# Circularity

Design of New Brick

Group 4

Fuqi (Oren) Li, Nibin Koshy and Qiuyan Xu

McMaster University

SEP702 Systems Engineering and Public Policy

Dr. Greg Zilberbrant

March 18, 2024

# Contents

# Circularity

Design of New Brick

Group 4

## 1. Problem Set Scope and Methodology

Assess and provide recommendation using a commercial circularity tool.

This analysis uses Circular Transitions Indicators (CTI) tool (provided by WBCSD) to analyze the material flow with consideration for circular economy principles to calculate a circularity percentage for a process.

Based on the result, the organization would like to know where to focus their efforts to maximize circularity.

## 2. Basic Scenario

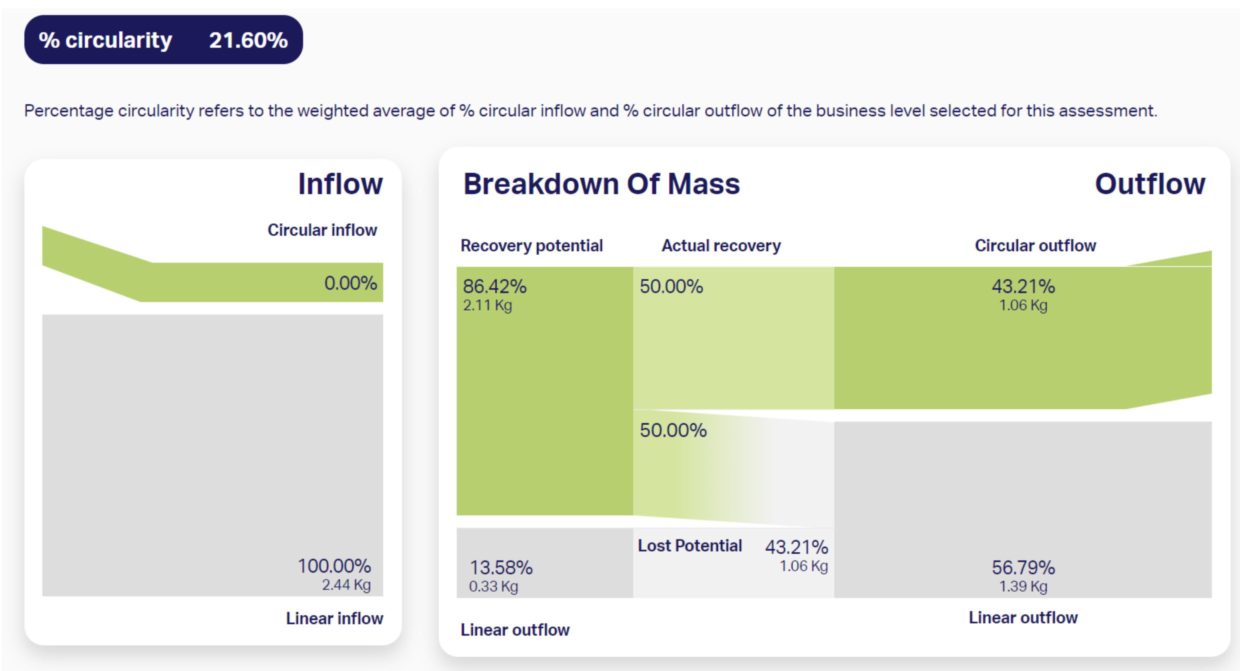
**Input:** Water = 0.244 kg, 10%; Sand = 0.734 kg, 30%;

Aggregate = 1.222 kg, 50%; Cement = 0.244 kg, 10% (All virgin materials)

**Output:** Brick weight: 2.2 kg, 90%; Manufacturing Waste: 0.244 kg, 10%

**Usage:** Wear during use: 4%

**End of Life:** Potential Recycled Rate: 96% (100%-4%), Actual Recycled Rate: 50%



## 3. Improvement Scenarios

### 3.1 Scenario 1

- Introduce 80% slag to substitute cement

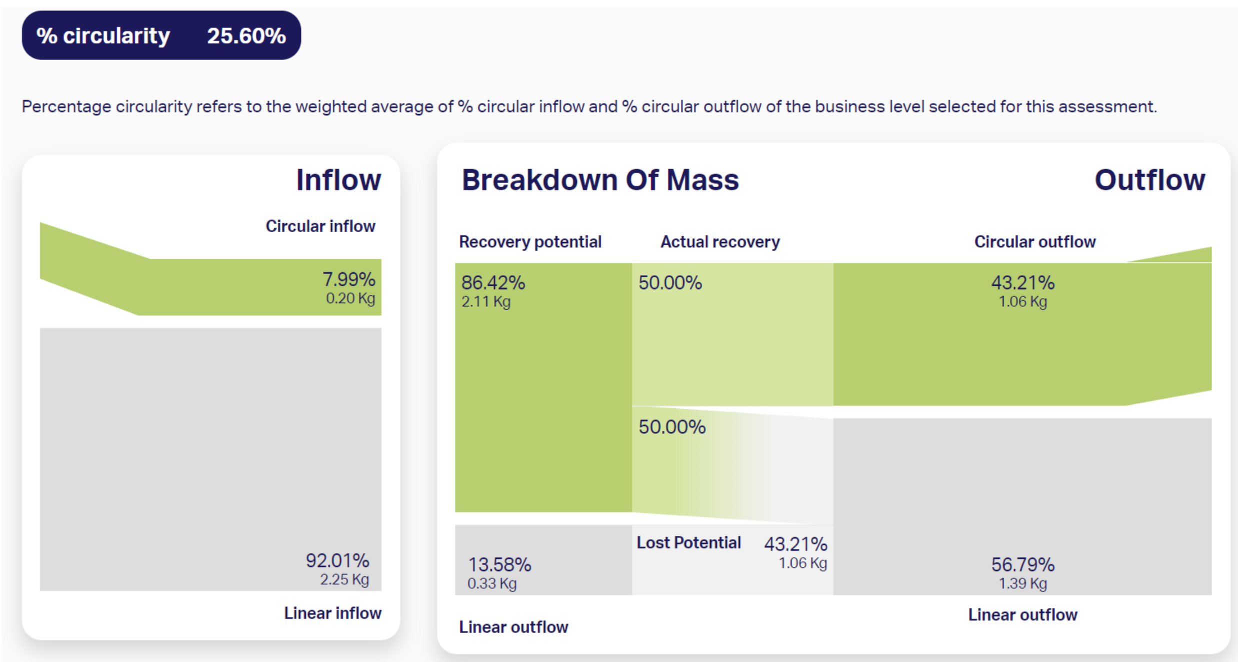
**Input:** Water = 0.244 kg, 10%; Sand = 0.734 kg, 30%;

Aggregate = 1.222 kg, 50%; Cement = 0.244 kg, 10% (80% slag)

**Output:** Brick weight: 2.2 kg, 90%; Manufacturing Waste: 0.244 kg, 10%

**Usage:** Wear during use: 4%

**End of Life:** Potential Recycled Rate: 96% (100%-4%), Actual Recycled Rate: 50%



## 3.2 Scenario 2

- Introduce 25% recycled aggregate to substitute virgin aggregate

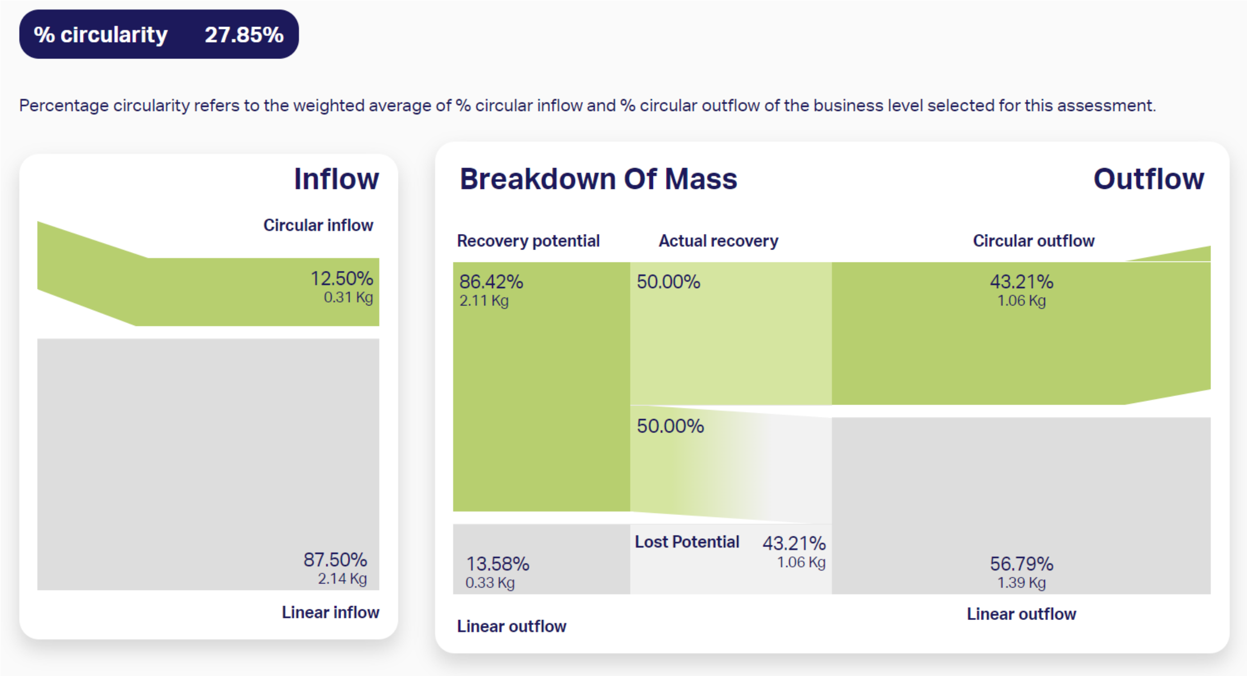
**Input:** Water = 0.244 kg, 10%; Sand = 0.734 kg, 30%;

Aggregate = 1.222 kg, 50% (25% recycled); Cement = 0.244 kg, 10%

**Output:** Brick weight: 2.2 kg, 90%; Manufacturing Waste: 0.244 kg, 10%

**Usage:** Wear during use: 4%

**End of Life:** Potential Recycled Rate: 96% (100%-4%), Actual Recycled Rate: 50%



## 3.3 Scenario 3

- Reduce waste in the manufacturing process to 2%

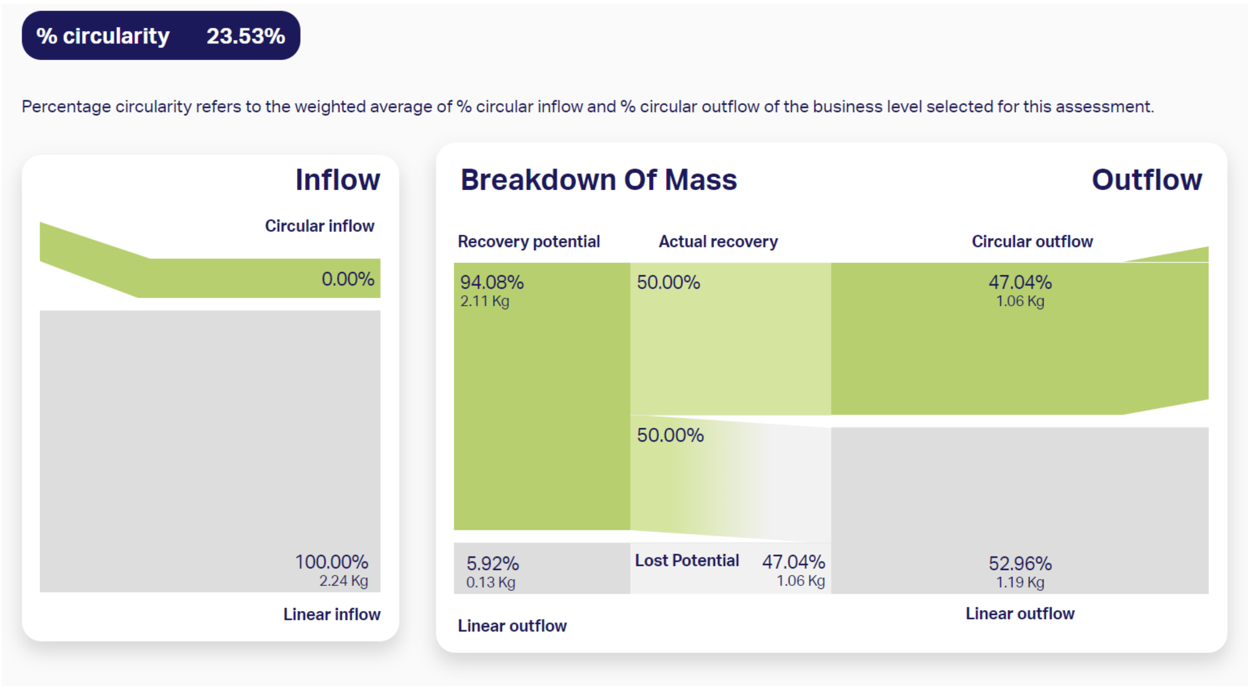
**Input:** Water = 0.224 kg, 10%; Sand = 0.674 kg, 30%;

Aggregate = 1.123 kg, 50%; Cement = 0.224 kg, 10% (All virgin materials)

**Output:** Brick weight: 2.2 kg, 98%; Manufacturing Waste: 0.244 kg, 2%

**Usage:** Wear during use: 4%

**End of Life:** Potential Recycled Rate: 96% (100%-4%), Actual Recycled Rate: 50%



### 3.4 Scenario 4

- Reduce wear to 1% (this option would limit recycled aggregate to a maximum of 10%)

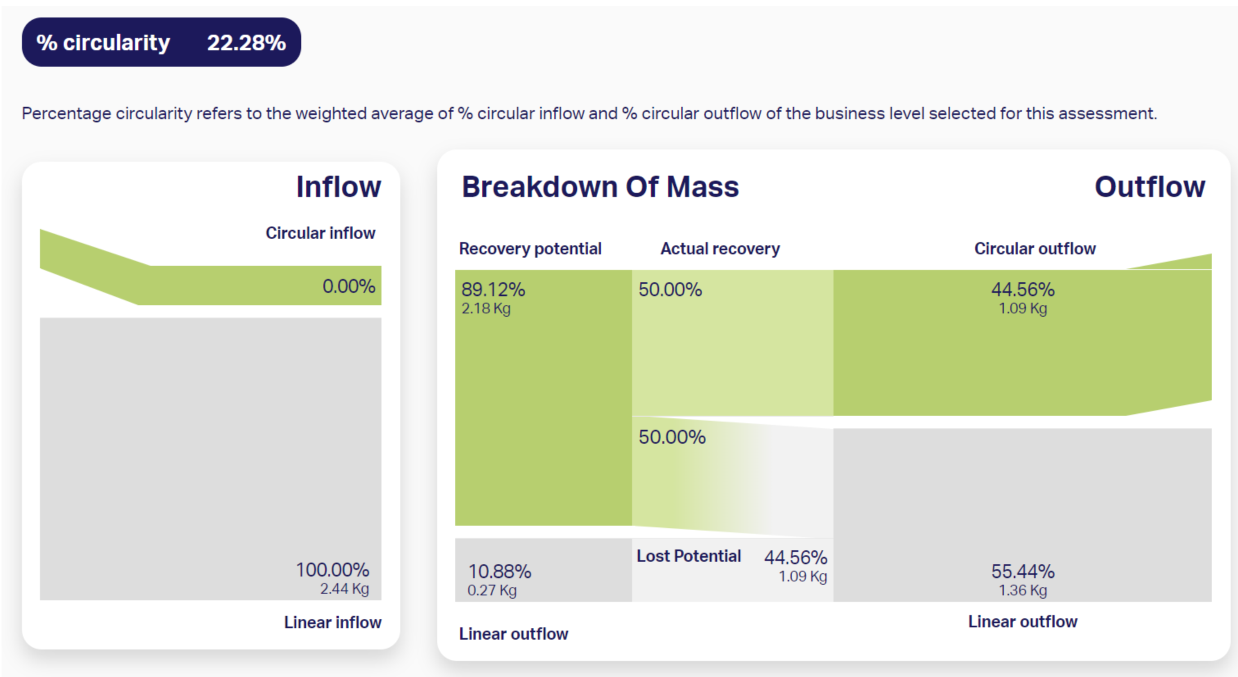
**Input:** Water = 0.244 kg, 10%; Sand = 0.734 kg, 30%;

Aggregate = 1.222 kg, 50%; Cement = 0.244 kg, 10% (All virgin materials)

**Output:** Brick weight: 2.2 kg, 90%; Manufacturing Waste: 0.244 kg, 10%

**Usage:** Wear during use: 1%

**End of Life:** Potential Recycled Rate: 99% (100%-1%), Actual Recycled Rate: 50%



## 3.5 Scenario 5

- Work with municipalities/reclaimers to improve infrastructure and have 80% of all recovered bricks being recycled/reused

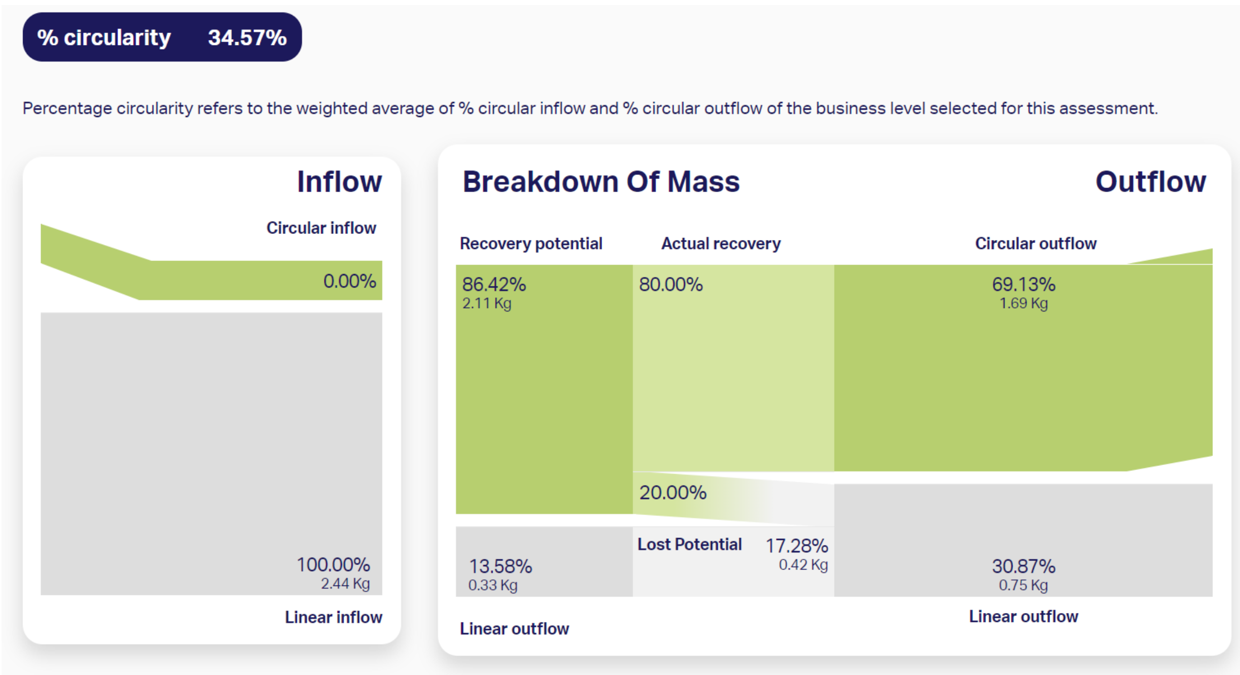
**Input:** Water = 0.244 kg, 10%; Sand = 0.734 kg, 30%;

Aggregate = 1.222 kg, 50%; Cement = 0.244 kg, 10% (All virgin materials)

**Output:** Brick weight: 2.2 kg, 90%; Manufacturing Waste: 0.244 kg, 10%

**Usage:** Wear during use: 4%

**End of Life:** Potential Recycled Rate: 96% (100%-4%), Actual Recycled Rate: 80%



### 3.6 Scenario 6

- Improve the longevity of bricks so their service life is 2 times greater, this will limit the slag input to 65%

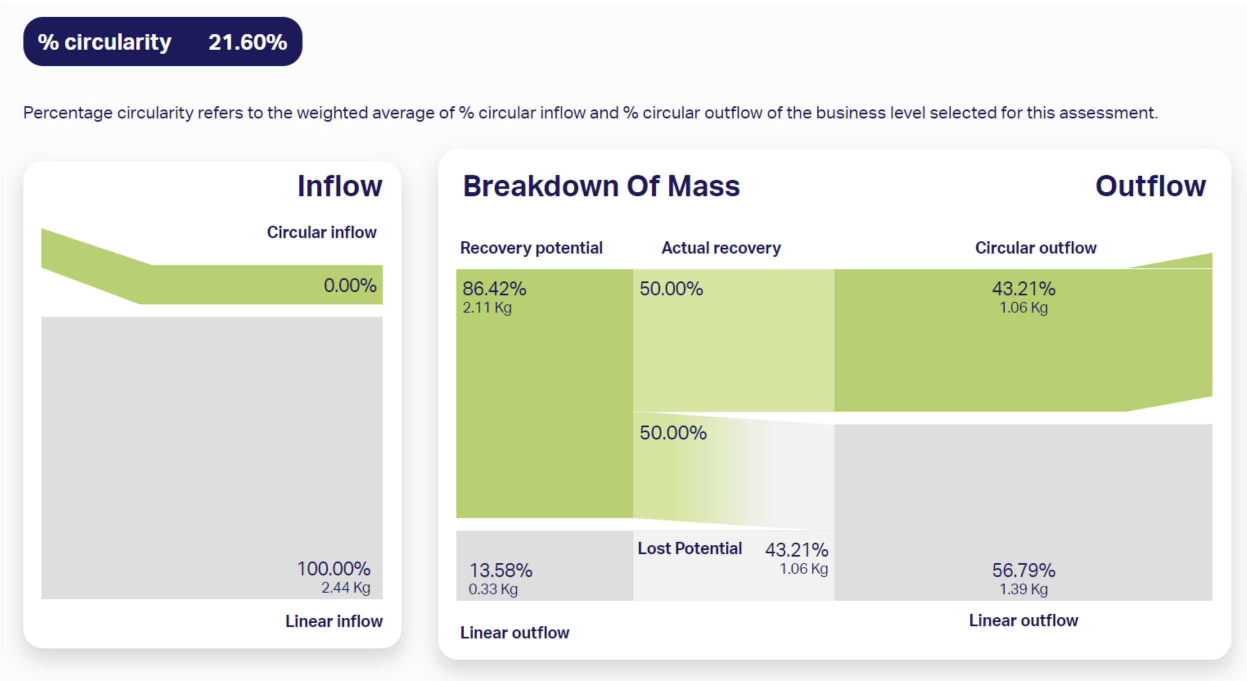
**Input:** Water = 0.244 kg, 10%; Sand = 0.734 kg, 30%;

Aggregate = 1.222 kg, 50%; Cement = 0.244 kg, 10% (All virgin materials)

**Output:** Brick weight: 2.2 kg, 90%; Manufacturing Waste: 0.244 kg, 10%

**Usage:** Wear during use: 4%

**End of Life:** Potential Recycled Rate: 96% (100%-4%), Actual Recycled Rate: 50%




The circularity of Scenario 6 mirrors that of the Basic Scenario initially. Lifespan extension alone doesn't necessarily alter circularity within a single life cycle. However, when considering multiple life cycles and the utilization of recycled versus virgin materials, circularity dynamics may shift.

Yet, determining whether lifespan extension is beneficial relies on numerous factors. For instance, if users typically replace products before reaching their lifespan, extending it may yield no tangible advantages. Moreover, such extensions could introduce added costs and requirements. In this scenario, for instance, there's a restriction on slag input, capped at 65%.

Therefore, while lifespan extension holds potential benefits, its effectiveness hinges on nuanced considerations like user behavior, additional costs, and operational constraints like material input limitations.

## 3.7 Combined Scenario

- To maximize the circularity percentage, combining Scenario 1+2+5

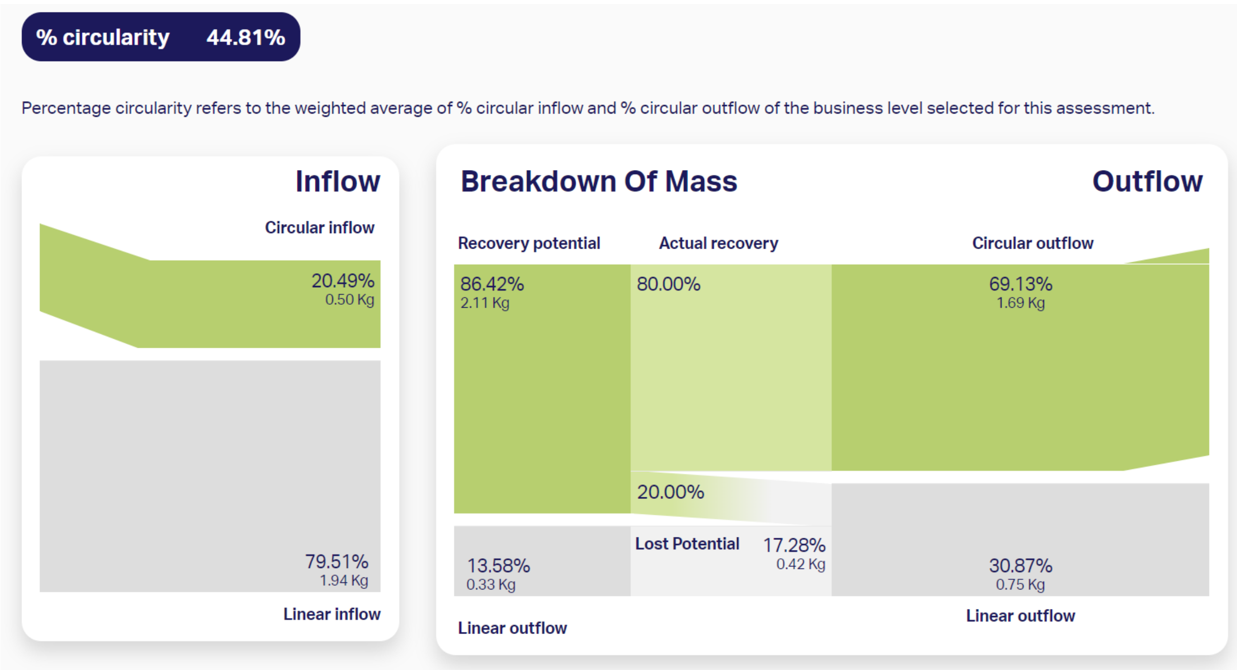
**Input:** Water = 0.244 kg, 10%; Sand = 0.734 kg, 30%;

Aggregate = 1.222 kg, 50% (25% recycled); Cement = 0.244 kg, 10% (80% slag)

**Output:** Brick weight: 2.2 kg, 90%; Manufacturing Waste: 0.244 kg, 10%

**Usage:** Wear during use: 4%

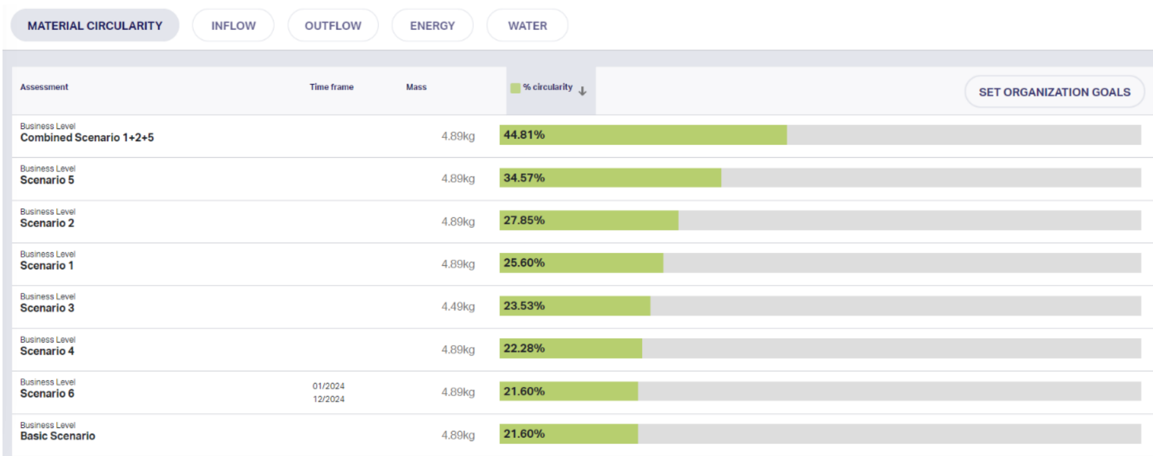
**End of Life:** Potential Recycled Rate: 96% (100%-4%), Actual Recycled Rate: 80%

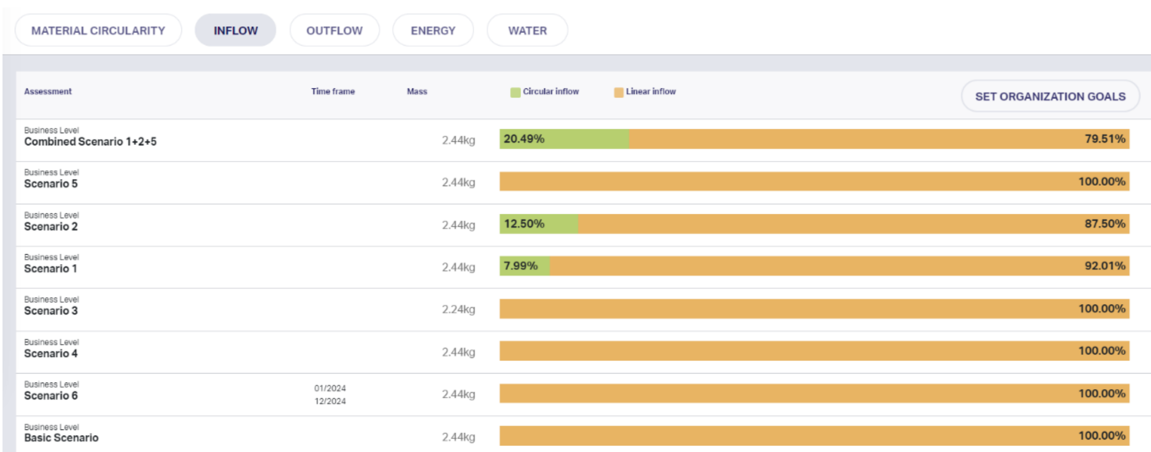


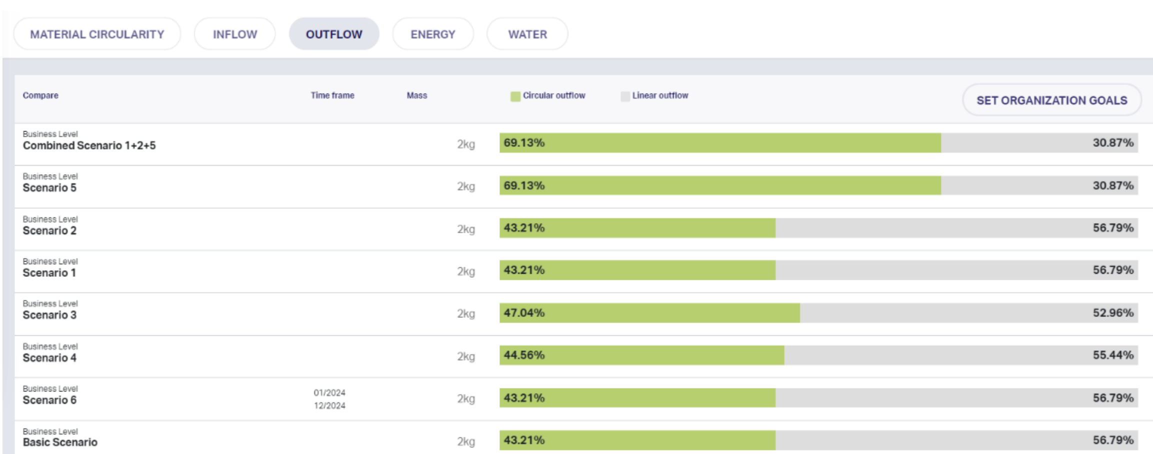
## 4. Comparison and Recommendation

### 4.1 Circularity comparison

The combined scenario achieves the highest circularity levels (44.81%), with both the inflow circularity percentage (20.49%) and the outflow circularity percentage (69.13%) experiencing significant increases.



## 4.2 Recommendation

Before proceeding with the recommended Combined Scenario, several key assessments are vital from a system engineering perspective:

- **Pilot Testing:** Initiate pilot testing to assess feasibility and optimize the program. Focus on factors such as slag and recycled aggregate utilization rates, brick quality, and recovery rates to tailor the program effectively.
- **Supply Chain Sustainability Analysis:** Evaluate the sustainability of alternative materials' supply chains, specifically slag and recycled aggregate. Consider factors like resource availability, environmental impact, and social considerations. Conducting life cycle assessments (LCAs) for each material can provide insights into their environmental footprint and circularity compatibility.
- **Lifecycle Cost-Benefit Analysis (LCC):** Conduct a comprehensive LCC to evaluate economic implications. Estimate upfront investments for infrastructure improvements and potential cost savings from material substitutions, waste reduction, and increased recycling rates. Consider short-term and long-term financial impacts for sustainability.
- **Stakeholder Engagement and Collaboration Assessment:** Engage relevant stakeholders to assess their willingness to support circularity initiatives in the construction sector. Identify barriers, partnership opportunities, and strategies for alignment to facilitate circular economy principles.
- **Risk and Uncertainty Analysis:** Evaluate potential risks and uncertainties associated with proposed changes. Assess factors like market volatility, regulatory compliance, technological feasibility, and supply chain disruptions. Develop risk mitigation strategies and contingency plans to ensure the resilience of the circular business model.

By conducting these assessments, the organization can better understand the implications and opportunities of maximizing circularity in brick manufacturing and optimize the circularity of their bricks.