Sustainable Packaging in a Circular Economy

(Learning from IDE TUDelft's *Sustainable Packaging in a Circular Economy* on edX)

Episode 1: Packaging in a Circular Economy

Why do we need a circular economy for packaging? Get acquainted with the benefits and challenges of current packaging and explore the opportunities of a circular economy for packaging.

Why do we need packaging?

- Primary function: product protection and safety
  - In terms of function and sustainability
  - Protect valuable goods
  - Preserve our food
- Utility
  - Effective product use
  - Distribution (store and transport products)
  - Point-of-sale presentation
- Communication
  - Gives you information about the product
  - Communicating product or brand information
  - Attracts consumers to buy the product
- Are products that 'flow' (e.g. fast fashion, food and disposables)

Current industrial model

- Linear model
- Destroys the material value embedded in (waste) packaging
- Packaging that becomes litter represents a negative externality
- Costs to clean up the litter are (usually) incurred by society instead of the manufacturer

1) Extracts (Take)
2) Uses (Make and use)
3) Disposes resources (Dispose)

- Plastics waste generation is growing rapidly, negatively affecting the environment and human health
- Recovering plastic waste represents a substantial economic opportunity
- Currently only a limited amount of global plastics waste (most of it packaging) is recovered

Circular economy

- Regenerative by design
- Reimagine products and their packaging from a systems perspective
- Minimise waste and keep resources locked in a cycle of restoration
- Prevent the end-of-life 'value drop' for packaging items

What to do?

- Design packaging *as well as* the whole cycle in which the packaging is function
- Always check first: *Can I make the product last longer?*
- There are certain situations where you need products with a short lifetime, so make a design that *fits* the situation

Fast Moving Consumer Good (FMCG)

- What packaging is considered as
- Definition: products designed to have a short lifespan and are constantly in rotation
- Developing packaging solutions for FMCG within a circular economy requires different strategies than those used for regular consumer goods which are designed to last

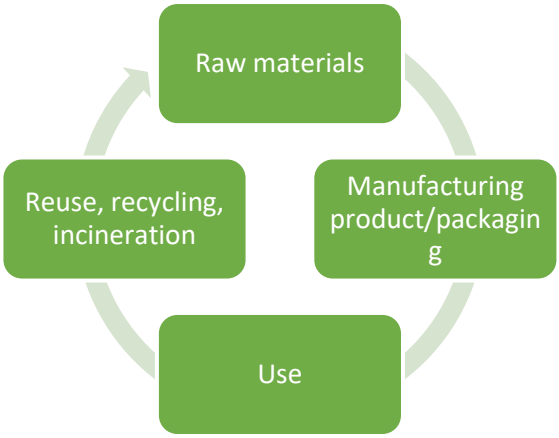
Products that "flow"

- Consumed in large quantities and at a fast pace
- Value is relatively low such that it's a challenge to collect them when they've been disposed
  - Find ways by a collective system
  - Need to get financial support to organise this
- Such products require different strategies for circular value creation than durable products such as consumer electronics or furniture
  - For example, food cannot last long – so same goes for the packaging around food, it will be used for a very short period
- Strategies

1) **Rethink**
   - Why are we doing this?
   - Why do we use this packaging?
   - Why are we using disposables?
   - Ask yourself these questions, they may have good reasons but these questions may bring up new solutions which will have no waste at all
2) **Reuse**
   - Make packaging reusable
   - Not only designing the packaging but also in combination with the system
   - For example, a bottle – can be refilled again and again but also requires a system to sustain it.
3) **Recycling**
   - In the future, every waste should be recycled
   - Remember when designing that recycled content should be reused up front in the packaging of products (for companies etc)
   - Not only recycle but also find a way to use recycled content
4) **Renew**
   - 2 strategies: using (bio-based content) and (making it recyclable again or biodegradable)
   - Using bio-based content like paper, carton, bioplastics, natural fibers etc to make packaging
   - Making it recyclable or biodegradable like giving back to nature
   - Strategy to use always depends on the product or client (also an important factor) or other factors

The Packaging Lifecycle

Linear Economy	Circular Economy
• Resources make a one-way trip from raw material through the production and use phases to become waste	• Resources recovered instead of being wasted after the use phase of the product/packaging item • These items will cycle back into the manufacturing phase to maximise the use of their value and minimise waste and environmental impact



Product-Packaging Combination (PPC)

- When a product depends on its packaging in order to be used
- Especially for fast moving consumer goods, packaging often integral part of product
- E.g. hand soap dispenser, soap it contains
- Developing PPC in the context of a circular economy requires a systems thinking approach
- Things to consider for manufacturers, designers:

1) Integrate development of product and its packaging

- Develop packaging while designing product
- How do they depend on each other?
- Reimagine the product in such a way that its packaging becomes obsolete (reduce the involvement of packaging as much as possible)

2) Consider sustainability aspects at the beginning of a new PPC development process

- Does the packaging increase the product's lifespan (in order to prevent food waste)?
- Can packaging help users use the correct amount of product (reduce wastage of product)?
- What happens at the PPC's end-of-life?

3) Involve all stakeholders that are part of the PPC's value chain

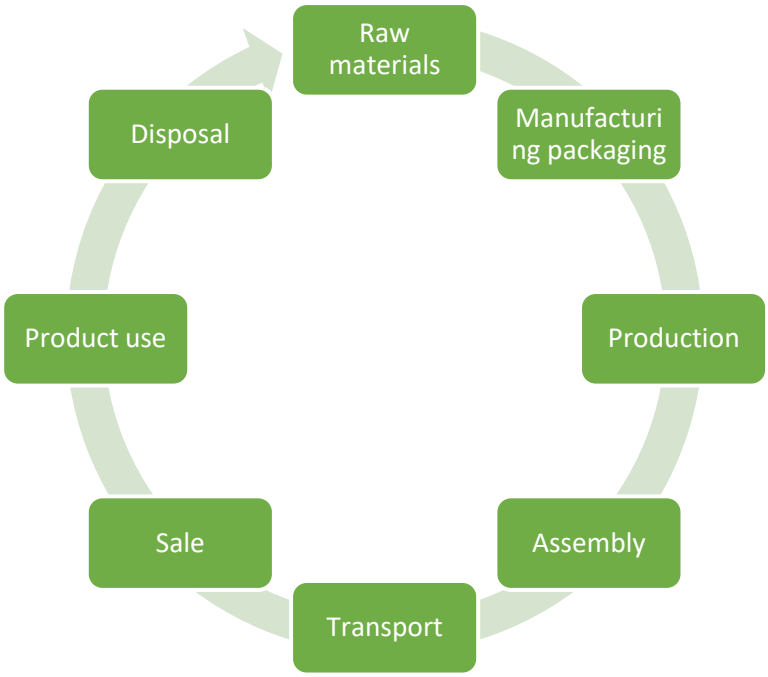
- In addition to engineers and designers, bring in other stakeholders that interact with the PPC during its lifecycle to take part in the development process
- E.g. consumers, suppliers, waste collectors, recyclers

Product-Service System

- Product that depends on a service

Circular Strategies for Packaging

- **Rethink**: reimagining the design or application of the packaging/product in order to maximise positive and minimise negative environmental and societal impacts
- **Reuse**: collecting, cleaning and reusing packaging items for the same purpose
- **Recycle**: converting waste packaging into materials for new packaging items
- **Renew**: using renewable and/or biodegradable materials in packaging
- Execute these strategies within the lifespan of the product



Case Study: **Lush**

- Exploring the different strategies that their company employs to design out packaging waste

1) Packaging buyer, Maria Feast

- Discuss main challenges for designing *naked* products which do not require packaging
- As well as company's vision on sustainable packaging
- Also need to consider how the consumer **brings** the product home, take away from the shop (recycled, reusable bag etc)
- First consider function, what is it made from, where does it come from, what will happen at the end of its life
- Making packaging free cosmetics requires the company to adjust the design and composition of the product
- The regular functions of packaging still need to be considered: safe transportation, supply of product information, storage at home
- The design of sustainable packaging starts by thinking about the sourcing of the materials and taking the end-of-life of the packaging into account

2) Head of Earthcare department, Giles Verdon
- Explain how in-house recycling of plastic packaging
- Lush improved the recyclability of their packaging by using just one material
- Using recycled material requires adjustments in the production process, but it can be reused to make packaging again
- One main challenge in recycling system is getting consumers to cooperate and getting enough packaging returned for recycling
- Consumers may not have the correct knowledge on what plastics are recyclable and what not to put in which can contaminate the main source
- The reason why the company recycles is less to do with financial reasons and more about social responsibility

3) Packaging buyer, Lee Carpenter
- Discussing renewable materials used in Lush packaging (although used, but only in limited quantities)
- The most important considerations when implementing renewable plastics
- Issues around the sourcing and end-of-life bioplastics currently restricts the use of these materials at Lush
- The implementation of resuable packaging in the near future, an important step to design out packaging waste
- Ways to help the problem
  - Offer a choice to consumer where they can choose to take packaging, those with a reusable second-use aspect
  - Offer refills for that packaging, reduce amount of single-use packaging
  - Focus on reusable aspect of packaging
  - If unable to avoid single-use packaging, then offer a recycling route for it

In-depth Discussion 1: The Manufacturer Dilemma
- Milk packaging for life-long milk (cardboard milk carton VS PET milk bottle)
- Both are recyclable materials
- Both must meet strict requirements and standards to ensure food safety
- Both must also preserve the milk's freshness and taste (reduce the amount of milk wasted)
- Both cannot be applied as single material if they were to be designed into proper milk packaging
- Cardboard carton
  - Needs an aluminium layer on the inside (barrier to protect milk from oxygen and UV light)
  - Plastic coating on inside and outside (protect cardboard from moisture)
  - Needs to be boiled to separate the cardboard from the aluminium and plastic layers
  - Cardboard needs to be further processed and recycled
  - Aluminium and plastic layers end up as waste
- PET bottle
  - PET is actually transparent
  - Colour pigments and other additives (protects PET from UV light)
  - An additional plastic layer like a sleeve or a sticker (label)

    - Pigments of PET may disturb the recycling process as there is no separate sorting process for coloured bottles yet, if packaging gets mixed with transparent PET bottles, gets difficult to create transparent bottles again and lowers the value of the recycled materials
    - There is the risk that this makes it difficult to create
- Cardboard vs PET
    - Cardboard made from wood, a renewable resource
    - PET made from oil
    - Cardboard smaller carbon footprint than PET
    - PET requires less land
    - Cardboard and plastic each have sustainability advantages and disadvantages
    - Adds to the complexity of making a choice from a sustainability and circular economy perspective
- Decisions of choice of packaging can also depend on the public perception of the sustainability of certain materials
- Designing a sustainable packaging can lead to complex trade-offs between functionality and environmental impact
- Criteria across which companies can determine the sustainability impact of packaging includes recyclability, carbon emissions, fossil fuel depletion, land use and the potential to manage food waste

Episode 2: Recycling

Explore the process of packaging recycling and zoom in on plastic packaging in particular. Learn about the business opportunities and challenges for packaging recycling and potential future solutions.

- Process that has been used for decades
- Some materials can be easily recycled into the same product (e.g. glass)
- Other materials pose a bigger challenge (e.g. plastics, a commonly used material in packaging because of its many advantages)
- Definition: Process in which products are broken down into fragments to reclaim the materials they consist of; these materials can be reused in other products
- Extra energy is required in both the destruction of the old product and the production of the new product
- It is preferred that a **product's lifetime** is as long as possible before it is recycled, to make optimal use of the value embedded in a product
- Most packaging has a short lifetime and little to no **value** when wasted

Packaging Recycling Process

- **Closed loop recycling:** process of (continually) converting waste materials into new materials of equal or higher quality
    - So they can be reapplied for their original (or a comparable) purpose
- **Downcycling:** recycling a high-quality material into a material of lesser quality
    - Preserves less of the original value
- Generic recycling process
  1) Waste packaging collection
  2) (Manual or automated) separation of different materials and/or sorting by type
  3) Reprocessing waste packaging into new raw materials
  4) Applying recycled materials to manufacture new packaging
- Metal is infinitely recyclable material, as a permanent material, it never loses its properties
- Two important considerations

  1) Optimise the use of materials to facilitate the recycling process
    - *Adhere to the basic 'design rules' to improve recyclability of most types of packaging*
    - Prioritise the functionality of packaging
    - Avoid toxins
    - Use one single material when possible
    - If multiple materials used, make sure they are easily separable
    - Communicate the material composition and end-of-life options (to consumers)

  2) Take a system perspective on recycling

- *Consider some rules in order to strengthen recycling from a product life cycle management perspective*
- Apply recycled materials whenever possible/save resources by making packaging more recyclable
- This will help create further demand for recycled materials, which will, in turn, improve the economic viability of recycling efforts
- Pay attention to the efficiency of forward and reverse logistics

Plastic Recycling by Suez (*video*)

- Overview of a closed loop recycling process for plastic packaging in the Netherlands
- In most Dutch municipalities plastic waste is collected separately
- First, waste is collected at a regional location
  - Big pieces of waste that don't belong are taken out
  - Remaining waste is brought to a hyper modern sorting installation in Rotterdam
- Hyper modern sorting installation sorts plastic packing material, cans and drink cartons to make them suitable for recycling
  - Plastic waste is fully automatically sorted in 5 types of plastics
  - A drum sieve with different sized holes sorts the waste by size
  - Light materials (e.g. foil) are transported to another conveyer-belt
  - Flat and 3-dimensional shapes are separated by shaking
  - Remaining waste is sorted by infrared light
- After sorted plastic is checked, it is stored by type in storage bunkers
- When a bunker is full, it is automatically emptied
  - Plastic is pressed in bales by type and prepared for transport to different processing plants
  - For example, a plastic factory in QCP in Geleen
  - Factor produces resources for new products from plastic waste
  - Sorted plastic is shredded first and then washed intensively
  - In a big machine, the mixed flakes are then processed to uniform gradules
  - Plastics from these resources are just as good as plastics made from oil, and can make new products
- Uniform granules are melted and processed into a tube which are cut to size and get the desired shape in a metal mould (remaining material is cut off and reused)

Recycling Plastic Packaging (*video*)

- Packaging is about 40% of all the plastics that we use in the world
- Packaging is ideal for recycling
  - It has a short lifetime
  - The moment it is produced, it is used and available for recycling
  - Whereas for example, cars – by the time the plastics hidden are available, they're really old
- When plastic is used, it becomes obsolete
- It gets a quality that is very difficult to bring back to the virgin level (i.e. difficult to make that recycle the plastic back into the same product)
- There are many additives in the plastic that make it worse once you recycle them
  - Some additives put into the plastics are meant to avoid the plastic from oxidising during its lifetime (as an antioxidant)
  - There are many different types of antioxidants and some of these types produce discolouration (e.g. the yellow discolouration of some plastics)

Types of Plastic Recycling

- Two general types of process for plastics recycling
- **Mechanical Recycling**
  - Usually consists of a size reduction (i.e. shredding or pulverising) of the plastics waste after which the material is sorted, washed, dried, extruded and often compounded
  - Compounded is the process of mixing or blending in other polymers, additives and fillers in order to create a plastic formulation that meets certain requirements
- **Chemical Recycling**

- Involves chemically return plastic waste to monomers in order to create new polymers
- Properties of these recycled plastics are equal to virgin plastics, but the required energy input is higher than for mechanically recycled plastics
- In most cases, this type of recycling is not (yet) commercially viable

Demand driven innovation

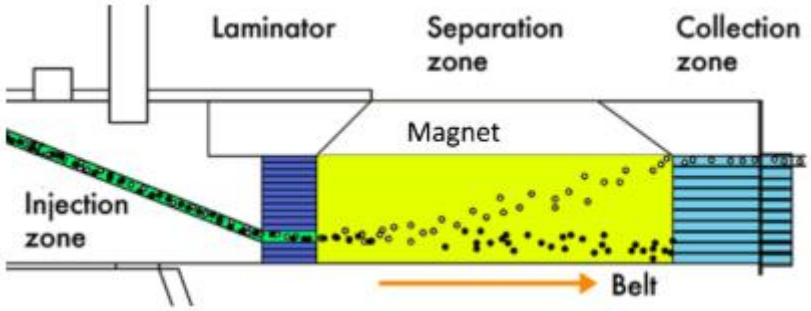
- *Polymer manufacturers* have little interest in making the 'perfect' polymer, because (unlike other material manufacturers) they have not integrated recycling into their own processes
  - Not economical to do so, since it would make it very easy for their competition (i.e. the recyclers) to compete with them on the market
  - Very unattractive to make the perfect polymer which can be recycled endlessly since it would make the manufacturers' production process obsolete
- Brands have started exploring the possibility of recycling their own plastics due to growing consumer demand for sustainable packaging
- This interest has put pressure on polymer manufacturers to produce plastics that are easily recyclable
- Plastics are manufactured in hundreds of different colour, which can complicate recycling process
- New sorting technologies may provide a solution to this problem
  - For example, thousands of microscopic robots sorting all the plastic flakes into different categories and colours
- If a recycled material is pure enough, it requires little or no extra processing to use it in new products
  - No intermediate chemistry needed or processes

Sorting Plastic Waste in Detail

- Technologies used to separate plastic scrap from a mixed waste stream, and then sort the result by plastic type
- **Sink-Float Density Separation**
  - Mixed plastic waste introduced to a flotation bath
  - Plastics separated based on their density relative to that of the fluid they are in
  - Some plastics will sink in the liquid, others will float
- **X-Ray Technology**
  - X-rays are used to distinguish between different types of polymers according to their density
- **Near Infrared Spectroscopy**
  - When plastics illuminated, they mostly reflect lights in the near infrared (NIR) wavelength spectrum
  - A NIR sensor can distinguish materials based on how they reflect light
  - Air jet used to blow materials into separate streams
  - NIR Spectroscopy less suitable for dark coloured plastics since they absorb nearly all light

Future Recycling Technology (*video*)

- Peter Rem
- New technologies can greatly improve the quality and effectiveness of plastics recycling processes
- New technology and approach to traditional float sink density separation by creating a density gradient within the liquid, different types of polymers will float at a different height within that liquid such that they can be sorted in a single process
- This new technology uses a nano liquid – a magnet is used to manipulate a flotation bath filled with a ferromagnetic fluid in order to create a density ""gradient" within it; such that plastic particles with different densities can be collected from the bath at multiple levels
- Traditional float sink density separation techniques involve using different number of flotation baths; each bath has a liquid with different densities and can separate mixes of particles in either floating or sinking based on the respective density
- Another new technology applies to micro robots to manipulate plastic flakes in space, arranging these robots in a row to filter out specific flakes for sorting
- Important limitation is the equipment required for these new technologies (still being developed)



The Limitations of Technology (*video*)

- Technological innovation alone cannot solve all the problems associated with plastic packaging
- Plastic foils are still a big problem, they have a sort lifespan and relatively little value (e.g. plastic bags)
- Policy makers have a big role to play in resolving these issues (i.e. politics)
- In the future, we'll have to use paper and cardboard as alternatives for plastic foil, which are materials from renewable resources

Case Study: **Coca-Cola** (*video*)

- Robert Seegers, Vice-President Public Affairs & Communications of Coca-Cola European Partners
- Coca-Cola, world's largest soft drink producer
- The company distributes its drinks in different forms of packaging: glass bottles, aluminium cans and plastic bottles
- Explains why they invest in recycling, how they build towards 100% recycling, and the challenges in that process (considerations involved in the implementation of a recycling strategy)
- Their strategy consists of reducing the number of materials used in their packaging, collect and recycle as much of their material as possible, and using recycled material in their bottles
- To obtain high quality recycled material that can be used in packaging, the company has to be involved with the collection and processing of the packaging waste (play an active role in recycling, inspire consumers to do the right thing)
- With adjustments made to the production process, there can be a gradual transition to the use of recycled material in the packaging
- Investments in this transition need to be made to sustain a positive and responsible brand image
- Recycled PET (rPET) is much more expensive than oil-based virgin plastic still, at the stage of packaging

The Design of a Recyclable Cola Bottle (*video*)

- Knowledge of the sorting process is used in the design of the bottle
- The glue is soluble in water, the material for the cap (PE) and label (PP) have lower densities than water and will float, while material of bottle (PET) has a higher density and will sink (densities: glue < PE, PP < water < PET)
- Coca-cola is gradually increasing the amounts of recycled material in their bottles, as they don't want to make concessions on the quality of their packaging
- Proper collection of packaging waste is regarded as a main challenge in closing the circular loop
- After designing for recyclability, the next challenge is to **design for 100% "sortability"**, make sure that it is identified as a bottle that can be recycled
- **Make sure that recyclable packaging is being distinguished from the non-recyclable**
- In Coca-Cola bottles, the sleeve is designed such that machineries can still detect that it is a PET bottle and pick them out in order to make them ready for recycling
- Three types of plastics used: one for the bottle, label and cap and the company is comfortable with using three different materials as they are easy to sort (through their densities) for recyclers
- Glue that is on the bottle is also made sure not to interfere with the recycling process
- In Netherlands, 40% of plastic used has a source from rPET feedstock
- Cannot do concessions on quality, since primary purpose of packaging is for protection, and for the consumers

- In the end, it's always the consumer who decides whether he closes the loop or not, and makes the choice (no matter what kind of deposit system or collection system used)
- Overall strategy: sustaining a positive brand image and securing high quality raw material for packaging production
- Coca-Cola's vision on packaging with three elements:
    - Avoiding the use of (raw) materials as much as possible
    - Collect and recycle as much as possible
    - Play an active role in recycling by obtaining more recycled content and inspire consumers to do the right thing

In-depth Discussion 2: Recycling Confusion

- Even when packaging is designed to be fully recyclable, the involvement of consumers is crucial to realise a successful recycling process
- This section explores the consumer perspective on plastic recycling
- Missing or confusing information on packaging regarding recycling could lead to undesired disposal behaviour
- To realise recycling of packaging in practice, the perspective of consumers needs to be considered at the design stage

Episode 3: Renewables

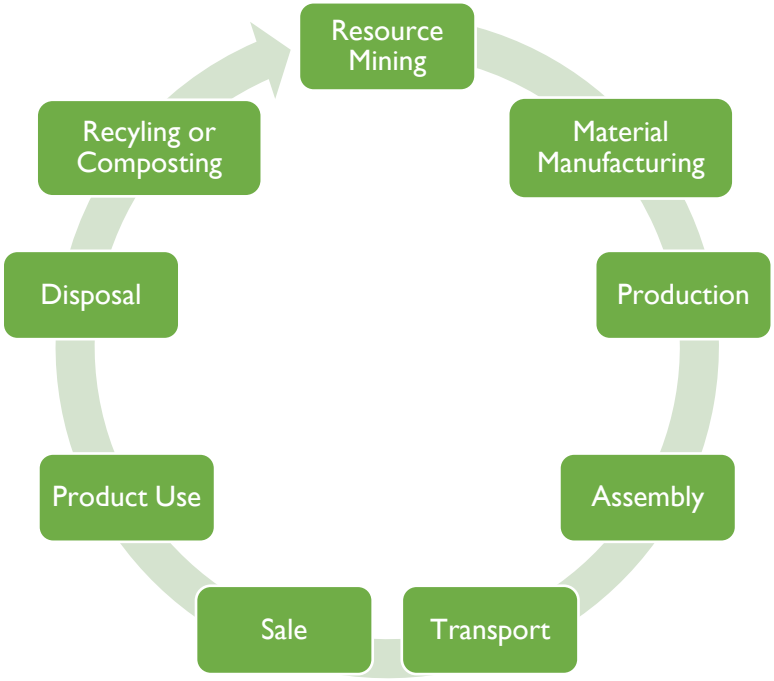
What are the benefits and challenges of renewable materials for packaging? Learn about the most important consideration involved in choosing renewable materials.

Introduction and Feedback

- Ultimately depends on the effort of the consumers as to how well a material will be separated before collection
- This episode will look in to renewable and biodegradable packaging
- Awareness about separation and collection are recurring themes

Renew as a Circular Strategy

- Renewables are materials used in packaging sourced from renewable sources, as opposed to materials sourced from fossil origins
- For example, most food packaging is produced from plastics made from fossil oil
- Examples of renewable packaging materials are cardboard and cotton, from which the plant-based raw materials can be regrown
- Plastics made from renewable material (e.g. cornstarch, seaweed) have been getting more attention lately



- Use of renewable materials can be regarded as a circular strategy since biological nutrients/materials can be cycled through continuous loops in the biosphere

Summary of a few Key Definitions

- **Biobased**
  - A product or material completely or partially derived from biomass
  - Includes harvested plant-based materials
  - Examples are wood, animal-based materials such as wool, processed biomass such as paper, man-made materials derived from natural sources such as the plastic PLA which is made from sugars
- **Renewable**
  - Resource that can be naturally regenerated on a human timescale
  - Rate of regeneration has to keep up with harvesting and consumption
  - Biobased does not necessarily mean renewable (for example, regeneration of tropical hardwood does not naturally keep up with logging activities)

Renewable materials for packaging (*video*)

- Christiaan Bolck, programme manager biobased materials at Wageningen University and Research
- Three categories of biobased plastics:
  1) Made directly from polymers from biomass (e.g. starch)
  2) Made from polymerised monomers (converted into building blocks of polymers) extracted from biomass
  3) Made by micro-organisms from biomass (e.g. bacteria)
- Main benefit of biobased materials is that they don't require non-renewable resources (e.g. oil) for their production
- Like fossil-based resources, biobased materials have their own challenges such as the risk of deforestation, and safeguarding the labour conditions throughout their production chain (other considerations)
- Biomass is a viable alternative for fossil-based resources for the plastics industry
- Main benefit of bio-based material is that fossil resources aren't used (related to climate change)
- Acceptable to make packaging biodegradable when it is certain that it will be industrially composted at its end-of-life and when there is no controlled waste management and/or it is likely to end up in soil or water

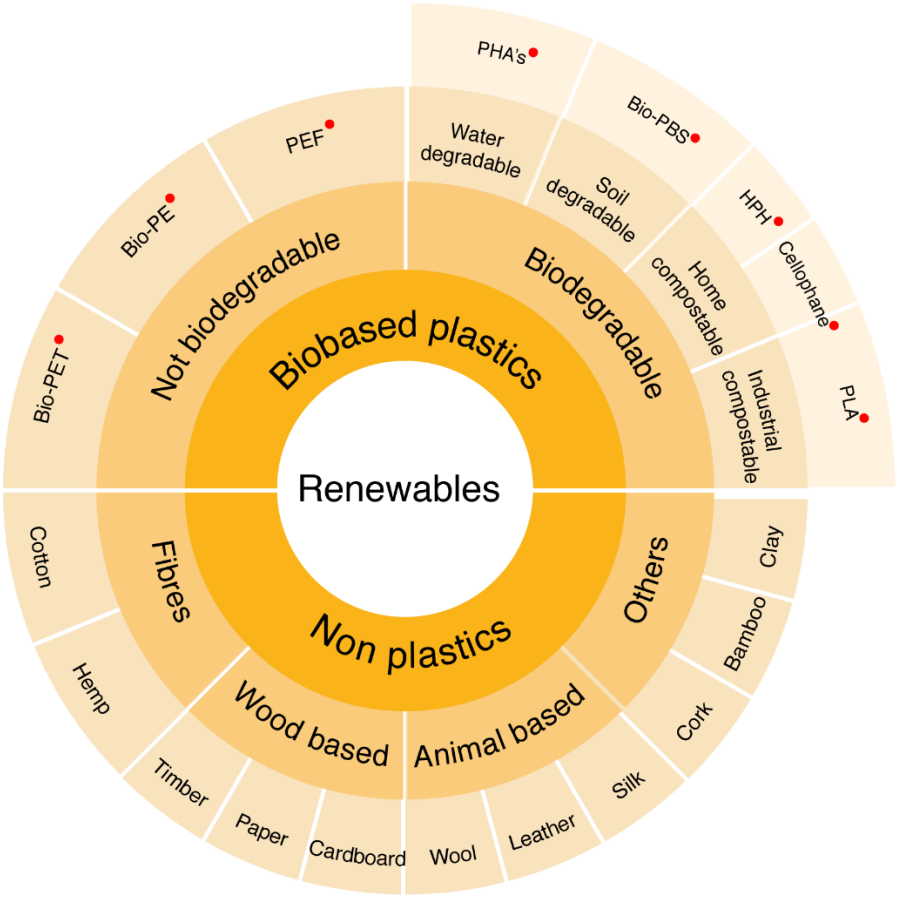
Biodegradable Materials (*video*)

- Can distinguish renewable raw materials based on the disintegration of the materials at the end of life
- At the end-of-life, some materials can biodegrade which happens under specific circumstances (3 factors - presence of certain micro-organisms, a certain temperature or humidity)

- Conditions differ from home composting to industrial composting
- Some materials may biodegrade in all types of environments while others require very specific industrial (composting) processed
- Currently, research is focused on making biodegradable materials more cost effective (against fossil resources)
- A key challenge in designing such products is making sure that it does not biodegrade *during* its functional life (e.g. through contact with the product/environment)
- Downside of such materials is their vulnerability to micro-organisms which degrade their quality when attacked by them
- Need to know the product and the environment product is being packed in
- Biodegradability always has to make sense as a product's end-of-life strategy
- If impossible to retrieve waste packaging for recycling or reused (uncontrolled waste management), might be better to make it biodegradable

A Few More Definitions

- **Biodegradability**
  - A material regarded as so when it can be broken down by living organisms into biomass, water and natural occurring gases (e.g. methane, carbon dioxide)
- **Compostable (at home/industrial)**
  - Is biodegradation in composting conditions
  - Means that the material is broken down by micro-organisms in certain conditions (e.g. temperature, humidity, presence of oxygen) in a certain time without negatively influencing the quality of the compost
  - Can be either done in a conventional compost heap, making it home compostable or only specifically in an industrial composting facility with higher temperatures, more humidity, more oxygen
  - Diagram below shows a selection of renewable materials used for packaging:



- There is a wide range of materials classified as renewable. However, this also requires resources to be replenished at the same rate as their production - to avoid exhausting renewable resources

Renewable Materials	
Bio-PET	
Bio-PE	
PEF	From sugar cane, sugar beet, wheat grain, algae
PHA's	From bacterial fermentation
Bio-PBS	From bacterial fermentation
PHB	From bacterial fermentation
Cellophane	From wood, cotton or hemp
PLA	From sugar cane or corn starch

- Not all biobased plastics are biodegradable
- Biodegradability varies widely, depends on the nature of the plastic and may ask for specific composting conditions

The Future of Renewable Packaging (*video*)

- Besides plastics, there are other innovative biobased packaging materials (e.g. replace conventional plastics with fibre-based materials)
- For example, tomato leaves
- Main challenge for developing these materials is recreating the properties of plastics
- Fibre-based materials have some notable downsides compared to conventional plastics
  - Less resistant to humidity
  - Weigh more
  - Provide a less effective gas barrier
  - Making an effective combination of materials (in relation to recycling)
  - Pricing (in relation to consumer uptake)
- One main barrier to widespread adoption of renewable and biobased materials is the resistance to change from industry stakeholders who wish to maintain status quo

Case Study: Bio4Pack (*video*)

- Patrick Gerritsen, CEO of Bio4Pack
- Company's products are fully compostable, hence a higher reduction of CO^2
- However they are not home compostable; a compost heap (maximum 45 degrees in the center) does not reach the required temperature (68 degrees) to break down PLA into CO^2 and water - requires industrial composting
- Different types of packaging requires different materials such as cellulose or dextrose made from corn or sugarcane
- Choice of material largely depends on the properties (e.g. flexibility, rigidity) required by the packaging application
- For a stable material like PLA tray or a material to make a transparent film/tray, use dextrose made from corn
- Starch can be used for more flexible packaging
- Cellulose can be used for laminates; which are different kinds of material stuck to each other with a compostable glue
- For example, a circular packaging solution involves recovering agricultural waste from rice paddies (which would otherwise be burned) and turning it into trays for fresh produce

Challenges with Renewables (*video*)

- Some challenges that Bio4Pack has to deal with in order to realise their ambitions
- Bio4Pack is able to provide renewable and compostable alternatives for about 80% of all packaging types
- Challenges, limitations and disadvantages
  - Depend largely on the barrier properties that the packaging requires
  - Specifically, vacuum bags and cling/stretch film

    - Limited maximum shelf life of certain biobased packaging items (which after a certain time will start to degrade)
    - Price compared to conventional alternatives (double, tripled the cost)
    - Legislation (For example, in Netherlands, compostable packaging may generally not be disposed of in bio-bins because of composters are not able to tell the difference between packaging types and wish to avoid contaminating waste stream with non-compostable plastics)
- Biobased does not necessarily mean compostable
- Bioplastics (e.g. PLA) can be recycled like conventional plastics but are not done so since they are currently used in relatively small volumes, making it economically non-viable to recycle (to set up a separate waste stream)
- But they are very easy to separate from conventional plastics in a recycling process (e.g. differentiate PET and PLA tray with infrared)

The Growth of Renewables in the Packaging Industry (*video*)

- Discussing the role of Bio4Pack in the transition towards the use of renewable materials and his vision for the future of the packaging industry
- Some disadvantages of renewable and biodegradable plastics are the result of novelty
- For instance, the price of packaging will go down with an increasing market share (i.e. economies of scale)
- Packaging is price-driven and often seen as "extra cost"
- There is no single answer for all packaging needs (in Bio4Pack) since each product requires different material properties that need to be assessed to find the right match
- There is a customer demand for sustainable packaging and will eventually lead to a growth in the market share for renewable and compostable packaging
- Bio4Pack sees themselves as a partner to develop together with retailers their packaging

Report by Wageningen University

- Production of bio-based plastics leads to lower non-renewable energy use and GHG emissions
- However, the use of land for production of feedstock for bioplastics may directly or indirectly lead to land-use change which may negatively influence GHG emission reduction (however, the size of this reduction is under debate)
- Although biodegradable, these plastics should not be considered as a solution to the problem of litter
- The issue needs to be addressed by educative and informative measures to raise awareness for proper and controlled ways of management, disposal and organic recycling

In-depth Discussion 3: Bioplastics and Sustainability

- Not all bio-based plastics are biodegradable
- Discussing the use of bio-PET in packaging
- In 2009, Coca-Cola introduced their Plant Bottle, a fully recyclable bottle that is partially made of bio-based resources (i.e. bio-PET)
- PET is made of ethanol + terephthalic acid
- Bio-Pet
- Made from bio-ethanol (from plants) + terephthalic acid (made from oil)
    - Consists for 30%% of bioplastic
    - Looks, functions, recycles like traditional PET plastic (not biodegradable)
    - Leaves a smaller carbon footprint on planet

The Concept of Repack (*video*)

- Repack is a Finnish packaging service - not just packaging producer, also provides reusable packaging for e-commerce
- Jan Berbee, Dutch packaging entrepreneur and partner of Repack
- When and how to apply reusable packaging
- Discussing the implementation of reusable packaging for shipments from their web shop
- Reusable packaging reduces plastic waste and CO^2 emissions when applied right

- 20 turns with a RePack saves 80% of CO^2 in comparison to recyclable packaging (since recycling takes energy)
- Compared to the traditional cardboard and poly bags
- RePack is also made of recycled materials (no virgin materials)
- A service model was adopted to create incentives for end users to send back the packaging and offer additional benefits to the e-commerce companies that use the packaging
- Product can also be used for product returns
- Currently, RePack is only used to pack soft and unbreakable items because of their material and shape
- Fashion stores were targeted as first users because of their big market share in the e-commerce market
- The order should be Reduce, Reuse and Recycle; aim to reduce consumption first
- Motivation to use RePack
    - Environmental reasons
    - Allows business to give end users a broader choice
    - Offer RePack at a price such that web store does not need to bear the cost of packaging
    - Use with a voucher system that draws in business in the long term
    - Offer a free RePack with a minimum purchase amount, translating into higher sales

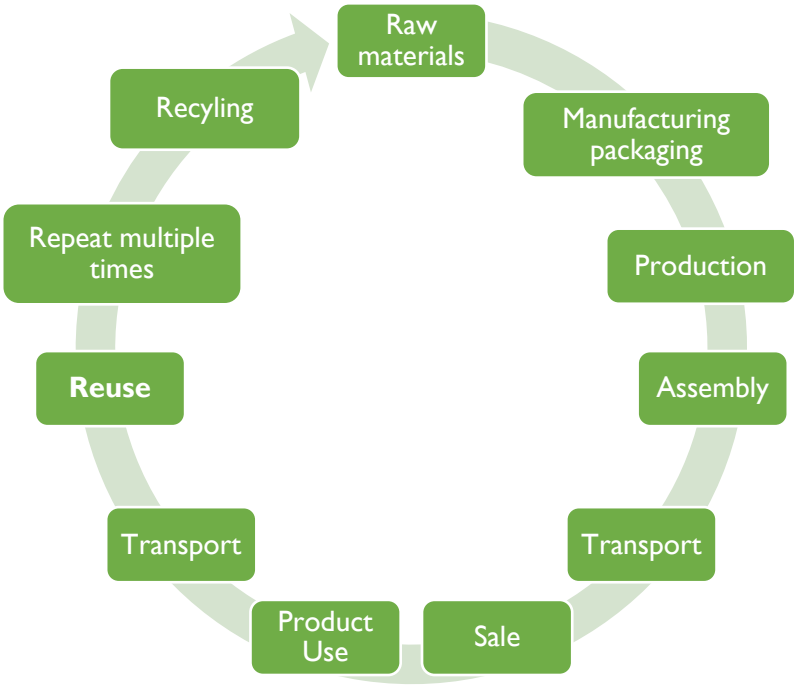
Episode 4: Reuse

Get acquainted with circular business models, the opportunities for reusable packaging and how to assess its benefits and drawbacks.

Reuse as a Circular Strategy

- Performing a life cycle analysis can help in making informed design choices
- Circular business model archetypes can be applied to fast moving consumer good such as packaging
- Bas Flipsen, senior lecturer at TU Delft faculty of Industrial Design Engineering
- Within context of a circular economy, reusing a packaging item means to use it again for the same purpose, in its original form and without significantly altering or enhancing it
- For example, beer bottles (manufacturer uses bottles for a certain amount of cycles)
- Repurposing a packaging item at home (e.g. to store other products or food) is not considered reuse
- Reusing a packaging item (rather than recycling it) preserves more of its embedded value in terms of energy, materials, labour and capital
- "Power of the inner circle" - referring to the activities at the centre of the butterfly diagram such as repair and reuse
- In the circular economy perspective, often preferred to keep products and their materials in use for a longer time before recycling them
- It can be a good strategy for prolonging a packaging's lifetime and can be applied to a product's primary, secondary or tertiary packaging
    - Example
    - Primary: PET soda bottle
    - Secondary: Boxes used to ship bottles to supermarkets
    - Tertiary: Protective materials and wooden pallets on which boxes are shipped
- Need the different levels of packaging and their appropriate circular strategies to work together
- When doing impact analysis
    - Think in systems
    1) Not only impact of materials and production
    2) Take into account the transport of materials and goods (across the globe, last mile to consumer's home)
    3) Resource consumption during use (e.g. energy, feedstocks such as water and lubricant)
    4) Chosen end of life strategies (e.g. recycling, waste incineration, landfilling)
- Reuse strategy can be applied in 2 ways
    1) Consumers own the packaging and refill it with the desired product
        - They buy packaging once and maintain and clean it themselves
        - They buy new refills of product while reusing the same packaging

    - For example, refilling a jerrycan with gasoline for the lawnmower
2) Producer owns and fills the packaging, consumer uses the product and returns the packaging
    - Producer has to collect the packaging, clean and maintain it
    - They can sell a new product in a refilled packaging
    - For example, beer bottles
- Both strategies can be applied in a business-to-consumer transaction and also in a business-to-business market



- Usually need investments to make packaging reusable, added costs in making the packaging more sturdy and reusable
- More costs are added when packaging is returned to producer
    - Product needs to be durable, easily cleaned
    - Efficient take-back logistics
    - Costs in reconditioning (cleaning, maintenance) of packaging
    - Costs and emissions that come with production, return logistics and reconditioning of packaging are reduced when spread out over multiple use cycles of the same packaging
- More durable reusable packaging will improve product protection and reduce product damages

Packaging Systems

- Defined as the combination of primary, second, tertiary or even quaternary packaging
- All levels of packaging need to be considered in order to create circular packaging systems

Comparing Different Options (*video*)

- Determining which circular strategy to choose and understanding when reusing packaging makes environmental sense
- In a Life Cycle Assessment (LCA), the environmental impact of all stages in a product's life cycle (source, production, transport, use, disposal) is calculated
- Both resource inputs and waste output have an effect on nature, human beings and the limited material resources on the planet
- Effects are expressed in metrics commonly known as the CO^2 footprint or Global Warming Potential, expressed in kilogram CO^2 or effects like water usage, Cumulative Energy Demand and also aggregated impact indicators (e.g. eco-indicator, ReCiPe)
- Life Cycle Assessment

1) To compare two or more products (or packaging items) that fulfil the same function in a different way, first define a **Functional Unit**
    - This is the goal that must be reached with the use of packaging alternatives
    - The basis of comparison for comparing different functional solutions
    - Use a fair functional unit, such that can compare apples with oranges
2) Create a **Use Scenario** for each alternative that leads to the achievement of this goal
    - This helps to find all the aspects that contribute to the total impact of the packaging on the environment over its life cycle
    - Define all processes needed to reach the same goal
3) **Systems Boundaries** are defined to limit the scope of the analysis
    - Have to consider to what extent something will impact the outcome of the analysis
    - Consider how much effort it will take to incorporate it in the calculations
    - Define use-scenarios which fit the functional unit for each solution
    - Limit system by, for example, not taking into account impact of water used
    - Things to determine can include the amount of materials used, calculating its impact for material and production, in-between transportation, energy and feedstock used (e.g. detergents) can be measured or estimated
- Compare two functional solutions and their environmental impact after aggregating all data for the complete life-cycle scenarios of each product/packaging (or different cycling strategies)
- Have to include the complete system, not just the product production phase

Circular Business Models for Packaging

- Slowing, closing and narrowing resource loops (i.e. recycling, renew, reuse)
- Each loop is made possible by different circular design and business strategies
- Slow down loops like making packaging last longer and having business models that enable transition to a circular economy
- Two fundamental and one distinct approach to the cycling of resources:
    1) **Slowing** down resource loops - extend a product's useful life in order to slow down overall flow of resources
    2) **Closing** resource loops - creating a circular flow through the recycling of resources
    3) **Narrowing** resource flows - using fewer resources per product
        - Efficient use of resources (**reduce**) is already applied in linear business models
        - By itself, it does not affect the speed at which products are cycled in the economy or whether their resources are retrieved through recycling
- Bakker's 5 circular business model archetypes that support the cycling strategies

1) **Classic Long Life Model**
    - Traditional business model
    - Focused on providing products with a long lifetime (known to last long, sold like a normal product)
    - For example, a plastic reusable crate for distribution instead of a cardboard box
2) **Hybrid Model**
    - This model relies on a long lasting product with consumables (often disposables) to fulfil a certain function
    - Recurring sales of consumables forms the main source of revenue
    - This is usually a reusable packaging that requires refills of a specific product from the same producers, with regard to packaging
    - For example, an ink cartridge for a printer that can be refilled with ink
3) **Gap Exploiter Model**
    - A business model that exploits the residual value of the otherwise wasted resources from one production chain to another
    - The original producer does not make use of the resource or business opportunity
    - For example, using agricultural waste to make packaging (e.g. packaging made from tomato leaves - Christiaan Bolck)
4) **Access Model**
    - Manufacturer retains ownership of a product

- Consumers pay a fee in order to access it
- For example, a consumer product like a car rental system (pay to use the car for a certain amount of time)
- In terms of packaging, this is usually a secondary or tertiary packaging in the business-to-business market
- For example, a pooling system with shipping containers or reusable pallets

5) **Performance Model**
   - This model is focused on performing a certain function for consumers rather than the actual product
   - Companies promise to fulfil a certain service, without specifying how they do it
   - For example, phone subscription (pay service provider to have reliable connection, don't need to know what kind of transition tower they use)
   - For example, in relation to packaging, a shipping company paid to safely transport goods from Russia to India within a certain time, without specifying the packaging used in the process

Case Study: Repack (*video*)
- Jan Berbee discussing the design of the current RePack packaging and future plans
- When designing reusable packaging, need to consider firstly, the material - has to be strong enough to endure repeated use cycles and still be recyclable at the end of life
- Also need to consider ease of use for both web store and end user and protective use (e.g. RePack: able to be folded small and processing is quick and easy)
- Packaging items can be made more expensive and have additional features due to high number of use cycles
- New changes can be attaching chips or small electronics like RFID tags embedded into packaging
  - Create virtual reality or augmented reality where people can scan the package upon receiving their order and have information directed to the web store or advice on how to use the product
  - Data about the freshness of food, information on sourcing, sustainability information, dynamic pricing etc
- New targets for RePack are e-commerce markets of food, electronics and jewellery
- RePack package made of recycled polypropylene

Considerations in the Use of Reusable Packaging (*video*)
- Aad Putters, manager of logistics at Bever (outdoor store in Netherlands)
- Explaining the implementation of this novel way of packaging and deliberations in the implementations of sustainable packaging in general and reusable packaging in particular
- Sustainable packaging has 3 benefits for Bever
  1) Meet customer demands
  2) Decrease environmental impact (e.g. waste, carbon footprint)
  3) Reduce shipping costs
- Implementation of RePack packaging comes with several challenges
  - Guarantee of product protection
  - Fit of products in the packaging (not all products fit in the size of the package)
  - Changes that need to be made in the logistics and webstore (e.g. customers need to have an option to choose RePack or not)
- Challenges that come with sustainable packaging in the future
  - Cost-efficient recycling processes
  - Cost-efficient production of environmentally friendly materials (i.e. cheaper)
  - Return logistics of reusable packaging

In-depth Discussion 4: Single-use Packaging
- Explore recent legislation that was designed to prevent single-use packaging (SUP) from ending up as ocean plastic
- Packaging makes up of around 60% of post-consumer plastic waste in the EU
- In May 2019, the European Commission approved the single-use plastics directive, which aims to reduce the impact of plastic products on the environment (in particular, plastic packaging)

Single-use Packaging: Legislation and Alternatives (*video*)

- Ruud Balkenende, professor of circular product design, explains the single-use packaging legislation, and some of its unintended side effects
- Ban single-use plastics by 2025
- Reactions from supermarkets
    - In UK, selling 'bags for life' - thicker bags which consumers still use a lot of (making the problem of ocean plastic worse)
    - Dutch supermarket PLUS circumvent legislation by marketing plastic cutlery as an environmentally friendly "washable" and reusable product

Episode 5: Rethinking

How can taking a systems perspective help to completely rethink a packaging solution on a functional level? This episode combines previously taught sustainable strategies and explores new theories on consumer behaviour and innovation acceptance.

- Looking critically at the functionality of your product and its packaging, as well as the needs of users can help to rethink the current packaging system and develop new circular solutions
- Rethinking is not a cycling strategy
- It is a way to look at your product and envision a sustainable alternative for its packaging that takes its entire lifecycle into account
- Can be used as a method to improve the current design, to choose one of the cycling strategies or to completely redesign an existing packaging solution, product and even business model

Twenty: Cleaning Agents Without Water (*video*)

- Designer, Mirjam de Brujin
- Rethinking a whole product-packaging combination
- Twenty: a brand forecast setting an example for the industry
- Change the products (i.e. eliminate water from detergents, shampoo, dish soap) and change their packaging as well as they way they are transported
- About 80% of water in these products which is transported and packaged - doing with less of this can save energy and waste
- In the development of Twenty, rethinking of the product went hand in hand with rethinking the packaging, to create a sustainable product
- Start by asking questions about the current way detergents are produced, packaged and sold
- Inspiration can come from many places, but it can be as simple as applying the principles of one product sector to another
    - For example, inspiration came from food (e.g. cup-a-soup, concentrated lemonade etc)

Rethinking Shampoo and Household Detergents (*video*)

- Need to convince others to be able to continue project
- Describing steps taken to develop project and its exact focus
    - Research on consumer behaviour
    - Literature research
- Main focus was not to change the way people wash their hair, but to find a new way to *deliver* the shampoo
- The challenge was to use design as a means to convince people to try something new, taking an extra step
- Focus was on normal consumers, not people who are already for the cause
- Prove that there is demand and support for your idea (e.g. doing user study)
- Task of designer to change a product into something a consumer wants instead of something that he/she doesn't want (even though its better)

Challenges of Innovation (*video*)

- Developing an idea into a marketable product takes time and effort
- This cannot be done alone - find people to collaborate with, to do aspects you cannot do or don't like to do yourself

- Arrange financial support - either within a company, by getting investors on board or by winning prizes
- Keep your vision in mind and constantly check whether you're still on track
- If product turns out to be unsustainable, be honest with it
- Having public support is important, shows to the industry that there is demand for this

Functions and Needs

- Can deconstruct a packaging item into **a set of functions** that it performs in order to fulfil a number of corresponding **user needs**
- Key to rethinking any packaging system is to think critically about users' needs
- In the example of Twenty, rather than just redesigning the bottle, Mirjam redesigned the way people use shampoo, taking into account every phase in the life cycle (transport, use, disposal etc) of the packaging and the product

Defining User Needs

- Simple method to identify user needs
- *How/Why Laddering* method
  1. Establish a need that the product-packaging fulfils
  2. "Move up the ladder" and ask *why?*
  3. "Move down the ladder" and ask *how?*
  4. Moving further up, the more abstract needs become
  5. Moving further down, needs become more specific

Asking the Right Questions

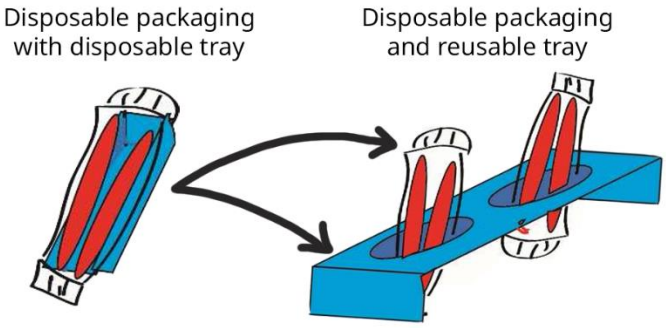
- Determine which level of user to address, before rethinking product-packaging combination
- Largely depends on context, for example, might be difficult for the manufacturer of laundry detergent to devise a completely new way to make customers feel confident about their appearance (higher level of *why* in the ladder)
- Your solution may be limited by your company's/client's scope and ability to influence the wider system
- For new solution to work, many aspects of original design may need to change
  - Product/service itself
  - Business model
  - How product-packaging combination is used, distributed and/or disposed of
- Establishing the right scope can be helpful to reframe the design challenge as a 'How to' question
- For example, *How can we enable users to keep their clothes clean and fresh?*

Rethinking New Design Solutions

- In design process
  1. Formulating scope or design challenge
  2. Search for solutions through research and design
- Complex trade-offs are often inevitable
- Rather than improving existing solutions, a rethinking strategy triggers the development of new solutions

Case example: On-the-go food packaging

- Charlotte de Wit (Msc Integrated Product Design, TU Delft)
- Explored solution spaces to reduce the negative environmental impact of on-the-go food packaging by systematically abstracting, reformulating and extending already known solutions
- Packaging of wraps has a storage and a presentation function (packaging of each wrap combines plastic and cardboard)
- Rather than just improving on current packaging, new solution separates the presentation and storage
- A durable cardboard standard is used to present the product, while the wrap is held in a disposable protective plastic packaging
- The images used are adapted from images by Charlotte de Wit in her thesis titled Reducing the environmental impact of on-the-go food packaging (2019)



Innovation Acceptance

- When designing new products, important to consider
  - Technical feasibility
  - Consumer acceptance of products
- Need to people to buy product, especially when
  - Product-packaging combination (PPC) is radically changed
  - Investments are made
- Implementing circular PPCs involves change in the whole system and also requires a change in consumer behaviour

Acceptance of Radical Innovation (*video*)

- Lise Magnier, Assistant Professor of Consumer Research at the faculty of Industrial Design Engineering of TU Delft
- Explaining how to take consumers into account (consumer acceptance)
- When changing the visual appearance of a PPC, the categorisation it fits should still remain the same (packaging helps consumers to categorise products, create perceptions on the quality of the product)
- An atypical packaging for a product can lead to negative perceptions among consumers
- When rethinking a PPC, should maintain its usual functions
- By monitoring what assumptions people make, insights can be made into what works or not
- Much easier for new packaging to get accepted if physical appearance does not change much
- Challenges include communicating the reasons for the changes
- Keep in the mind the usual functions of packaging - either constant or improved

Rethinking as part of the innovation process (*video*)

- Rethink the current situation
- Explaining how to deal with innovation in a system containing multiple stakeholders
- Elaborating on the reasons why companies start or haven't started rethinking their packaging to fit a circular economy
- All stakeholders should be involved and take ownership of the project to successfully implement a sustainable innovation
- Important to have convenience and unity, to get consumers (i.e. stakeholders) to engage

- Companies are urged to change by legislation and increasing consumer awareness (need to realise what are the consequences of not starting to rethink their PPC)
- Question whether current brand image is a reason not to rethink a product
- Food packaging - environmental burden of both packaging and food waste (conservation, protection of products)

The Consumer and Innovation in a Circular Economy (*video*)

- Sustainable solutions are adopted or rejected by consumers for various reasons
- Creation of social norms works well
  - People relate to it
  - Example, smoking and tobacco
- Once accepted by the consumer, one innovation can still have an undesired outcome
- Discussing more about the aspects that should be taken into account to improve the chances of a successful implementation
- People need to be convinced to do something for the right reason, not because they are afraid of punishment
- Rebound effect
  - A negative action after a positive one has been made ("one step forward, two steps back")
  - Happens when a sustainable innovation has negative results because of inappropriate use - hence, considering the use phase of a product is of great importance
  - For example, more concentrated product causing consumers to use more of it than necessary
- When consumer is left to choose, clarify options so that he/she is able to consider the sustainability of alternative options
  - Make their choices easier, enable them to compare options
  - Can have strong influence on purchase decisions
- Making recycling facilities and other facilities easy and convenient to use
- To engage most people in a circular economy, costs have to be acceptable
  - Or else, will reach a small segment of consumers
  - For a circular economy to really work, need to involve as many people as possible - find a price that is acceptable to most people

In-depth Discussion 5: Redesigning Product-Packaging Combinations

- Looking at complexities in redesigning alternatives
- Example: Possible side effect of using concentrated products, overuse by consumers
- Example: chip bags
  - Composed of up to seven layers plastic
  - Light and strong
  - Layers of polymer materials keep contaminants and moisture outside and prevents the leaching of components of materials
  - Thin layer of aluminium foil on the inside serves as an oxygen barrier
  - Bag is filled with nitrogen to create an air cushion so the chips won't get damaged and have a negative influence on the taste of the chips

Episode 6: Recap

What are the main challenges in the transition to a circular economy for packaging? Hear about the predictions and contemplations about the packaging industry from experts featured in this course. You will apply the knowledge acquired over the past 5 episodes in a final assignment and quiz.

Didns't cover this episode.