Context, Rules, and More Information

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Overview

6Cycle is a game which was designed to demonstrate the use of material passports as a data traceability mechanism in circular supply chains, to derive value from product composition data and achieve the complementary objectives both of improving resource recovery and of optimizing material use.

The game is set up for 4 players, each representing a stakeholder in a circular economy: two Manufacturers, one Recycler and one Consumer. The economy consists of two products, assumed to be substitutable. Each product is made by one Manufacturer and consists of two materials of specified quality and proportions. Each Manufacturer is tasked with making one product, using materials from the primary materials pile and/or recycled materials supplied by the Recycler; the Consumer buys equal quantity of products from both manufacturers but may choose to give additional 'market share points' to one Manufacturer based on perceived 'green-ness' of a product; the Recycler accesses end–of-life products from a waste depot and chooses to supply recycled materials of specific quality and quantity to manufacturers. Each player plays to maximize their points while ensuring primary materials pools are not exhausted.

Context

Current material flows along supply chains are leaky material and data pipelines. Conserving this data (through material passports or other traceability mechanisms) can help conserve materials and transition to a circular supply chain in a way that creates value both downstream and upstream in supply chains. This value creation can occur in two ways.

- At the recycler/downstream end: data on material composition and properties can enable investing in targeted material recovery as well as novel material design technologies;
- At the manufacturer/upstream end: traceable and trackable data on material composition and properties can enable effective communication of sustainable strategies employed

as well as provide an expanded supply of recycled materials that meet performance needs.

Examples of current implementation of digitized product information include: the HolyGrail project where digital watermarking technologies in packaging are being employed for accurate sorting of end-of-life products; Buildings as Material Banks (BAMB) initiative on creating circular solutions in the buildings sector including developing, integrating and demonstrating the use of materials passports in 6 pilot projects; more recently, the Global Battery Alliance's Battery Passport launched in 2023 to increase transparency in battery value chains by establishing digital twins of products. Key questions raised regarding implementation of digitization include ensuring that the benefits of data availability and traceability are accessible at various locations of the supply chain, particularly at points where significant investments are made. While existing games such as the Blue Connection and CircuSChain game simulate transitions to circular business models, this 6cycle game specifically demonstrates the benefits and trade-offs of transparency in product composition data across a supply chain.

Learning Objectives

The game highlights the degree to which two key areas of opportunity in data conservation along material flows can form a positive feedback loop at industrial scales.

1. *Increasing the efficiency of material recovery through data collection:* providing data on product composition, with the goal of unmixing waste streams and enhancing material recovery.
2. *Using material recovery data to optimize materials for circularity:* treating mixed waste streams as valuable information streams, and informing predictions of the functional properties of mixed materials with the goal of identifying new materials which are both more useful and recoverable in industrial supply chains.

Game set-up:

1. 4 players:
    a. 1 Recycler, who acts as a recycled material supplier and draws materials from a Waste Depot
    b. 2 Manufacturers, each of whom make one product
    c. 1 Consumer, who buys both products and sends all end-of-life products to a Waste Depot

2. The market consists of 2 products:
    a. Each manufacturer makes 1 product
    b. Each product is a combination of 2 materials in different proportions: yellow and grey Blargox
    c. Each product has different quality specs for each material (e.g. Product 1 may need yellow Blargox to have Quality A > 0.3)
    d. Each product is associated with a Material Passport that includes quantity and quality of each material used in the product

3. Each manufacturer 'makes' products by drawing from either a finite Primary Material Pool (primary materials always meet quality specs and are 'free') or the recycled materials supplied by recycler. At the beginning of the game, each Manufacturer has

50% market share.

4. While primary materials are free, i.e. it does not cost a Manufacturer any points to draw from the primary materials piles, the game ends and everyone loses if any of the primary materials piles are exhausted.

What to play with: *(see linked slide deck)*

How to Play:

1. The game begins with the Recycler accessing end-of-life materials from the Waste Depot and selling them to Manufacturers.
    a. If the Recycler does not have access to a material passport (which they do not at the start of the game), they guess the quality specs of manufacturers and then decide whether to supply recycled materials (based on the cost of recovery and quality of recycled materials made available to them).
    b. If one manufacturer's material passport is shared, the Recycler has access to information about quality specs AND there is an option to make a new material mix that meets the specs of one of the Materials.

2. Manufacturers may buy recycled content from Recycler (if quality specs of a material are met) and/or draw from the finite Primary Materials pool to make their products. Manufacturers may play EcoLabel or Materials passport cards to gain market share through the Consumer if recycled content is used in products.

3. Consumers are motivated to buy sustainable products. They may shift Marketshare towards a manufacturer (flip a 1 star in any round) if products are perceived to be more sustainable than the other.

Scoring:

Recycler:
- If manufacturers do not buy recycled materials, material goes back to waste depot and -1 point for recycler for overestimating sales
- If manufacturer(s) buy recycled materials, +1 point for each successful sale to each manufacturer (up to +2 points per turn)
- + Revenue from sale of material to Manufacturer (as specified in recovery cost curve)

Manufacturer:
- Starts with 5 points. Loses/Gains points as the game proceeds :
    - Play EcoLabel: -1 (lose a point but may gain market share for making sustainable products)
    - Play Materials Passport: -2 (lose 2 points but may gain Marketshare if recycled content is used and Recycler may tailor materials to meet manufacturer's material specs)
    - Dominate Marketshare: +1 for each star >5; counted in each round a manufacturer maintains dominant Marketshare (consumers can flip 1 Marketshare star per turn between manufacturers based on perceptions of their products' recycled content)

Consumer:

- Gets points for buying 'green' : +1 point for each EcoLabel, +1 points for product with recycled content if Materials Passport shared

Material leakage:

- Number of marbles in Waste Depot

Ending the game: The game ends when any one of the 2 Primary Materials Piles runs out

Additional rules of the game:

Recyclers:

- Can access 2 of each material in the waste depot if no material passport is shared.
- Can access all materials needed for a product if a material passport is shared.
- The cost of recovering each material of specific quality is available to recyclers through recovery cost curves

Manufacturers:

- Manufacturers get first dibs on recycled materials if Materials Passport shared.
- Can use up to 3 EcoLabels to signal recycled content use and gain market share.
- Has one material passport to share; gains Marketshare if recycled content used and materials passport shared.
- Marketshare points count in each round where dominant Marketshare is maintained

Consumers:

- Consumer must be silent (no negotiating with Manufacturers)

Key insights from playing this game:

We played the 6Cycle Game during the MCSC Member Meetings Nov 15-16 2023. Our key takeaways from playing in a group of 40 participants were:

- Manufacturers can collude (no recycled materials bought or material passport shared)
    - In this case, the game ends early due to primary materials piles being exhausted

- Manufacturers can cooperate (both share materials passport early and enable recycler to tailor materials for each)
    - In this case, the Recycler or Consumer accrue most points in the game for successful recycled material sales or buying sustainable products respectively
    - In practice, Manufacturers would benefit too through additional sales of products (product sales are restricted to specific quantities in this game, i.e. consumer cannot drive demand for products)

- There may be one benevolent manufacturer (manufacturer buys expensive recycled content)
    - This manufacturer may make sustainable products but is bankrupt (i.e. lowest points) by the end of the game
    - Consumer can play an important role in ensuring that sustainable products manufacturers maintain greater Marketshare (and earn more points)

- Recycler can be risk-averse without material passport and choose not to recover any materials
    - In the absence of product composition data, it is risky for the Recycler to guess quality specs of manufacturers and ‘invest’ in recovering high quality materials

- Recycler can be preferential to one manufacturer (when both material passports are shared) in which case one manufacturer loses out despite sharing material passport
    - Recycler can choose the quality and quantity of recovered materials and may avoid recovering high quality materials due to cost
    - In practice, manufacturers can change the quality specs of their materials and adapt to recycler’s supply but this strategy is excluded from the game

- Consumer perception and trust: Manufacturer’s market share is determined by consumer’s trust on ecolabel or perception of sustainability when a material passport is shared.
    - In practice, consumer perception and trust would depend on other factors such as manufacturers’ reputation, brand loyalty, etc. which are not captured in this game.

- Scoring live is fairly complicated and can undermine the gameplay if players do not understand it. People who play board games are signing up for complicated scoring, people in conferences do not necessarily care enough about the raw numbers.
    - Perhaps a simplified scoring system or a dedicated scorer is appropriate for future conference events.

- Rounds likely need timers to ensure that the simulation runs quickly enough and people do not dwell for an unreasonable amount of time on decisions or give in to small talk.

- In this version of the game, any manufacturer has the ability to secure 100% Marketshare. In reality, products may only be partially substitutable with constraints on consumer action space (i.e. how many Marketshare stars can the Consumer flip in favor of one Manufacturer)
    - Should reaching 100% marketshare imply the failing manufacturer goes bankrupt / loses / “dies”?

Proposed next steps:

- This game could evolve into an MCSC Climate Scholars summer project: developing a simulation tool/digital user interface for the game accessible through the MCSC website.
- We welcome direct MCSC member company engagement to drive further refining of the game with an option of involving the MIT Game Lab.
- Sloan Sustainability Initiative events such as the Sustainability Summit.