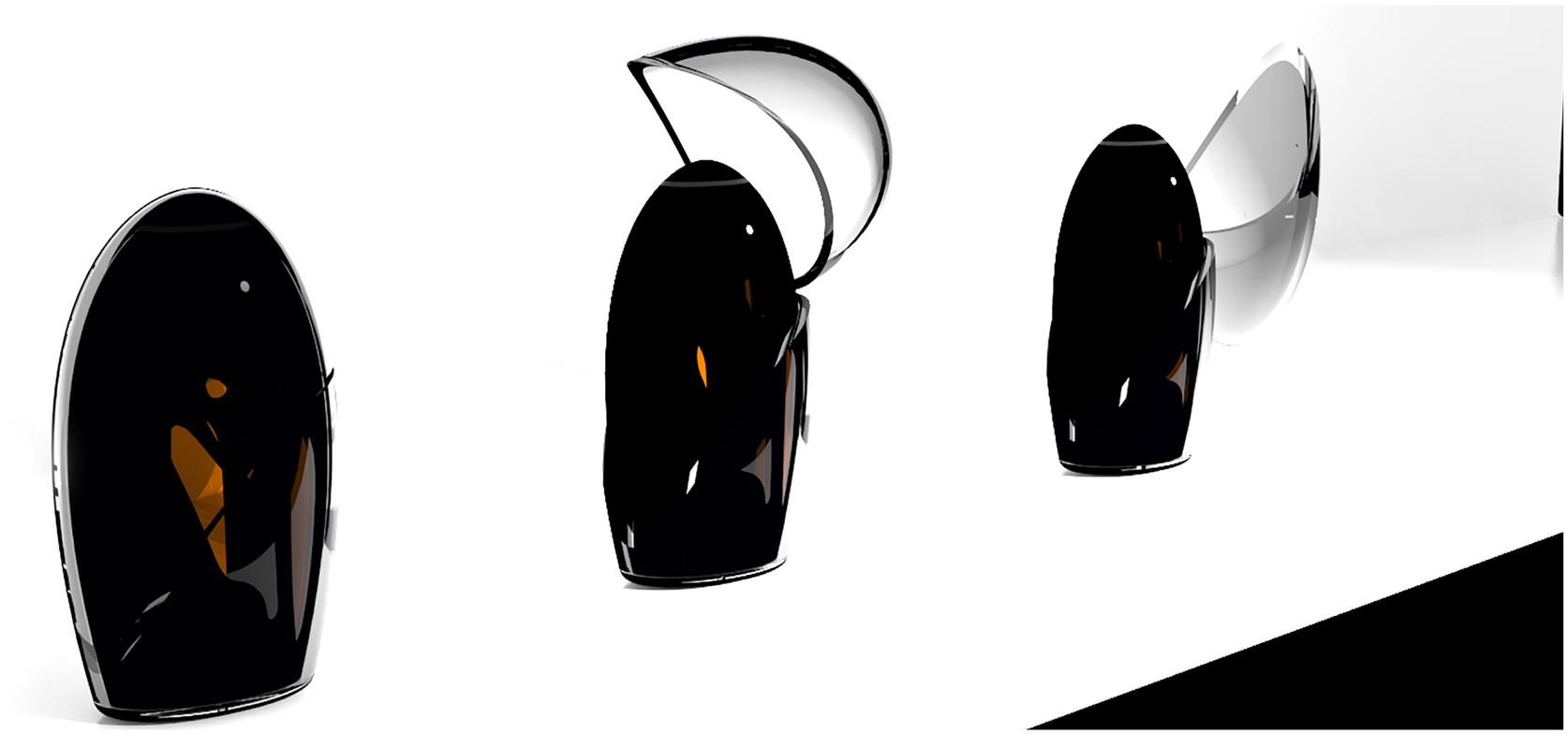

Image 47: 3D Render 4 - Duncan Anderson - 2016

Image 48: 3D Render 5 - Duncan Anderson - 2016

The complex primary packaging is also possible with additive manufacturing (Image 48). The perfume is added during the printing process, much like the standalone microchips were added to the 3D printed drone with integrated circuitry during printing. The button at the top is pressed to spray the perfume (Image 49).

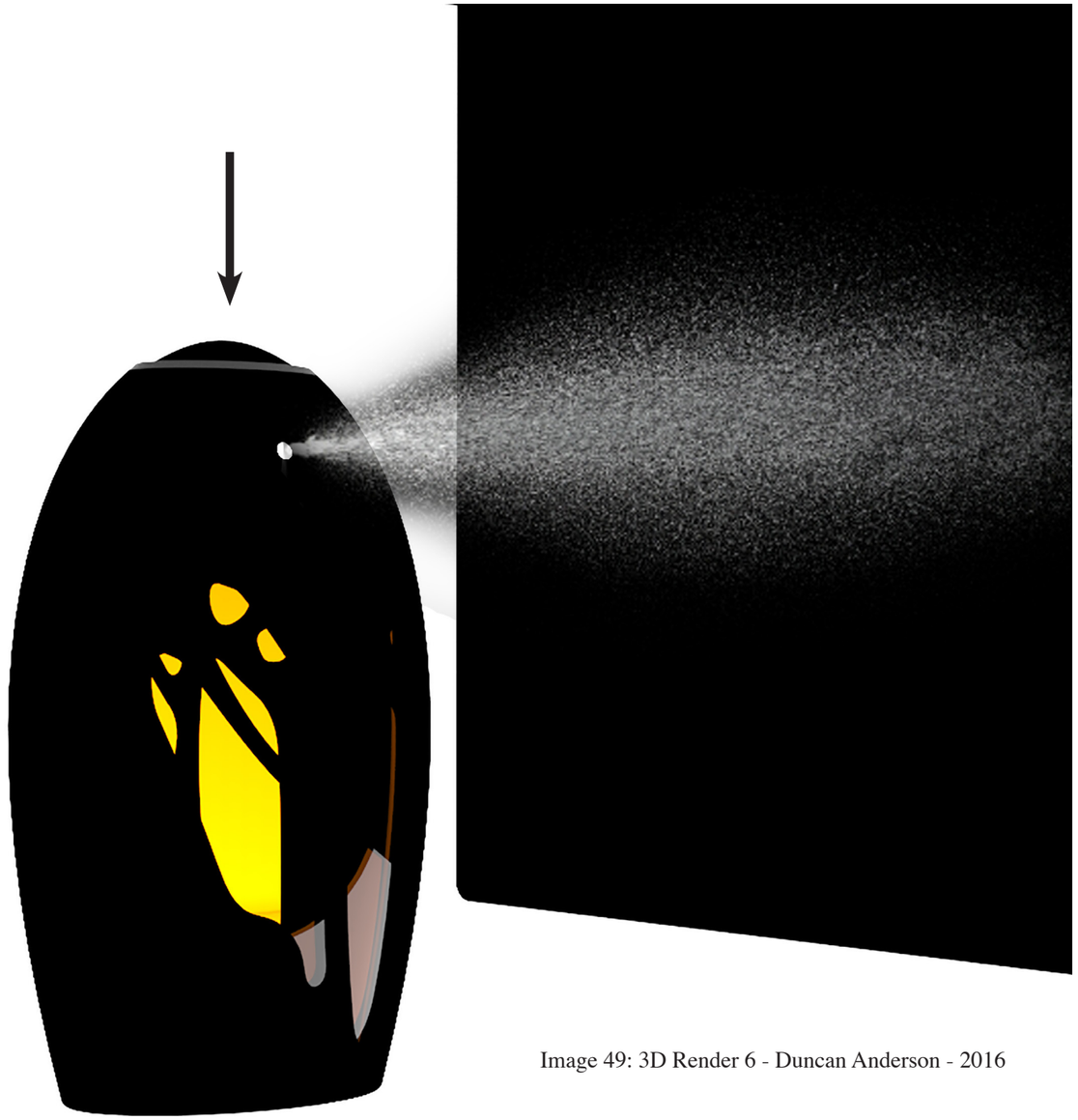

Image 49: 3D Render 6 - Duncan Anderson - 2016

8.5 Scenario

This is Lucy. Lucy likes luxury but she's also conscious of the effects her choices have on the environment (Image 50).

Image 50: Lucy Intro Sketch - Duncan Anderson - 2016

When Lucy goes shopping augmented reality shows different icons around the products indicating their level of sustainability (Image 51).

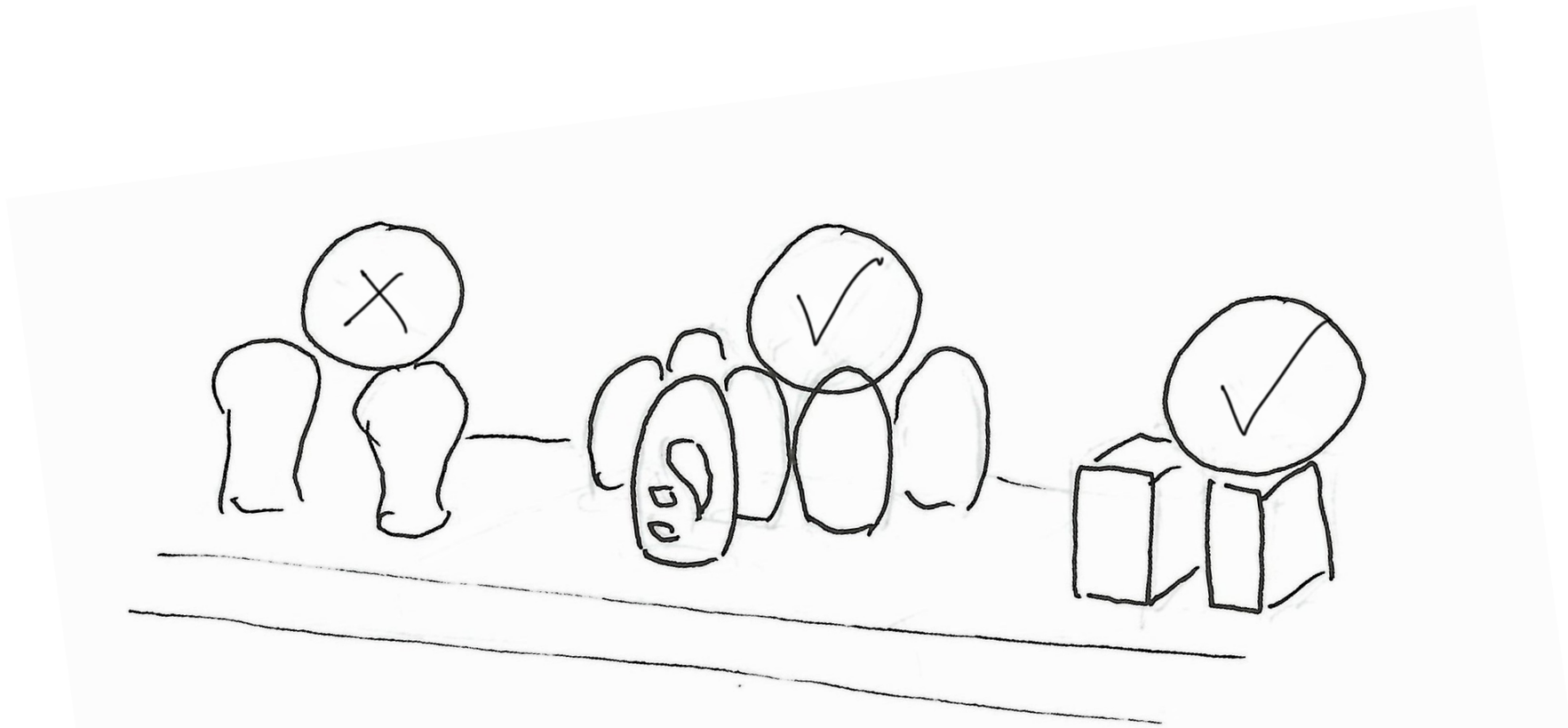

Image 51: In-Store Sketch - Duncan Anderson - 2016

Lucy picks up Chrysalis and up pops a window with further information about the product and packaging (Image 52). If Lucy desires she can scroll down to see further information about the material source of the packaging giving precise information about stock as indicated by the SPREAD scenario (Image 53).

Image 52: More Info Sketch - Duncan Anderson - 2016

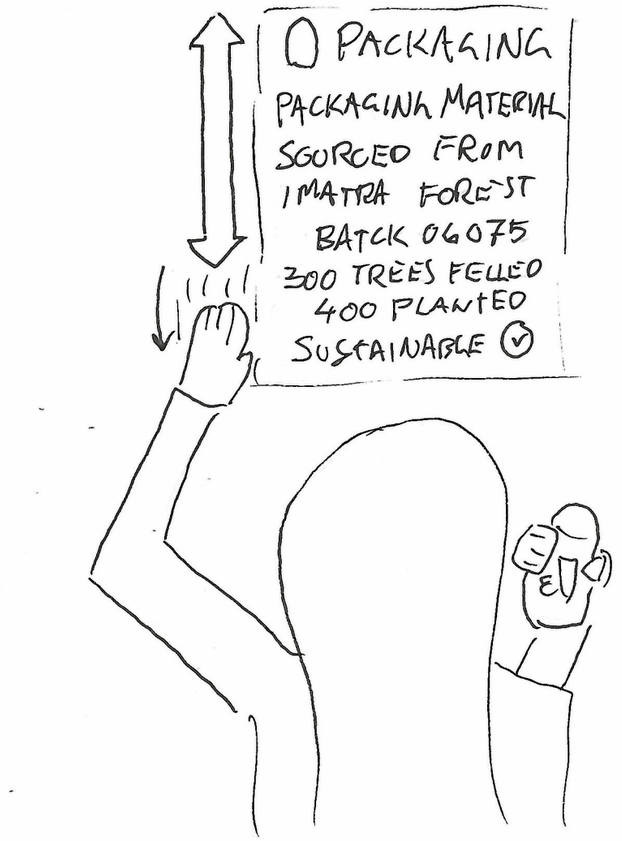

Image 53: Scrolling Sketch - Duncan Anderson - 2016

Lucy chooses to buy Chrysalis. Wow, great choice! Lucy just gained 20 sustainable points (Image 54). Lucy can gain or lose points depending on her choices. The points she gains can be traded for goods or services. These would be collected, much like you might collect coupons, for a grand prize. Rather than being a small reward such as a deposit system for bottles, the grand prize makes it seem worthwhile to make the right choices.

Lucy cares about the environment and she seeks out ecological choices anyway, so the points system is an added bonus. In contrast, the buying decision of some of her friends is not influenced by the ethical factors of the products they buy. However the rewards system means that they usually prefer to purchase these products over others.

Image 54: Points Sketch - Duncan Anderson - 2016

At home Lucy initiates the self opening via the augmented reality (Image 55 & 56). When the product is open she receives a message thanking her for her purcha and informing her of special offers due to her loyalty sustainable efforts. Over time as she buys more produ she receives more tailored offers related to her taste.

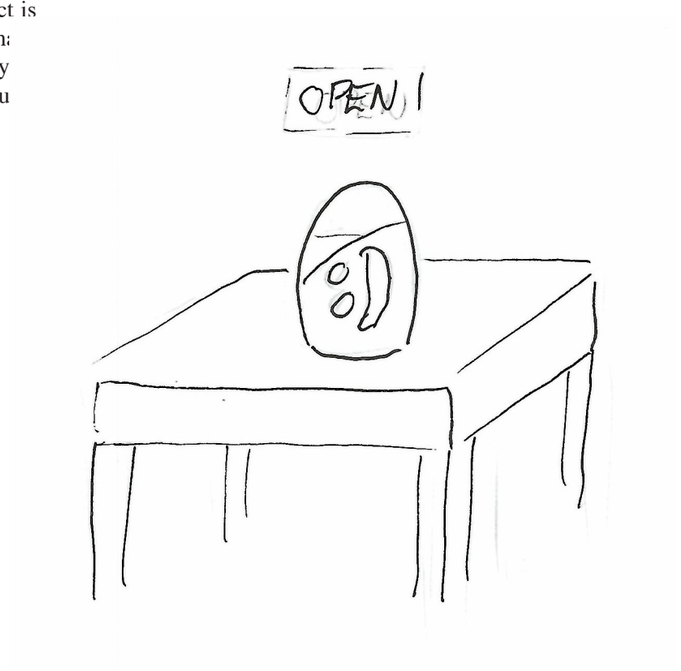

Image 55: Closed Sketch - Duncan Anderson - 2016

Image 56: Open Sketch - Duncan Anderson - 2016

After use the packaging can be recycled into new products using Lucy's 3D printer (Image 57). The printer can use not only raw material but also waste packaging material. Lucy decided to make her own butterfly drone from the Chrysalis packaging. Chrysalis sent her the design for the butterfly and she was able to customise it however she liked. She controls the drone via augmented reality controls (Image 58).

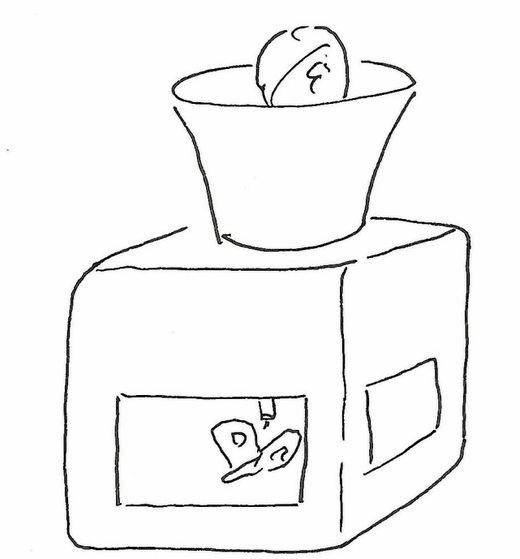

Image 57: 3D Printer Sketch - Duncan Anderson - 2016

Image 58: Drone Sketch - Duncan Anderson - 2016

9.0 Conclusions and Evaluations

I feel the research in my thesis has been a beneficial learning curve. When looking at packaging on the internet you often come across examples of eco-friendly or renewable materials and at first they can seem like a real winner, but I've learned that you can't always take it on face value. Doing a bit of research into the material can reveal some ugly truths. Researching about bio-PE and bio-PET for example opened a Pandora's box. It was quite difficult to go through the various articles about sugarcane monoculture in Brazil, the information is vast and quite complex. Some of the issues raised can also be quite unsettling. Trying to channel it and focus it to keep it on topic was a challenge, the section could have been twice as long but I tried to keep to the key points relating to packaging material producers. I found that it's important to keep sceptical about new materials especially when you have strong views about environmental and social ethics. Although there may be a fine line between scepticism and pessimism and I hope the tone hasn't been too negative at points during this paper.

I enjoyed reading about the future scenarios put forward by SPREAD and how a society might live sustainably in the future. I feel it was a valuable addition to channel the design process and gave it a strong foundation. In hindsight I could have made several scenarios rather than focus on just one, or make one scenario for each of the four scenarios they identified. This perhaps might have resulted in a more in-depth design solution. However I think it's been a rewarding challenge to design packaging for a world that doesn't or may never exist. This kind of exercise can open your mind creatively as you have to think outside the box but still keep within the constraints of the research. I feel like this thinking can be applied to working life as I endeavour to be innovative but I know I have to keep within restraints like manufacturing capabilities and cost. I feel in this way that the design solution has been a successful professional process for me.

One key point that came up was how to influence consumer buying decision for more ecological and socially ethical products and packaging. In society there are people who seek to purchase these kinds of products, but there are those for who it is not important and there are those who are interested but it doesn't have much influence over their buying decisions. By implementing a points reward system for better buying decisions it makes it more inclusive to all people. In this way it makes buying more ethical products fun and less patronising about the issues it is trying to address.

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