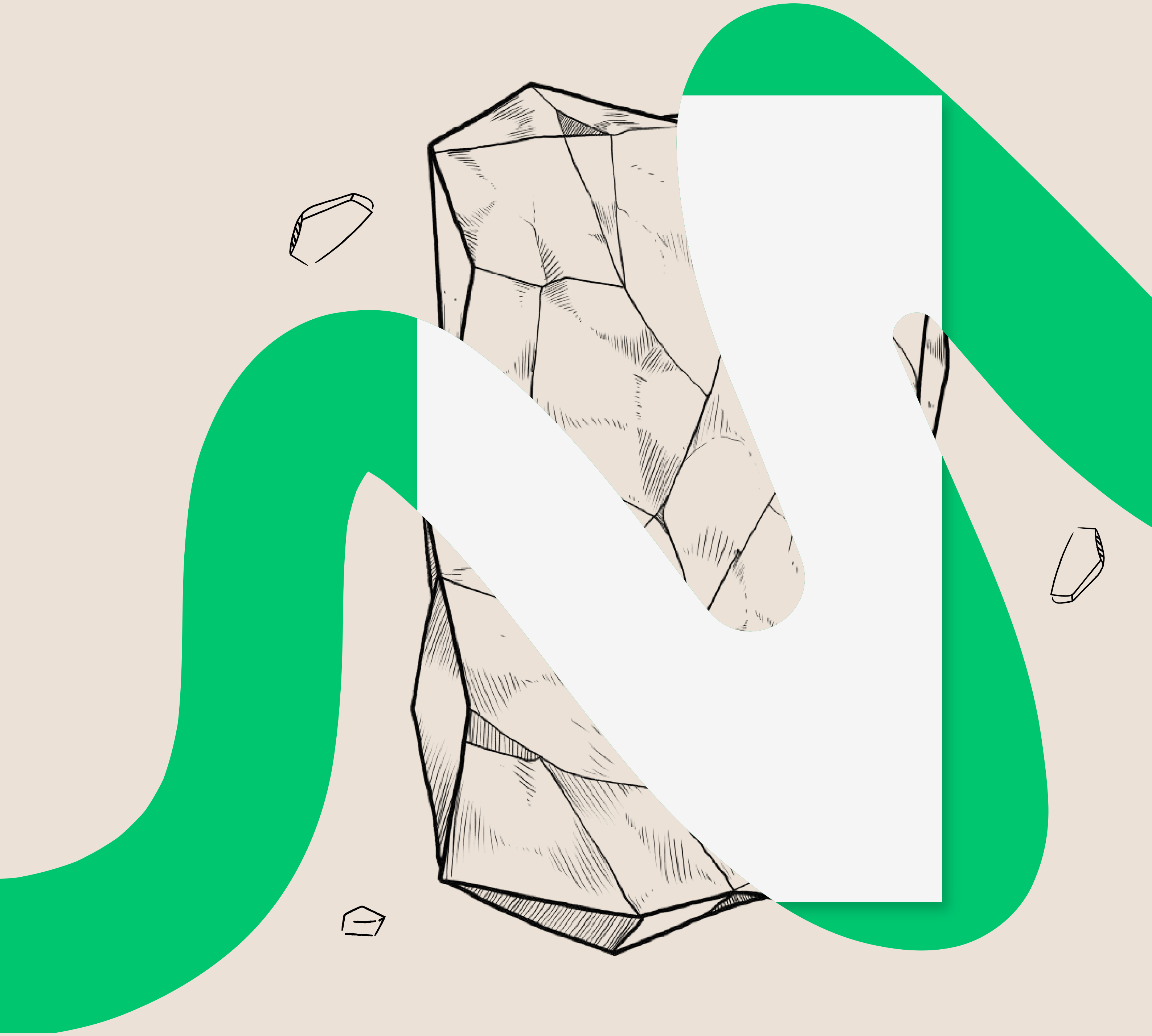
MOYU

# Life Cycle Assessment

## An Environmental Impact Assessment of the MOYU Reusable Notebook



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Introduction

# Executive Summary

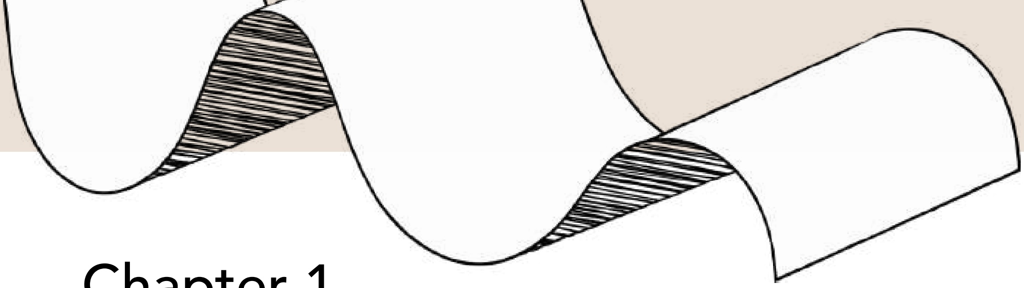
This study presents a comparative Life Cycle Assessment (LCA) between a MOYU Rewritable Notebook made from stone paper and a conventional A5 wood pulp paper notebook, focusing on the impact category climate change (GWP100a). Stone paper, composed of calcium carbonate and polyethylene, is produced without water or chemical additives, offering a potentially more sustainable alternative to traditional wood-based paper.

A cradle-to-grave LCA approach was applied, following ISO 14040 and 14044 standards. The functional unit was defined as enabling note-taking for three years, allowing the comparison of a single MOYU notebook to fifteen disposable paper notebooks. The Ecochain Mobius software, combined with the EcoInvent 3.6 database, was used to quantify greenhouse gas emissions for both products across three life cycle phases: production, transport, and end-of-life.

The findings show that the MOYU notebook emits **0.37 kg CO2-equivalent** over three years, while the paper notebook system emits **6.0 kg CO2-equivalent**, assuming fifteen units are required to match the functional performance of the reusable alternative. The highest emissions for paper notebooks stem from the production phase (0.36 kg $CO_2$-eq per unit), especially the manufacturing of virgin paper sheets. Stone paper notebooks demonstrate lower emissions during production (0.18 kg $CO_2$-eq), largely due to the absence of water and deforestation-related impacts. However, their end-of-life phase, currently incineration in Europe due to lack of recycling infrastructure, contributes disproportionately (0.14 kg $CO_2$-eq), reducing some of the upstream gains.

The study confirms that **using a MOYU notebook results in a net reduction of 5.63 kg CO2-equivalent** over a three-year period per user. Good to note is that even comparing in single use, the $CO_2$-equivalent is 0.07 kg lower. Sensitivity analyses highlighted the influence of paper origin, transport mode, and recyclability. While the stone paper lifecycle currently ends in municipal incineration, its recyclability potential (98–100%) suggests further environmental benefits if circular recovery systems are introduced—something MOYU now actively offers to clients through a return scheme.

Recommendations include expanding the assessment to other impact categories such as water use and biodiversity, comparing a broader range of competing notebook types, and conducting LCAs for other MOYU products using the same methodology. Overall, this research provides quantitative evidence that reusable stone paper notebooks offer a credible and lower-impact alternative to conventional notebooks in the context of climate change mitigation.



Chapter 1

# Goal and Scope Definition

## Goal of the Study

The primary goal of this research is to conduct a **comparative Life Cycle Assessment (LCA)** of two functionally equivalent products:

- the *MOYU Rewritable Notebook A5 | Hardcover | Ring Binder*, made from stone paper, and
- a conventional *A5 paper notebook with ring binding*, produced from wood pulp.

This comparison focuses on the **climate change impact** (Global Warming Potential - GWP100a, expressed in kg $CO_2$-equivalents) and aims to quantify the environmental benefits or drawbacks of using reusable stone paper notebooks instead of single-use paper notebooks. The results are intended to support sustainability claims, inform stakeholders, and guide strategic decisions at MOYU regarding environmental communication and product development.

Additionally, this study aims to identify the life cycle phases that contribute most significantly to environmental impact, and to explore potential improvement strategies for both materials, especially concerning the end-of-life phase.

## Intended Application and Audience

The results of this study are intended for use by:

- **MOYU's internal sustainability and product design teams**, for improving product circularity and communication;
- **External stakeholders**, including business clients, suppliers, and policymakers;
- **Consumers and environmental communicators**, to substantiate claims around $CO_2$ savings;
- **Researchers and practitioners** in the field of sustainable product development and life cycle thinking.

## Scope of the Study

### Functional Unit

The functional unit (FU) for this study is defined as:

**"Three years of notebook use for taking notes by an individual user."**

This enables a fair comparison between a reusable notebook (MOYU, designed for repeated use) and single-use paper notebooks. Based on usage data from Rabobank and internal estimates, one MOYU notebook replaces **fifteen** conventional A5 paper notebooks over this period.

### System Boundaries

This study applies a **cradle-to-grave** system boundary for both products, encompassing the following phases:

- Raw material extraction

- Manufacturing/production
- Transportation to Europe
- End-of-life treatment

The **use phase** and **packaging** are not included in this comparison, based on the assumption that their contributions are either negligible or similar between the two systems. However, sensitivity to these exclusions is discussed in the interpretation chapter.

### 1.3.3 Impact Category and Methodology

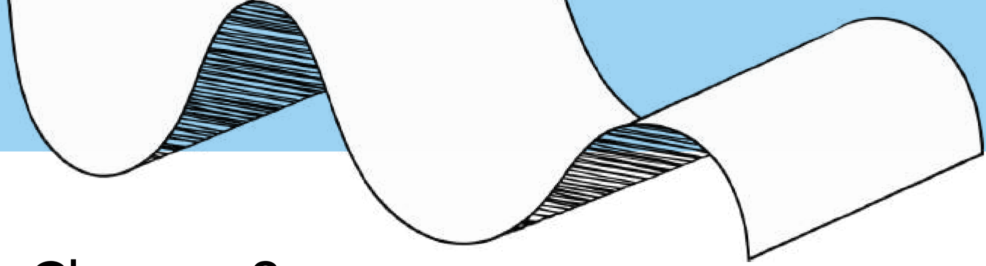
The environmental impact category under assessment is:

- **Climate Change (GWP100a)**, expressed in **kg CO2-equivalent**.

The impact assessment was conducted using **Ecochain Mobius**, linked to the **EcoInvent 3.6 database**, compliant with **ISO 14040 and ISO 14044** standards.

### 1.3.4 Allocation and Assumptions

- No cut-off rules were applied except where dictated by data availability in the EcoInvent system.
- The composition and weights of notebook components were based on empirical measurements and validated through literature and supplier data.
- For stone paper production, proprietary coating data was unavailable; kaolin was used as a representative proxy.
- Transport distances and modalities were determined based on supplier and retailer information (e.g., HEMA and MOYU logistics).



Chapter 2

# Literature Review

## Stone Paper

Since 2008, stone paper has been available on the Dutch market. This paper consists of calcium carbonate extruded with polyethylene into thin sheets of stone paper. The producer of this paper is Taiwan Lung Meng Tech Co. Ltd, based in Taiwan. The factory claims that the production of stone paper emits less CO2 compared to conventional paper. For example, unlike standard paper, no water or chemicals are used in the production of stone paper. Therefore, stone paper may be a good alternative to traditional paper.

Previous LCAs have been conducted on stone paper. An independent study commissioned by Gaia-Concept BV showed that the production of 1,000 kilograms of stone paper results in 474 kg of CO2 emissions. This study used a cradle-to-gate system boundary, which includes the production and transport phases (Hol, 2013). Another study by students at the University of Michigan in the United States, which used a cradle-to-grave system boundary similar to this research, found that 1 m2 of stone paper emits 0.275 kg of CO2. Converted to an A5 sheet, this amounts to 0.085 kg CO2 (Affeldt et al., 2016).

## Paper

Each year, about 100,000 km2 of forest is cut down, equivalent to 2.5 times the area of the Netherlands (Albert, 2022). Of this, 33% is used by the paper industry (WWF, n.d.). Deforestation is one of the greatest threats to the climate and biodiversity. Trees are essential: they absorb carbon dioxide and produce oxygen. Many people and animals depend on forests. As a result, the issue of deforestation caused by the paper industry is increasingly acknowledged by companies and organizations. More and more initiatives are pursuing sustainable forest management. One example is the Forest Stewardship Council (FSC) certification, awarded to products that meet certain environmental, social, and economic standards. Nevertheless, the global forest area continues to decline (The World Bank, n.d.).

Recently, the European Union reached an agreement requiring products to meet criteria that prevent further deforestation. These rules still need formal approval, after which traders will have eighteen months to comply. This development has significant implications for the entire paper industry (Trouw, 2022).

A standard LCA methodology has now been established for paper under the EU Product Environmental Footprint Initiative. This methodology is based on Environmental Footprint-compliant datasets commissioned by the European Commission. These datasets include process and flow types. As a result, numerous studies have already been conducted on the LCA of paper.bius is generally easy to use, which makes it user-friendly. The software contains an extensive environmental impact database for a wide range of products. The rationale for selecting this tool is provided in Appendix 1 (Ecochain, n.d.).

Chapter 3

# Method

This research uses a quantitative approach. The associated data collection methods are discussed in this chapter. Secondary data were collected through literature review to consolidate existing knowledge and data. These data are mostly expressed in numbers, graphs, diagrams, and tables. The methodology used is further detailed below.

## Definition of Components

In the first step of an LCA, it is important to define what will and will not be assessed. The following sections explain what is assessed in this study and to what extent.

### Impact Categories

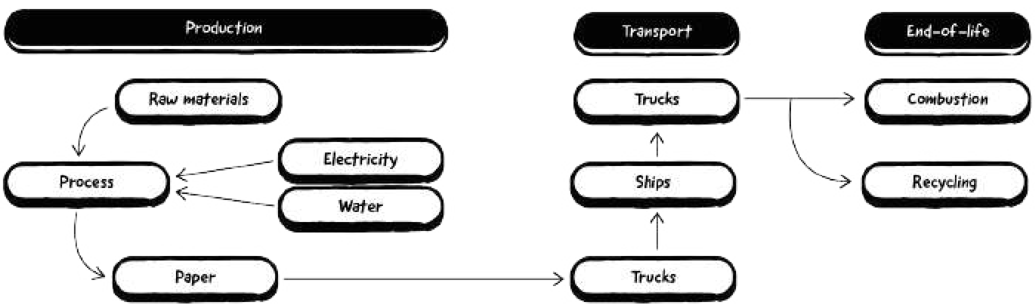
An LCA can use various impact categories. Ecochain Mobius utilizes eleven environmental impact categories, which can be converted into a single unit. In this step, the parameter to be used for this study is selected. Appendix 2 lists all eleven environmental parameters with brief explanations. This study focuses on the impact category of climate change. This category accounts for all greenhouse gases, expressed in a single equivalent unit. This facilitates comparison and communication, as the CO2 equivalent per weight unit is well known to the public.

### Functional Unit

This study compares two products with the same function. By establishing a functional unit (FU), different types of note-taking systems can be fairly compared. Since stone paper and wood pulp differ in weight and surface area, the FU is based on the performance of the notebooks: enabling note-taking for three years. Given the differing lifespans of stone paper and wood pulp paper, the FU is defined as three years of notebook use. This FU thus describes and quantifies the product (Weidema et al., 2004).

### System Boundaries

The next step in the LCA process is determining the system boundary. This defines which parts of the chain are included in the calculation. The key question is: "Which components fall within the system, given the functional unit?" Not all processes need to be mapped; for instance, recycling alone could be considered. The system boundaries cradle to grave, cradle to gate, and cradle to cradle help clarify this.




*Production, Tranport and End-of-life process*

### Cradle to Grave

Cradle to grave covers the entire life cycle from raw material extraction to waste disposal. All four LCA phases are included, and all inputs and outputs are considered. For the paper industry, this includes everything from tree seed extraction to incineration of the used paper. Recycling is not included.

### Cradle to Gate

This approach evaluates a product from raw material extraction to the factory gate. Transport to the consumer and subsequent life cycle phases are excluded. It is useful when only the impact up to the point of sale is considered. An example is tracking the paper's journey from tree seed to the point it leaves the factory.

### Cradle to Cradle

Cradle to cradle maps the product's life cycle from raw material extraction to recycling. This means the materials from the original product are reused to create a new product—either the same or different. An example is recycling used paper (De Vries, 2015).

Other, more specific LCAs are also possible. For instance, a disposal scenario could be analyzed, focusing only on optimal product reuse (Zitzen, 2019). As this study includes the production, use, and disposal phases of the notebooks, it adopts a cradle-to-grave system boundary.

# Inventory

After defining the components, the second phase of the LCA—the inventory phase—begins. In this phase, the product system is specified. In consultation with Roel Schatorjé, the comparison is based on three years of use of the MOYU Hardcover Notebook A5 Ring Binder with 40 pages versus the Hardcover A5 Wood Pulp Ring Binder Notebook with 80 pages. This choice was made because the MOYU hardcover notebook is the most commonly used and preferred for research. Through literature review and interviews, environmental inputs and outputs are quantified for both products, covering production, transport, and end-of-life phases. The methods and outcomes are briefly explained below.

## Paper

Following the system boundary established in section 3.1.4, the paper notebook is analyzed from cradle to grave. This includes raw material extraction, production, transport, and end-of-life.

### Production

Table 1 shows the production data for an A5 paper notebook, including the datasets used. Weighing one A5 paper sheet revealed it weighs 3 grams. The notebook contains 80 sheets. The paper type used is wood-free coated paper. An Ecoinvent dataset for this type of paper was selected. The ring binder and cardboard cover were also weighed and assumed identical to the MOYU notebook: 5 grams for the ring and 40 grams for the cover. Ink data came from Drukkerij de Coker in Antwerp, Belgium, who provided the amount used per A5 sheet, the same for both paper and stone paper.

| Name | Amount | Process | Data |
|---|---|---|---|
| Sheet | 0.24 kilogram | paper production, woodfree, coated, at integrated mill \| paper, woodfree, coated \| Cutoff, U \| Rest-of-World | Ecoinvent v3.6, Cut-Off |
| Wire-o binder | $5*10^{-3}$ kilogram | wire drawing, steel \| wire drawing, steel \| Cutoff, U \| Rest-of-World | Ecoinvent v3.6, Cut-Off |
| Cardboard cover | 0.04 kilogram | sulfate pulp production, from hardwood, bleached \| sulfate pulp, bleached \| Cutoff, U \| Rest-of-World | Ecoinvent v3.5, Cut-Off |
| Ink cover | $2.43*10^{-4}$ kilogram | market for printing ink, offset, without solvent, in 47.5% solution state \| printing ink, offset, without solvent, in 47.5% solution state \| Cutoff, U \| Europe | Ecoinvent v3.6, Cut-Off |
| Ink sheets | $2.15*10^{-5}$ kilogram | market for printing ink, offset, without solvent, in 47.5% solution state \| printing ink, offset, without solvent, in 47.5% solution state \| Cutoff, U \| Europe | Ecoinvent v3.6, Cut-Off |

*Paper production data*

## Transport

HEMA, a well-known notebook retailer, was consulted to determine the origin of their notebooks, which are produced by Ningbo Guangbo Plastic Products Manufacture Co in China. The first transport leg is by truck (50 km) from the factory to Ningbo port, followed by sea freight (22,126 km) to Rotterdam. From there, it travels 52 km by truck to HEMA's distribution center in Utrecht. These distances were entered into the Ecochain transport template for automated calculations.

| Name | Amount | Process | Data |
|---|---|---|---|
| Ship | 6.26 kilometre | transport, freight, sea, container ship \| transport, freight, sea, container ship \| Cutoff, U \| Global | Ecoinvent v3.6, Cut-Off |
| Truck (Europe) | 0.01 kilometre | transport, freight, lorry, all sizes, EURO5 to generic market for transport, freight, lorry, unspecified \| transport, freight, lorry, unspecified \| Cutoff, U \| Europe | Ecoinvent v3.6, Cut-Off |
| Truck (Rest of the World) | 0.01 kilometre | transport, freight, lorry, all sizes, EURO5 to generic market for transport, freight, lorry, unspecified \| transport, freight, lorry, unspecified \| Cutoff, U \| Rest-of-World | Ecoinvent v3.5, Cut-Off |

*Paper transport data*

## End-of-Life

Paper notebooks with a ring binder and cardboard cover can be disposed of with paper waste (Milieucentraal, n.d.). The paper and cardboard are recycled, the ink is used for energy, and the metal ring is incinerated and recovered using magnets (Ordner, n.d.).

| Name | Amount | Process | Data |
|---|---|---|---|
| Communal waste burning | $5*10^{-3}$ kilogram | treatment of municipal solid waste, incineration \| municipal solid waste \| Cutoff, U \| Netherlands | Ecoinvent v3.6, Cut-Off |
| Recycling paper & cardboard | 0.28 kilogram | treatment of waste paper, unsorted, sorting \| waste paper, sorted \| Cutoff, U \| Europe without Switzerland | Ecoinvent v3.6, Cut-Off |

*Paper end-of-life data*

## Stone Paper

As with the wood pulp notebook, the stone paper notebook is analyzed by phase: production, transport, and end-of-life.

### Production

Table 4 presents the production data for the MOYU Rewritable Notebook A5 I Hardcover I Ring Binder. Ring binder and cover weights are the same as previously noted. Ink data were sourced from Drukkerij de Coker. Other production data come from LCAs by Gaia-Concept BV and the University of Michigan, averaged.

| Name | Amount | Process | Data |
|---|---|---|---|
| Calciumcarbonate | 0.23 kilogram | limestone production, crushed, washed \| limestone, crushed, washed \| Cutoff, U \| Rest-of-World | Ecoinvent v3.6, Cut-Off |
| Wire-o binder | $5*10^{-3}$ kilogram | wire drawing, steel \| wire drawing, steel \| Cutoff, U \| Rest-of-World | Ecoinvent v3.6, Cut-Off |
| Cardboard cover | 0.04 kilogram | sulfate pulp production, from hardwood, bleached \| sulfate pulp, bleached \| Cutoff, U \| Rest-of-World | Ecoinvent v3.5, Cut-Off |
| Ink cover | $2.43*10^{-4}$ kilogram | market for printing ink, offset, without solvent, in 47.5% solution state \| printing ink, offset, without solvent, in 47.5% solution state \| Cutoff, U \| Europe | Ecoinvent v3.6, Cut-Off |
| Ink inside sheets | $5.37^{-4}$ kilogram | market for printing ink, offset, without solvent, in 47.5% solution state \| printing ink, offset, without solvent, in 47.5% solution state \| Cutoff, U \| Europe | Ecoinvent v3.6, Cut-Off |
| Coating | $3*10^{-3}$ kilogram | kaolin production \| kaolin \| Cutoff, U \| Rest-of-World | Ecoinvent v3.5, Cut-Off |
| Electricity | 0.22 kiloWattuur | electricity production, natural gas, combined cycle power plant \| electricity, high voltage \| Cutoff, U \| Taiwan, Province of China | Ecoinvent v3.5, Cut-Off |
| Oil | 0.41 Mega Joule | heat and power co-generation, oil \| heat, district or industrial, other than natural gas \| Cutoff, U \| Taiwan, Province of China | Ecoinvent v3.5, Cut-Off |
| Polyethylene | 0.11 kilogram | polyethylene production, high density, granulate \| polyethylene, high density, granulate \| Cutoff, U \| Rest-of-World | Ecoinvent v3.6, Cut-Off |

*Stone paper production data*

### Transport

Transport begins at Taiwan Lung Meng Tech. Co. Ltd. (TLM) in Tainan City, Taiwan. The notebook travels 80 km by truck to Kaohsiung port, then 18,352 km by ship to Rotterdam. It is then transported 120 km to the Coker printing facility in Antwerp and 129 km to Studie Bijdehand in Zuidland, the Netherlands. These distances were entered into Ecochain's transport template for emissions calculations.

| Name | Amount | Process | Data |
|---|---|---|---|
| Ship | 4.9 kilometer | transport, freight, sea, container ship \| transport, freight, sea, container ship \| Cutoff, U \| Global | Ecoinvent v3.6, Cut-Off |
| Truck (Europa) | 0.07 kilometer | transport, freight, lorry, all sizes, EURO5 to generic market for transport, freight, lorry, unspecified \| transport, freight, lorry, unspecified \| Cutoff, U \| Europe | Ecoinvent v3.6, Cut-Off |
| Truck (Rest of the World) | 0.02 kilometer | transport, freight, lorry, all sizes, EURO5 to generic market for transport, freight, lorry, unspecified \| transport, freight, lorry, unspecified \| Cutoff, U \| Rest-of-World | Ecoinvent v3.5, Cut-Off |

*Stone paper transport data*

### End-of-Life

Although stone paper has a Cradle to Cradle Silver certificate, it cannot yet be recycled in Europe. It is advised to dispose of the notebook with residual waste, meaning it is incinerated (Milieucentraal, n.d.).

| Name | Amount | Process | Data |
|---|---|---|---|
| Municipal burning | 0.27 kilogram | treatment of municipal solid waste, incineration \| municipal solid waste \| Cutoff, U \| Netherlands | Ecoinvent v3.6, Cut-Off |

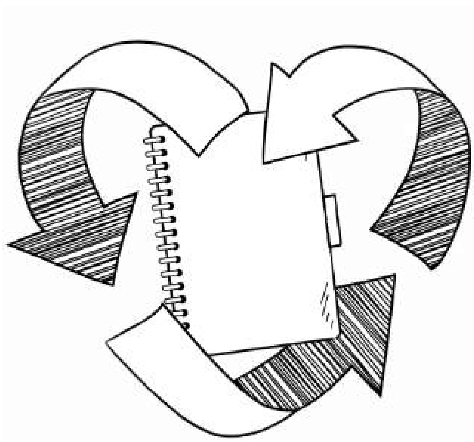
*Stone paper end-of-life data*

# Environmental Impact Assessment

In the third phase, the environmental impact of both notebooks is calculated using EcoChain Mobius, as established in section 3.1. The defined raw materials from phase two are entered and linked to the EcoChain Mobius databases based on the functional unit and impact parameters.

# Comparison

After calculating the environmental impacts, the notebooks are compared. According to Rabobank data, one MOYU Rewritable Notebook A5 I Hardcover I Ring Binder replaces fifteen A5 wood pulp ring binder notebooks (section 4.1.3). To ensure a fair comparison, a functional unit was established in line with ISO guidelines (section 3.1.2). Using EcoChain Mobius's comparison feature, the key differences in impact are identified and potential options to reduce overall impact are explored. This reveals whether the MOYU notebook truly has a lower environmental impact than the wood pulp notebook—and by how much.



Chapter 4

# Results

The results were obtained using the EcoChain Mobius software. The subheadings in this chapter are supported by figures and tables to better illustrate the findings.

## Environmental Impact of Notebooks

The following section discusses paper and outlines the environmental impact of one A5 paper notebook. Another section presents the environmental impact of the MOYU Rewritable Notebook A5 l Hardcover l Ring Binder. As the aim of this study is to conduct a comparative LCA, section 4.2.3 includes a comparison between the two products.

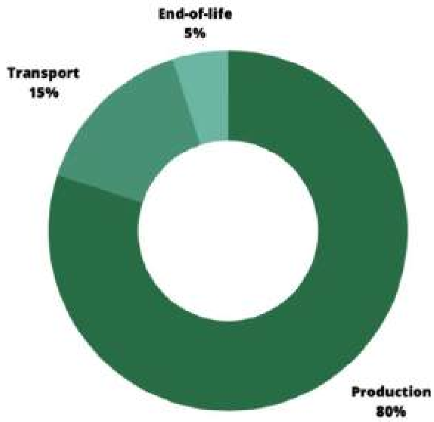
### Paper

The *Stone Paper End-of-life table* shows the environmental impact per component, expressed in the impact category climate change, as determined in section 3.1.2. In total, one A5 paper notebook emits 0.44 kilograms of CO2 equivalent. The largest share of emissions—0.3 kilograms CO2 equivalent—comes from the production of the paper sheets, accounting for 74% of the total impact. In addition, 14% of the emissions come from transporting the product from Ningbo, China to the port of Rotterdam, Netherlands by ship. Remarkably, recycling also contributes to CO2 emissions, comprising 4.8% of the total. The cardboard cover contributes 4.5%, nearly equal to recycling. The remaining components contribute less than 1% each.

| Phase | Item | Global warming (GWP100a) (kg CO2 eq) |
|---|---|---|
| Production | Carton Cover | 1.80E-02 |
| Production | Ink cover | 8.93E-04 |
| Production | Ink interior | 7.89E-05 |
| Production | Sheet | 2.98E-01 |
| Production | Ring binder | 1.68E-03 |
| Transport | Ship | 5.86E-02 |
| Transport | Truck | 1.86E-03 |
| Transport | Truck (ROW) | 1.79E-03 |
| End-of-life | Municipality Incineration | 2.59E-03 |
| End-of-life | Recycling | 1.92E-02 |

*Environmental impact of paper*

Looking at the different phases (Graph 2), the highest emissions occur during production, with a total of 0.36 kilograms CO2 equivalent. Transport accounts for 0.06 kilograms CO2 equivalent, and the end-of-life phase contributes 0.02 kilograms CO2 equivalent. Recycling emits more than incineration in the end-of-life phase, as 0.28 kilograms is recycled and only 5*10^-3 kilograms is incinerated. If these were equal, emissions from municipal waste incineration would be higher than recycling.




*Environmental impact of paper per life cycle phase*

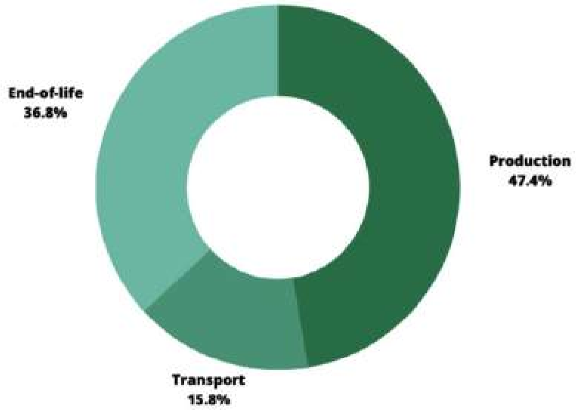
## Stone Paper

Table 8 presents the environmental impact of the MOYU Rewritable Notebook A5 l Hardcover l Ring Binder. The total environmental impact of one such notebook is 0.37 kilograms CO2 equivalent, which is 0.07 kilograms less than the paper A5 notebook.

| Phase | Item | Global warming (GWP100a) (kg CO2 eq) |
|---|---|---|
| Production | Ink cover | 8.93E-04 |
| Production | Carton Cover | 1.14E-02 |
| Production | Ring binder | 1.68E-03 |
| Production | Calciumcarbonate | 5.30E-04 |
| Production | Coating | 4.21E-05 |
| Production | Elektricity | 9.01E-02 |
| Production | Fuel Oil | 2.69E-02 |
| Production | Ink interior | 1.97E-05 |
| Production | Polyethylene | 4.74E-02 |
| Transport | Ship | 4.58E-02 |
| Transport | Truck | 8.33E-03 |
| Transport | Truck (ROW) | 2.70E-03 |
| End-of-life | Municipality Incineration | 1.38E-01 |

*Environmental impact of stone paper*

Graph 2 illustrates climate change impact per phase. The production phase has the highest contribution, totaling 0.18 kilograms CO2 equivalent. Compared to paper, this is 0.14 kilograms less. Unlike paper, the second largest contributor is the end-of-life phase at 0.14 kilograms CO2 equivalent. This difference arises because stone paper in Europe must be disposed of as residual waste and is therefore incinerated.




*Environmental impact of stone paper per phase*

## Comparison of Notebooks

The goal of this study is to conduct a comparative LCA. The total environmental impact of the MOYU Rewritable Notebook A5 I Hardcover I Ring Binder over three years is 0.37 kilograms CO2 equivalent. In contrast, the impact of the A5 wood pulp Ring Binder Notebook over the same period is 6 kilograms CO2, as MOYU notebooks are reusable. This means using a MOYU notebook saves 5.63 kilograms CO2 equivalent over three years.

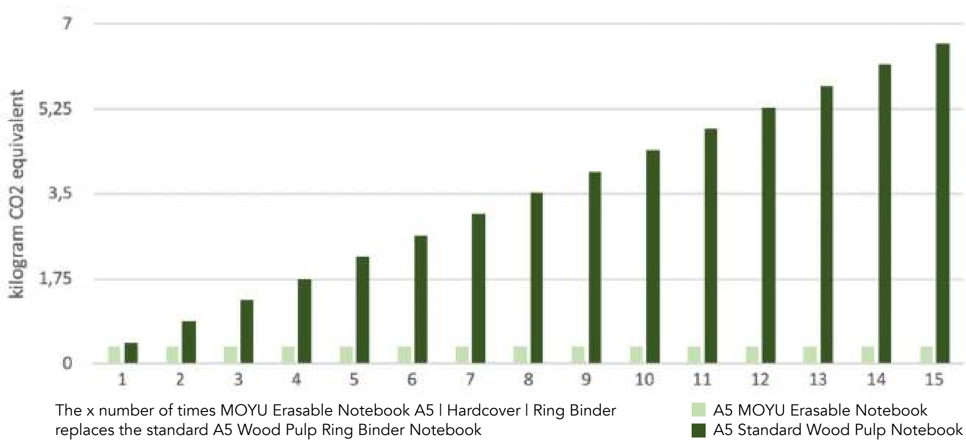
This comparison assumes that a user will fill fifteen paper notebooks during three years of use—based on data from Rabobank and MOYU. Table 9 shows the data requested from Rabobank.

| | |
|---|---|
| **Usage of notebooks per year** | 80000 |
| **Employees in the Netherlands** | 25000 |
| **Notebooks per employee per year** | 3,2 |

*Rabobank data*

Calculations show that each employee uses about three notebooks per year. Additionally, consumers use about two notebooks annually for personal purposes. Therefore, one MOYU Rewritable Notebook A5 I Hardcover I Ring Binder can replace fifteen paper notebooks over three years.

To illustrate the difference in notebook usage, the following graph was created:




*Comparison of notebook usage difference (light green is MOYU)*

# Interpretation

This section evaluates the results and discusses alternative considerations.

## More Sustainable Paper

This study assumed that paper used in notebooks originates from China (see section 3.1.2). The results may differ if recycled paper were assumed instead. However, this was not considered, as most consumers are assumed to purchase notebooks from HEMA, which sources from China. The dataset used reflects production of wood-free, coated paper in the Rest-of-World region. This assumption is supported by the fact that Ningbo Guangbo Plastic Products Manufacture Co does not use recycled paper (Guangbo, n.d.). This may explain the high emissions from paper sheet production. Recycled paper offers several climate benefits. It saves resources, energy, and reduces waste. One ton of recycled paper saves 17 trees, 7,000 liters of water, and 4,000 kilowatt-hours of energy (Georgetown University, n.d.).

## Packaging

In both LCAs, the phases production, transport, and end-of-life were calculated. The environmental impact of these phases combined forms the total impact. Although Ecochain allows for inclusion of packaging in cradle-to-grave analyses, it was excluded from this study. The reasoning is that stone paper and regular paper are assumed to be packaged similarly, rendering the difference negligible. However, packaging can significantly affect overall impact. Since one MOYU notebook replaces three paper ones, packaging emissions would be approximately three times higher for paper, potentially altering the results. Including packaging could improve the comparative accuracy.

## Use Phase

Just like the packaging phase, Ecochain allows inclusion of the use phase in cradle-to-grave studies. For MOYU notebooks, this includes pen ink refills and water for erasing. For paper notebooks, regular pens are used. These were excluded, as the study focuses solely on the notebooks and not the entire writing system. Including the use phase would raise the impact figures.

## Transport

Paper products are shipped from China by sea. Another common method is air freight. The results show that one MOYU Rewritable Notebook A5 | Hardcover | Ring Binder emits a total of 0.37 kilograms CO2 equivalent, with transport contributing 0.06 kilograms. If transported by air instead of ship, the impact would rise to 1.12 kilograms CO2 equivalent. This would significantly increase the overall environmental impact, demonstrating that sea freight is the more sustainable option.

## End-of-Life

Stone paper has a Cradle to Cradle Silver certificate, meaning the materials can be reused in new products. Stone paper has a recovery rate of 98–100% (Stone Paper Tech, n.d.). In this LCA, end-of-life emissions are high because stone paper is incinerated, as volumes are too low for separate recycling streams. If recycled, the end-of-life impact would be 0.04 kilograms CO2 equivalent instead of 0.14 kilograms—saving 0.10 kilograms CO2 equivalent per notebook.

Chapter 5

# Discussion

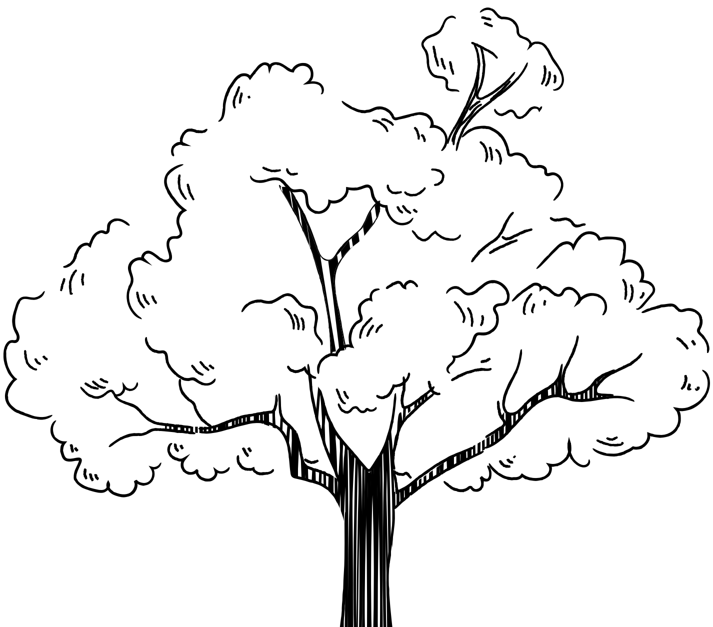
The aim of this study was to perform a comparative LCA focusing on the impact category climate change. The results indicate that using the MOYU Rewritable Notebook A5 | Hardcover | Ring Binder over three years emits 5.63 kilograms CO2 equivalent less than the A5 wood pulp Ring Binder Notebook. This assumes the MOYU notebook replaces fifteen paper notebooks in three years.

The number fifteen was therefore based on Rabobank usage data. However, this is not a fully reliable basis, as the specific types of paper notebooks used were not identified. A different result may arise if the study were repeated with more robust data.

Before the study, it was expected that finding accurate data on stone paper would be challenging. Surprisingly, reliable sources were found quickly. Only the coating material used in stone paper production remains a trade secret; therefore, the common coating kaolin was assumed. Because the data were transparent and current, decisions were made with confidence.

The LCA was calculated using Ecochain software, with the climate change impact derived from the EcoInvent database. This dataset complies with ISO 14040/14044 standards and includes more than 18,000 LCI datasets (DEISO, n.d.). EcoInvent is open and reliable and offers both aggregate and unit process datasets. It is also continuously updated. Therefore, the choice of Ecochain Mobius and EcoInvent is deemed appropriate.

Overall, the results matched expectations: using a MOYU Rewritable Notebook A5 | Hardcover | Ring Binder emits less CO2 than using an A5 wood pulp Ring Binder Notebook.



Chapter 6

# Conclusion

The results show that the A5 Wood Pulp Ring Binder Notebook has a climate impact of 0.44 kilograms CO2 equivalent. The production phase contributes the most at 0.32 kilograms, mainly due to paper sheet production (0.3 kg). The remaining production impact comes from the cardboard cover and metal ring binder. Transport contributes 0.06 kilograms CO2 equivalent, and end-of-life 0.02 kilograms.

The MOYU Rewritable Notebook A5 l Hardcover l Ring Binder emits 0.37 kilograms CO2 equivalent. The production phase is the largest contributor at 0.18 kilograms, with stone paper sheet production accounting for 0.17 kilograms. End-of-life adds 0.14 kilograms, and transport 0.06 kilograms.

This means the MOYU notebook has a lower environmental impact than the wood pulp version. The difference per unit is 0.07 kilograms CO2 equivalent. Moreover, the MOYU notebook can be reused three times more than the paper version in a year. Therefore, using a MOYU notebook (0.37 kg CO2) instead of paper (1.11 kg CO2) saves 0.74 kilograms CO2 equivalent per year.

## Recommendations

The following recommendations provide advice on reducing the environmental impact of stone paper:

### Broader Comparison

Compare the MOYU Rewritable Notebook A5 l Hardcover l Ring Binder with products other than just the 80-page A5 wood pulp version. Many notebook types exist today. Comparing stone paper notebooks with others can reveal which is most sustainable and help MOYU continue improving.

### Leasing System

The end-of-life phase accounts for 36.8% of the total climate impact of stone paper. Optimizing this phase is crucial. Currently, stone paper notebooks are discarded with residual waste. A leasing system could change this. When a notebook is no longer usable, customers could return it to MOYU for recycling. This could reduce the climate impact of the end-of-life phase. Update: As of 2023 MOYU offers clients to return the notebook to MOYU.

### Broader Impact Assessment

In addition to climate change, consider assessing other environmental impacts like biodiversity and water usage. Stone paper does not require wood or water during production, unlike wood pulp. Since the LCA framework is already in place, these additional impacts could easily be included.

### LCAs of Other MOYU Products

Lastly, assess the environmental impact of other MOYU products. Since the LCA of the MOYU Rewritable Notebook A5 l Hardcover l Ring Binder is complete, it can serve as a template for evaluating other products. With stone paper data already available, calculating additional impacts would be straightforward. This would allow MOYU to communicate the environmental impact of its full product range.

# Data Sources & Methodology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# Appendix 1 - Software

Several software tools are available to support LCA processes. The most well-known programs are briefly described below (Zitzen, 2022). These software tools typically include multiple databases. In terms of data, a distinction is made between primary and secondary data. Primary data are raw measurements not previously recorded by other researchers, such as interviews. Secondary data are previously collected measurements, which apply to this research. Examples include published reports. Figure 1 illustrates aspects of data quality (JRC, 2016).

## SimaPro

With a 30-year history, SimaPro is one of the most recognized LCA tools. It is primarily used by experienced LCA professionals. The software includes numerous LCI databases, such as EcoInvent and the sector-specific Agri-footprint database (SimaPro, n.d.).

## Gabi

Gabi is a widely used LCA tool, particularly in German industry. Like SimaPro, it has been available for a long time and offers many technical features for product development, making it especially popular among consultants. It also includes LCI databases with over 13,500 datasets (Gabi, n.d.).

## OpenLCA

OpenLCA is a free LCA software tool comparable to the programs above. It is attractive for LCA beginners who lack a large budget, though it can also be used for more technical applications. One drawback is that many of OpenLCA's databases are not free (openLCA, n.d.).

## Ecochain Helix

Ecochain Helix is especially suitable for companies looking to improve the environmental footprint of their entire product portfolios. It allows for the simultaneous creation of footprints and EPDs for entire portfolios and includes a large LCI database (Ecochain, n.d.).

## Ecochain Mobius

This study uses Ecochain Mobius. Ecochain Mobius is generally easy to use, which makes it user-friendly. The software contains an extensive environmental impact database for a wide range of products. The rationale for selecting this tool is provided in Appendix 1 (Ecochain, n.d.).

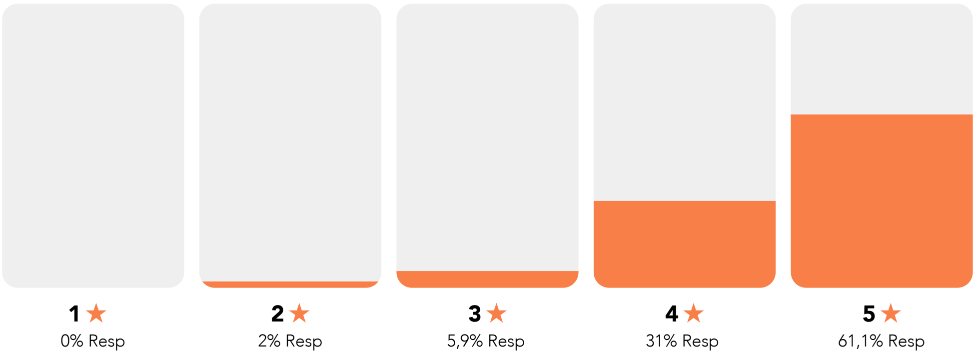
| | | | Data quality elements | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Representativeness | | | | | | |
| Quality level | Quality rating | Definition | Technological | Geographical | Time-related | Completeness | Methodological Appropriateness and Consistency | Parameter uncertainty |
| Very good | 1 | Meets the criterion to a very high degree, without need for improvement. | E.g. Process is same. For electricity from grid, average technology as country- specific consumption mix. | Country specific data | ≤ 3 years old data | Very good completeness (≥ 90 %) | Full compliance with all requirements of the PEF guide | Very low uncertainty (≤ 7 %) |
| Good | 2 | Meets the criterion to a high degree, with little significant need for improvement. | E.g. average technology as country- specific consumption mix. | Central Europe, North Europe, representative EU 27 mix, | 3-5 years old data | Good completeness (80 % to 90 %) | Attributional Process based approach AND following three method requirements of the PEF guide met: (1) Dealing with multi-functionality; (2) End of life modelling; (3) System boundary. | Low uncertainty (7 % to 10 %) |
| Fair | 3 | Meets the criterion to an acceptable degree, but merits improvement. | E.g. average technology as country- specific production mix or average technology as average EU consumption mix. | EU-27 countries, other European country | 5-10 years old data | Fair completeness (70 % to 80 %) | Attribution Process based approach AND two of the following three method requirements of the PEF guide met: (1) Dealing with multi-functionality; (2) End of life modelling; (3) System boundary. | Fair uncertainty (10 % to 15 %) |
| Poor | 4 | Does not meet the criterion to a sufficient degree, but rather requires improvement. | E.g. average technology as country- specific consumption mix of a group of similar products | Middle east, North-America, Japan etc. | 10-15 years old data | Poor completeness (50 % to 70 %) | Attributional Process based approach AND one of the following three method requirements of the PEF guide met: (1) Dealing with multi-functionality; (2) End of life modelling; (3) System boundary. | High uncertainty (15 % to 25 %) |
| Very poor | 5 | Does not meet the criterion. Substantial improvement is necessary. | E.g. other process or unknown, not available (n.a.) | Global data or unknown | ≥ 15 years old data | Very poor or unknown completeness (< 50 %) | Attributional Process based approach BUT: None of the following three method requirements of the PEF guide met: (1) Dealing with multi-functionality; (2) End of life modelling; (3) System boundary. | Very high uncertainty (>25 %) |

*Quality of Data (JRC 2016)*

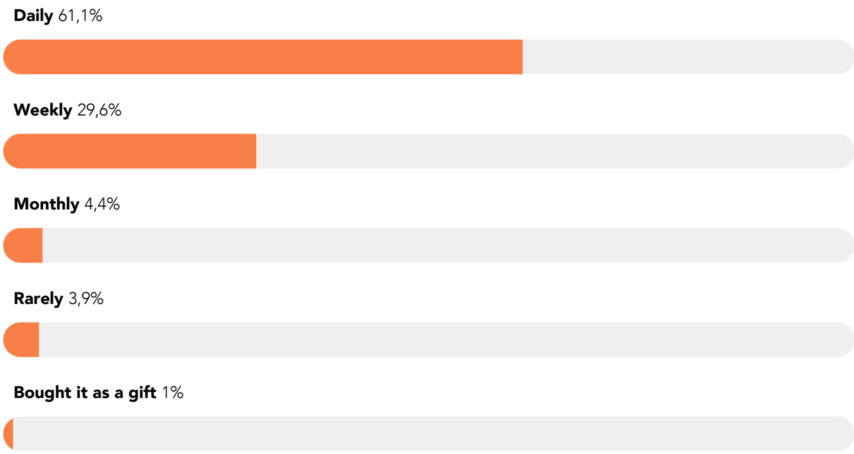
# Appendix 2 - Poll

To complement the Life Cycle Assessment and gain insight into public perception and consumer behavior, we conducted a short poll. The survey aimed to gather opinions on product satisfaction. The responses provide context to interpret the LCA findings in relation to real-world attitudes and behaviors.

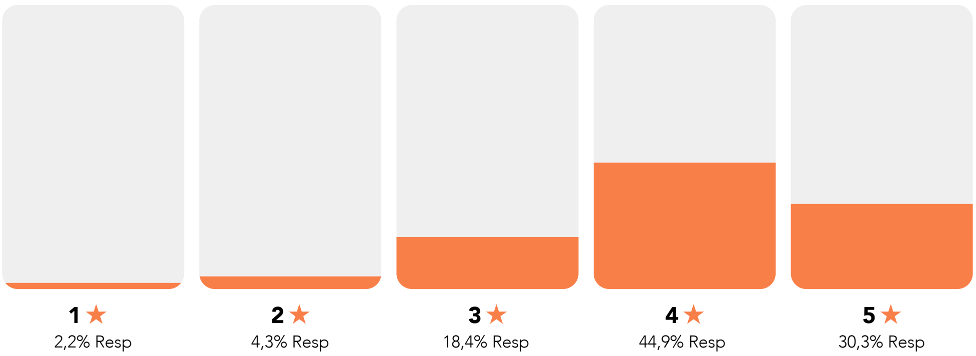
## How happy are you with your MOYU notebook?




## How often do you use your MOYU notebook?




## What do you think about the price/quality of a MOYU notebook?



# Final Note

This report represents MOYU's commitment to transparency, impact, continuous improvement and our mission is clear: to replace single-use paper.

**Wipe to Reforest.**