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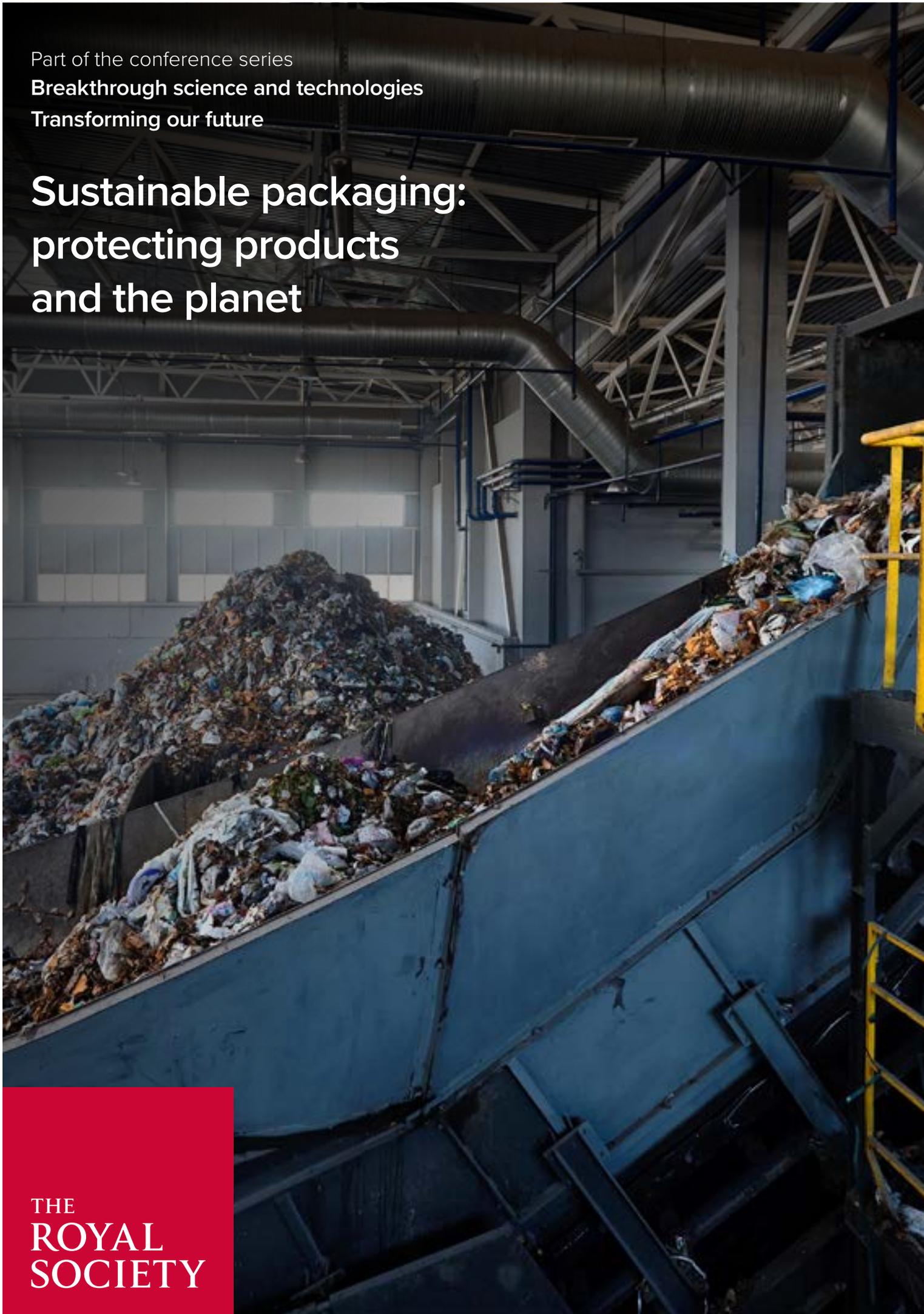
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Part of the conference series
Breakthrough science and technologies
Transforming our future

Sustainable packaging: protecting products and the planet

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Introduction

On the 2 July 2021, the Royal Society held an online symposium to explore recent advances and disruptive approaches in the field of sustainable packaging. The purpose of the event was twofold: first to give a platform to businesses worldwide who are working to reduce, reuse or revolutionise the use of plastic in packaging; and then to highlight key barriers that must be addressed for the packaging industry to be truly ‘sustainable’.

The meeting forms part of the Society’s wider Transforming our Future series, supported by AstraZeneca, and was organised by Professor Jas Pal Badyal FRS, Professor of Chemistry at Durham University, and Dr Geoff Mackey, Corporate Affairs and Sustainability Director at BASF.

Each conference in the Transforming our Future series brings together key stakeholders from across a sector to address a major scientific and technical challenge of the next decade. The series is organised through the Royal Society’s Science and Industry programme which supports the Society’s commitment to integrate science and industry across its activities, and to promote science and its value by building relationships and fostering translation.

This report is not a verbatim record, but a summary of the discussions that took place during the day and the key points raised. Comments and recommendations reflect the views and opinions of the speakers and not necessarily those of the Royal Society.

Executive summary

The low cost, protective and adaptable nature of plastic has transformed the manner and extent to which we can safely transport and store our goods, but our current system is failing. Studies suggest that only 14% of plastic packaging used globally is collected for recycling and only 10% of all plastic recycled has been so more than once. Around 40% currently ends its useful life in landfill.

Tackling waste and establishing a circular plastics economy will play a vital role in making the packaging industry sustainable.

From designing effective and affordable materials to mining discarded plastic, this event explored businesses, disruptors and innovators working to tackle plastic packaging waste. The conference then considered what lessons the sector must heed in its path to sustainability. It aimed to identify the existing barriers and necessary characteristics for any proposed packaging solution. Key to this was the message that any packaging solution needs the correct infrastructure in place to deal with it at its end-of-life in order to be truly sustainable.

The diversity of solutions featured in the conference highlighted that there is no one clear route to sustainability, and that many aspects must be considered when assessing the potential of a sustainable packaging solution. It also became clear over the course of the conference that there remains uncertainty around what a sustainable packaging sector will even look like and how it will be achieved.

The conference concluded with the summary that until a universal measure of sustainability is established, the only unequivocally sustainable option is elimination.

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“This is a global challenge and it was great to learn more about so many different innovations, and complementary solutions taking place around the world.”

Professor Jas Pal Badyal FRS, Durham University

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“We had an event about packaging, we talked about sustainability, and we opened more questions than we closed.”

Dr Geoff Mackey, BASF

.....
“The only unambiguously good thing you can do is not particularly recycle or compost, it’s just to buy less. If you buy less, then less carbon will go into the atmosphere. It’s the only way you can really guarantee that.”

Professor Mark Miodownik, UCL

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Developing, manufacturing, and introducing new sustainable materials into the food sector

Peter Hargreaves, The Alexir Partnership, spoke from the viewpoint of an established packaging converter with an increasing focus on sustainability and how they are approaching these challenges.

The Alexir Partnership is the UK's only independent business in the fast-moving consumer goods (FMCG) sector that creates, packages and packs products from design to delivery within one partnership. With plastic packaging coming under increasing pressure, Alexir looks to design, develop and manufacture a portfolio of board-based alternatives that will mimic the desirable properties of plastic packaging, thereby eliminating plastic from the supply chain.

Through design and material innovation, Alexir strives to remove plastic from the supply chain and provide solutions for common end-of-life challenges for packaging.

Design innovation to improve end-of-life treatment

Demonstrating how innovative design can enable conventional materials to be used in a more sustainable way, the Halopack was developed to replace vacuum formed plastic and plastic skin pack trays, thereby reducing the amount of plastic being used for food packaging.

The Halopack is a 90% board carton which is lined by a thin layer of Polyethylene (PE). Upon disposal, the PE liner is designed to easily peel away leaving a clean piece of cardboard ready to be recycled. The PE liner can also be recycled in municipal recycling streams. Though not eliminating the use of plastic altogether, the Halopack has approximately a 90% reduction by weight in plastic packaging compared with the conventional alternative.

The boards are also compatible with most existing top sealing machines, thereby enabling it to fit in the current packaging infrastructure/supply chain with only minor adjustments.

Material innovation to eliminate plastic use

Agriwaste board can be produced from a variety of plant waste including cereal crop waste, sugarcane, palm oil waste and general plant waste containing cellulose that would often be burnt. The boards contain between 50-100% plant waste with the remaining balance being timber fibres depending on the application and colour required.

Agriwaste board can be recycled in the same waste stream as timber-based board waste. They can also be printed and processed through conventional finishing equipment.

The cost barrier

At present, a major barrier for the widespread adoption of many more sustainable packaging alternatives is cost. Effective plastic-alternative materials exist but they are often more expensive, and the UK's competitive food sector won't accept increased food prices easily. As a result, many new and promising innovations in both material and pack constructions where price increase is the only option are still waiting to be accepted by the major retailers.

Developing place-based solutions

David Christian, co-founder of Evo & Co, talked about their vision to create a world without plastic pollution by provide biodegradable alternatives to single-use plastics, and create collaborative plastic awareness movement.

By the year 2050, it is expected that there will be more plastic in our ocean's than fish. Indonesia is the world's second-largest contributor to plastic waste in the ocean, 70% which is single-use food and beverage plastic containers. It is predicted that leakage of plastic waste into Indonesia's ocean is already costing the coastal tourism industry \$13 billion per year and impacting the 3.7 million Indonesians working in the fishing industry. If current rates of plastic waste collection and treatment are maintained in line with increasing waste generation, leakage of plastics into Indonesia's water bodies is projected to increase 30% by 2025 and more than double by 2040.

Local solutions

Evo & Co's first brand is Evoware which is focusing on providing single used plastic alternatives made from local seaweed farms. Its primary output is edible cups and seaweed-based packaging that can be used for both food and non-food products. Seaweed is a valuable plastic alternative that requires no fertiliser, minimal land and can be harvested every 45 days. Indonesia currently produces 11 million tonnes of seaweed per year but only uses 30% of the area that could be used; its potential is still relatively untapped.

Other local natural materials including bamboo, agriwaste, wood, industrial cassava and rice fodder are also used to make packaging provided by Evo & Co under the brand Evoworld. To make their products accessible to the lower- and middle-income market, the company also subsidises its products and educates micro businesses about plastic pollution under their Rethink Campaign.

Indonesia's domestic plastic pollution problem comes as much from a lack of understanding as from a lack of material alternatives. The company therefore works with individuals, businesses, institutions and governments to run a series of campaigns in and around Indonesia designed to prevent plastic consumption and waste.

.....
"Providing a solution is very important but it's also important to raise awareness. Especially in Indonesia where a lot of people don't understand and therefore don't care about the environment."

David Christian, Evo & Co
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Adapting the solution to the infrastructure available

Rhea Singhal, Founder and CEO of Ecoware, spoke about her work in India developing packaging products from 100% agriwaste material.

India's Ministry of Environment, Forest and Climate Change estimates that 75-80% of India's total municipal waste gets collected and only 22-28% of this is processed and treated. With no formal waste management infrastructure, it is estimated that around 31.5% of the plastic waste generated by India's 1.3 billion population is mismanaged.

Packaging from agricultural waste

Ecoware's products are made of waste from rice, wheat and sugarcane production and are designed to replace single-use plastic containers. They are 100% plant-based and contain no binders, no additives and no plastic. Ecoware works with farmers to collect crop waste which is typically burnt. They then clean, pulp and convert it into board containers through a thermal forming process for the food and beverage industry. The strength of fibre in the crop material makes the packaging temperature resistant from -20°C to 140°C and can be used safely in the fridge, microwave and oven. The material is both oil and water resistant.

Ecoware's impact and next steps

Ecoware has over 11 global certifications, to date has displaced over 300 million pieces of single-use plastics and its income is 100% derived from a circular economy model as recognised by the World Economic Forum. In 2016 a study by Impact Investment Exchange, Singapore calculated that for every \$1 invested in Ecoware, the company returns \$2.47 in Environmental, Social and Governance (ESG) impact.

While currently only operating in the food and beverage sector, Ecoware has plans to enter the e-commerce sector and the medical sector. Currently, 98% of UK hospitals use disposable medical devices to break the chain of infections in hospitals and reduce the risk of healthcare acquired infections. Ecoware is trying to extend this practice globally with their single-use sugar cane derived medical products.

Approaches to hard-to-recycle waste

Dr Sebastian Kernbaum, Founder and CTO of Saperatec, spoke about his work developing an innovative solution to problems associated with separating multi-layer materials for recycling processes.

Composite packaging is an effective packaging technology consisting of layers of valuable and often widely recycled materials such as metal, plastic and board. However, the difficulty in separating these component materials means that instead of being recycled, much of the composite packaging used today is incinerated or sent to landfill.

In Europe alone, up to €87 billion in material value is lost annually during the use and recycling life cycle for plastic, aluminium and steel.

A novel delamination process

The German start-up Saperatec has developed an advanced mechanical recycling solution for highly functional, yet hard to recycle multi-layer materials. Suitable for polymers, glass and metals, Saperatec's separation process de-bonds and delaminates the layers of material by weakening or disabling the intermolecular forces between the layers. These separated materials, largely unchanged by the delamination process, can then be fractionated and reprocessed into secondary raw materials that can once again be sold on the market.

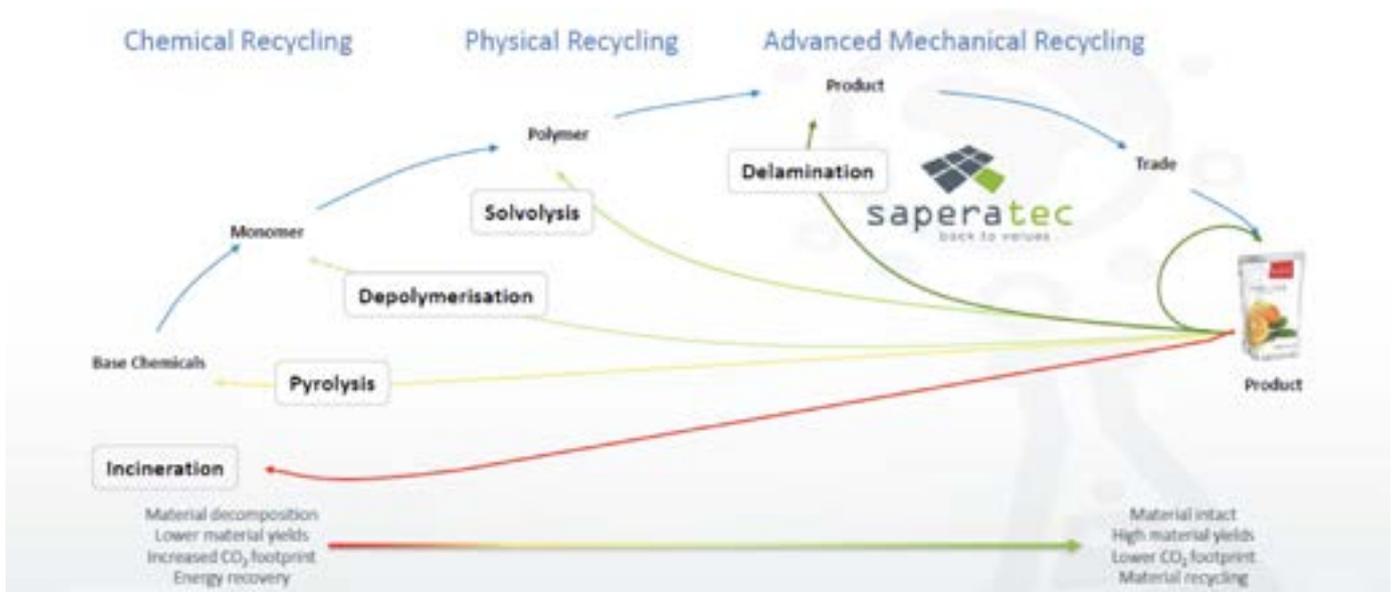
Saperatec's reusable separation fluid physically separates the layers of materials in solid form. This process can work in conjunction with current recycling processes to enable the high-value recycling of compounds that cannot otherwise be recovered and in most cases are incinerated.

Current focus and next steps

The company's current focus is on metal barrier laminates such as coffee bags with aluminium foil, crisp packets with metallisation and film from beverage cartons to produce film grade PE recyclates and aluminium that can be delivered to recycling partners. In recent lab trials on post-consumer aluminium barrier flexible packaging waste, Saperatec achieved greater than 78% recycling rates. They are now developing solutions to separate and sort mixed heavy plastics, which will increase the percentage further. In 2022 they will operate the first packaging waste recycling plant to recover both aluminium and polymers.

FIGURE 1

Saperatec recycling technology is a form of advanced mechanical recycling. It offers high recycling yields and good sustainability footprint.



Reducing waste, improving consumer satisfaction, and boosting the bottom line

Solveiga Pakštaitė, Founder and Director of Mimica, discussed the development of a gel-based freshness indicator that can be used to create a more accurate expiry date in the fight against waste.

One in three UK consumers throw food away solely because it has reached its use-by date, but over 60% (4.2 million tonnes) of the £12.5 billion-worth of food we throw away each year is safe to eat. In Europe, 61% of the food waste generated in 2019 was in households alone. Combatting unnecessary food waste is a valuable way to eliminate unnecessary use and subsequent discarding of packaging.

A bespoke freshness indicator

Mimica Touch is a freshness indicator that accurately gauges when food expires according to the temperatures that the food has been stored in. It has been developed to tackle our current overly-cautious expiry date prediction labels with a system that is accurate to within hours of food spoilage.

Mimica's tactile freshness indicators contain a temperature sensitive, vegan friendly gel that spoils and turns bumpy at the same rate as the food in the package. The gel can be calibrated to react to temperature conditions in the same way as the specific food it is used on, thereby giving the consumer a more accurate understanding of if their food is still recommended for consumption.

Reducing waste

In addition to the environmental benefits, both the consumer and the retailer benefit economically from reducing food waste. The value of unsold supermarket food is currently double the profits of sold food. Mimica's conservative goal to add just 2 days to product shelf-life would cut waste in homes by 63% and retail waste by 50% on perishable products, whilst also reducing the waste in material used to protect food.

Mimica's technology can be applied as a label or a cap on food packaging. They are currently working on pilots with major companies across Europe in the dairy, juice and meat sectors. The technology may also be useful with temperature sensitive therapeutics. Mimica have started a project involving COVID-19 cold storage vaccines.

Making packaging disappear

Rodrigo Garcia Gonzalez, Co-CEO and Founder of Notpla, discussed his work towards a novel solution to single-use plastic bottles – making them edible.

Plastic itself is not the problem, but rather the way we use it. The shelf life of plastic is dramatically misaligned with the shelf life of the material that it is used to package. Plastic packaging is typically used to store a product for a matter of months and yet the plastic packaging itself lasts for hundreds of years.

Replicating nature

Inspired by naturally occurring liquid-storing membranes such as grape peel or eggshell, Notpla has developed a membrane out of seaweed, Ooho, that can be made into sachets to contain liquid and be eaten whole.

Once in contact with soil, moisture or bacteria, Ooho will biodegrade in 10 days, which is faster than an orange peel. The material can be produced in on-site machines and its thickness and durability altered according to its application. It can be used to package solid, liquid, edible and non-edible goods such as food, drink, toothpaste, laundry tablets and metal screws.

Entering the market

Notpla have already demonstrated their product at the 2019 London Marathon, replacing 40,000 drinks bottles, and with Just Eat, replacing 50,000 single use plastic sauce sachets.

Other applications that they are developing made of Ooho include: a waterproof and greaseproof coating for paper food containers and a heat sealable film that can be used as a plastic alternative and can be made water soluble or insoluble depending on application.

Notpla will scale up its business model by leasing their production machines and selling cartridges of materials which will allow manufacturers, co-packers and event organisers to easily produce and sell Ooho as desired.

Dealing with plastic's legacy

Dr Stuart Wagland, Cranfield University discussed the UK Enhanced Landfill Mining Network's mission to retrieve and extract value from plastic packaging that has already been sent to landfill.

There are approximately 1 billion tonnes of plastic in landfills across the EU. As landfills are remediated for redevelopment, there is a significant amount of waste to process, the legacy of old discarded packaging must be dealt with.

Upcycling landfilled plastic

Enhanced landfill mining is the process of taking all material from a landfill and maximising the recovery resource. While it is possible to re-landfill or combust landfill plastics for a source of energy, the more sustainable method of processing would be to convert them into higher value products.

Of the 13 landfill sites that Cranfield University have analysed in the UK so far, plastics represent around 20–30% by weight of excavated landfill material. Polyethylene (PE) is the most abundant plastic followed by polypropylene (PP) and polyethylene terephthalate (PET).

The analysis found that plastics undergo a series of chemical changes, which in some cases are beneficial and in others damage the quality of the product. A reduction in quality can prevent reprocessing for recycling. While PE indicates no significant changes, PP undergoes significant amounts of degradation and contamination. As a result, direct recycling of plastic from landfill is not an economically and practically viable option.

On the other hand, the lower metal content detected in excavated plastics could be of benefit when upscaling landfill plastics into chemicals or fuels. Advanced thermal treatment through pyrolysis, presents a viable pathway for upscaling plastic waste. While landfill mining itself may not be economically viable, it could help maximise resource values and remunerate costs where landfill redevelopment is desired.

For the time being, gaining permission to mine landfills is one of the core challenges. At present, no specific regulations are in place to allow this to happen.

FIGURE 2

Integration of landfill mining in the circular economy. Image modified from.

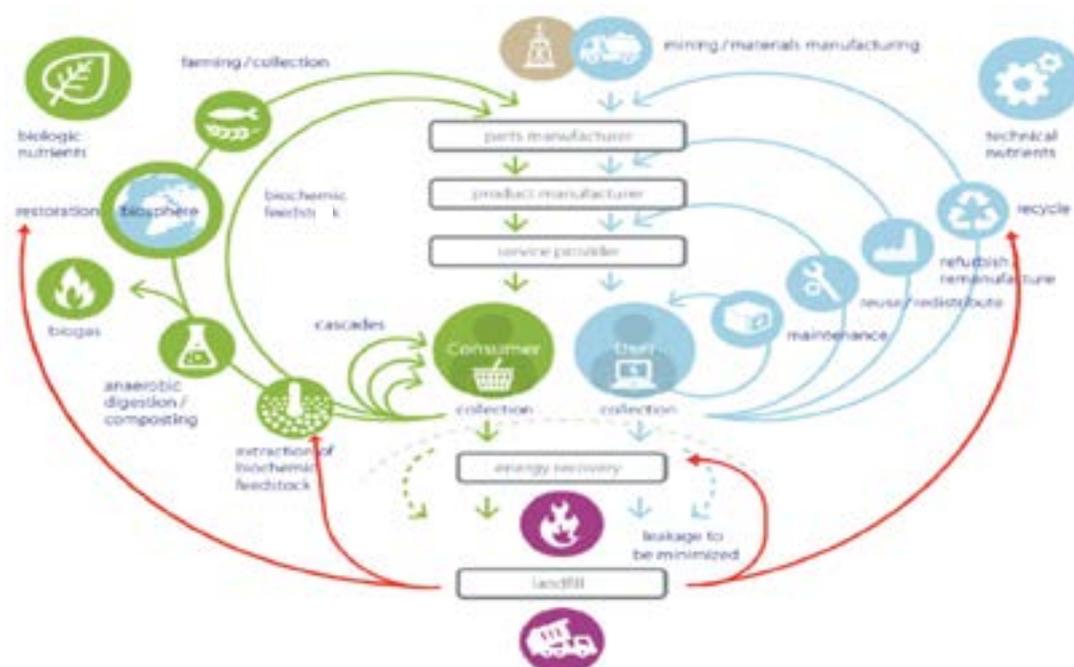


Image modified from Ellen Macarthur Foundation system diagram

Compostable plastics: unlocking existing barriers to systems change

Professor Mark Miodownik, Professor of Materials and Society at UCL discussed the result of the Plastic Waste Innovation Hub's systems analysis work and their resulting policy recommendations for a functioning system for compostable plastics in the UK.

For a packaging material to be sustainable, its lifecycle must be closed loop, net zero and profitable at every step. As part of their efforts to establish a circular plastics economy, the UK Plastics Pact aims to have effectively recycled or composted 70% of their plastic packaging by 2025. The Plastic Waste Innovation Hub at UCL examines the size of the role that compostable plastics can play in achieving this goal.

Compostable packaging is a popular alternative to conventional plastic packaging amongst consumers, with 85% reporting to be more likely to buy packaging that is listed as 'biodegradable' or 'compostable'. The Plastic Waste Innovation Hub's research explores whether the correct infrastructure is in place within the UK to deal with compostables in a sustainable way.

Composting plastics nationally

To be net zero, the carbon released as compostable plastics decompose must be sequestered for re-use as nutrients by agriculture. There are two options for composting plastics: small-scale home composting or a large-scale national collection and composting scheme.

In addition to a lack of access to home composters, UCL's Big Compost Experiment has shown that home composting does not typically replicate the conditions necessary. Of over 1,000 home-composting citizens, 68% reported their compostable plastic items to be entirely intact or only partially degraded after 15 months. The experiment concluded that the wide variety of home conditions make it unfeasible to design a plastic that will behave conventionally during its lifetime and then compost entirely in all cases.

There is no current UK-wide system to collect and compost compostable plastics, and anaerobic digesters used to process food waste cannot handle these materials. As such, most of this compostable waste is incinerated or sent to landfill, resulting in unsustainable release of methane into the environment. Unfortunately, the current costs required to collect, process, and compost the plastic at scale are large and make ventures unprofitable.

Without subsidising local collectors and sorters, it would be difficult to create a self-sustaining circular compostable plastic economy that profits at every stage of the packaging's life cycle.

A simple solution

UCL's Hub have demonstrated that for many applications where compostable plastic is being used to replace conventional plastic, solutions that adopt a recycle, reuse or removal approach would be more effective. Equally, while it is not feasible to replace conventional plastics with compostable plastics in every circumstance, there are applications where compostable plastics are the most sustainable packaging solution eg food liners, food stickers or tea bags.

When determining the best solution, it is vital to consider waste infrastructure and end of life treatment. While there are many exciting plastic alternatives on the market, if there is no system in place to deal with them, and no way to adapt the current infrastructure accordingly, then they are not environmentally sound and cannot be sustainably scaled up.

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"Don't bring something onto the market if you don't know where it's going to go at the end of its useful life."

Mark Miodownik, UCL
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Influencing consumer attitudes and behaviour towards packaging waste

The panel discussion was chaired by Dr Geoff Mackey, BASF. Panellists consisted of Rodrigo Garcia Gonzalez, Co-CEO and Founder, Notpla, Senior Lecturer, Kingston University; Professor Mark Miodownik, Professor of Materials & Society, UCL; Matthew S. Seidner, Senior Advisor, McKinsey & Company; Claire Shrewsbury, Director Insights & Innovation, WRAP.

- Surveys by McKinsey and WRAP show that citizens globally are more concerned about packaging sustainability and are willing to pay more for more sustainable products. However, they are confused about what sustainable packaging is and the role that they can play as a consumer.
- While there is a broad acceptance amongst citizens that multi-substrate packaging is the least sustainable packaging option, there is disagreement about what is the most.
- Point of sales data suggests that a change in attitude for the consumer does not necessarily equate to a change in behaviour. Citizens still appear to value traits such as function and value above sustainability in the products they buy. For a consumer, packaging should be protective, cheap, hygienic and convenient.
- No material is sustainable, only the way that it is used and the system that it is in. To tackle our 'take, make, consume and throw away' linear packaging economy and establish a sustainable circular one, citizens need to begin to judge the value of a material by how easy it is to recycle.

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“If you tell people that they’re consumers, they’ll consume. If you call people recyclers, maintainers or custodians then you change the framework with which you treat citizens and you change their behaviour.”

Mark Miodownik, UCL

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Changing citizen behaviour towards packaging through education:

- Educating children and adults about how their packaging waste is processed and where it ends up will help to tackle the ‘waste culture’ that has developed by ensuring that citizens feel more responsible for the packaging that they dispose of.
- When looking for material and cultural solutions for our currently unsustainable plastic packaging economy, we should heed previous consumer and trade systems that were in place before plastic. As well as using new technology and ideas to solve unsustainable plastic use, re-instating aspects of pre-plastic systems could help in developing post-plastic solutions.

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“Where do people think that throwing “away” is? There is no place called “away” that all these things go to. That’s an extremely powerful message to teach people. Where do they think waste ends up?”

Claire Shrewsbury, WRAP

.....

“Most of the solutions we’re looking for now, existed in the past and we should look there. Older generations may not know the definition of sustainability but their culture against waste means that things that cost money and valuable resources aren’t exploited. We need to refresh that common sense amongst younger generations.”

Rodrigo Garcia Gonzalez, Notpla

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Changing citizen behaviour towards packaging economics:

- Economics is a powerful and effective tool to change consumer behaviour. By designing a system that gives used packaging value, citizens will be motivated to waste less and contribute more to the social economy.
- By putting a financial or societal cost against packaging characteristics that accurately reflect its sustainability, consumers can be steered to buy the most sustainable products.
- Developing a unified scorecard of sustainability would enable people to better understand the trade-offs of what makes packaging 'sustainable'. The cost of packaging could then be altered to reflect this.
- By making producers economically answerable to the end of life and recyclability of their product, either they will be forced to use more widely recyclable materials or develop systems that can cope with more difficult to recycle packaging.

Changing citizen behaviour towards packaging infrastructure/systems change:

- The recycling infrastructure needs to cater to the majority who care about sustainability but are too busy to prioritise it. A system should be created whereby it is harder to not recycle one's packaging waste than to recycle it.
- A successful recycling infrastructure will require the citizen to do as little as possible. A simple, coherent and intuitive labelling and collection system would reduce consumer confusion about what to do with their waste.
- Developing infrastructure loops to collect, sort and recycle waste locally would reduce energy consumption and boost local employment. It would also increase citizen awareness of where their waste goes and the process involved in its end-of-life treatment. Local sorting and recycling plants would help to shift citizen perspective and encourage them to feel more responsible for what happens to their waste once it is thrown away.

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“Money has to flow where you want the material to flow. We can design a system, but we have to make sure it flows with the money... for people and businesses, money matters. If packaging is worth money once used, it will become sustainable.”

Mark Miodownik, UCL

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“You have to establish the infrastructure first. You can't make everything recyclable and tell everyone to recycle if they don't have the facility to do it. Everything must knit together and that's where systems thinking comes in. You need the system in place before the citizen will really engage.”

Claire Shrewsbury, WRAP

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“The Education component is critical in the issue of changing behaviour... but we also need to provide the infrastructure to make it harder not to think about the correct end-of-life than it is to just throw something into the bin.”

Matthew Seidner, McKinsey & Company

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The only certainty – eliminate packaging:

- Before focusing on reuse or recyclability, the first step for every single challenge is elimination and reduction. Avoiding consumption is key and developing an infrastructure to avoid the use of packaging wherever possible is more effective than developing ways to deal with waste. It is the only way to guarantee less carbon into the atmosphere.
- The three uses of packaging are containment, protection and marketing. We should push and pull on these levers to reduce the amount of packaging required as far as possible, while still catering to the citizen’s preference. From there, we can gradually steer citizens' preferences with the aim of reducing the amount of packaging even further. Reducing the amount of packaging used reduces the problem.

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“Elimination is so often the best solution and should be the first port of call. Instead of investing in infrastructure to deal with waste, we should invest in the creation of systems to avoid the need for the object in the first place.”

Rodrigo Garcia Gonzalez, Notpla
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Acknowledgements

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Professor Jas Pal Badyal FRS

Professor of Chemistry, Durham University

Dr Geoff Mackey

Corporate Affairs and Sustainability Director,
BASF

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Peter Hargreaves

Partnership Business Development Director,
The Alexir Partnership

David Christian

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The Royal Society is a self-governing Fellowship of many of the world's most distinguished scientists drawn from all areas of science, engineering, and medicine. The Society's fundamental purpose, as it has been since its foundation in 1660, is to recognise, promote, and support excellence in science and to encourage the development and use of science for the benefit of humanity.

The Society's strategic priorities emphasise its commitment to the highest quality science, to curiosity-driven research, and to the development and use of science for the benefit of society. These priorities are:

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- Supporting international collaboration
- Demonstrating the importance of science to everyone

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