Results from Research on the Carbon Impact of Cash and Cashless Payments in Japan

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Executive Summary

Sustainable Development Goals (SDGs) and climate change measures outlined by the international community are gaining momentum, with systematic implementation taking place in Japan. Simultaneously, there is a substantial increase in interest at the individual consumer level. While JCB International Credit Card Co., Ltd. (JCB) is also advancing initiatives in expanding cashless payments, the discussion on how this can contribute to the SDGs and climate change measures is still in its early stages. Given this, JCB believes it is important to objectively and quantitatively demonstrate how cashless payments can contribute to the realisation of a better society for consumers and the affiliated ecosystem.

As the first step in this effort, JCB and Your Arbor Inc. (Arbor) have conducted joint research to calculate and analyse the Carbon Dioxide (CO_2e) emissions associated with consumer payment actions.

This white paper follows recommended guidelines in Life Cycle Assessment (LCA[1]) methodology to account for scope, data and interpretation of results. All results are expressed in CO_2 Equivalents (CO_2e[2]), as recommended by the Intergovernmental Panel on Climate Change (IPCC[3]). This step is taken to standardise the global warming potential of various greenhouse gases (GHG[4]) emitted in one functional unit[5] and to analyse the impact of macro-economic trends on overall climate change.

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[1] Life Cycle Assessment (LCA) is defined as the compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle.

[2] A metric measure used to compare the emissions from various greenhouse gases on the basis of their global warming potential (GWP). CO_2e is derived by converting the amount of carbon dioxide (CO_2) emission that would cause the same integrated radiative forcing or temperature change, over a given time horizon, as an emitted amount of a greenhouse gas (GHG) or a mixture of GHGs.

[3] The Intergovernmental Panel on Climate Change (IPCC) is an intergovernmental body of the United Nations. Its job is to advance scientific knowledge about climate change caused by human activities.

[4] Gases that trap heat in the atmosphere are called greenhouse gases. These lead to the greenhouse effect, including gases like CO_2, methane (CH_4), and nitrous oxide (N_2O).

[5] The comparative functional unit is a unit of measurement of system components to which inputs and outputs of LCA are normalised. The comparative functional unit is a "quantified performance of a product system for use as a reference unit".

Introduction

In the dynamic landscape of consumer transactions, the choice of payment method is a decision influenced by numerous factors, including the nature and location of the purchase, the quantity of goods or services involved, as well as considerations of convenience and associated benefits. The objective of this white paper is to provide quantitative insights into the carbon impact of individual transactions carried out using various payment options in Japan. This white paper aims to foster a greater awareness and consideration of carbon emissions, associated with selecting a payment method.

Goal and Scope

In this white paper, multiple payment options are evaluated including banknotes, coins, card payments and mobile payments. To maintain fair and comparable results, this white paper aims to quantify the carbon impact associated with each payment method and its entire life cycle system. All calculations are performed to measure the global warming potential (GWP[6]) of each payment method in CO_2e.

Payment Types

In this white paper, the payment types are divided into two categories: cash payments and cashless payments. Cash payments are traditional transactions in the form of legal tenders, namely banknotes and coins. Cashless payments are new forms of payment options, including card payments (debit or credit) and mobile payments (Mobile Tap and QR code).

[6] The Global Warming Potential (GWP) allows for comparisons of the global warming impacts of different gases. It is a measure of how much energy the emissions of 1 ton of a gas will absorb relative to the emissions of 1 ton of carbon dioxide (CO_2), over a given period of time.

Cash

Banknotes

Banknotes can vary in size and transaction amounts. Japanese banknotes are produced in four different denominations. The distribution of the different denominations has been collected through multiple sources, including publicly available resources through the National Printing Bureau and the Bank of Japan (“Banknotes and Coins”).

The distribution of the denominations is considered to create a reference (average) banknote, which is used to calculate the functional unit. The reference banknote contains manila hemp fibre (1.01 g), ink (0.01 g), foil (0.06 g), and thread (0.010 g).

Coins

The occurrence and denominations of coins were also collected using primary data from the Japan Mint, along with the components and weights of each coin. Similar to banknotes, an average coin was derived. The reference coin in this white paper is made of copper (4.58 g), nickel (0.92 g), zinc (0.55 g), tin (0.001 g), and aluminium (0.01 g). This white paper assumes that the metals used in coin blanks, including steel, aluminium, nickel, zinc, and tin, are sourced from recycled materials.

Cashless

Physical Card Payments

Data was collected for four different card types based on their chip module:

1. IC Chip Only
2. IC Chip + Type F
3. IC Chip + Type A/B
4. IC Chip + Type A/B/F.

Cards embedded with an integrated circuit (IC[7]) are known as IC cards. IC cards utilise a robust embedded IC chip with substantial capacity to directly store extensive information. The presence of an IC chip enhances security, as these cards are challenging to counterfeit and decrypt ("IC Cards").

Using insights derived from the data collected for this white paper, these cards are divided into five components: card body, chip module, antenna, hologram, and signature (sign) panel. The differences in each of these card components lie in the material composition of their chip module, and antenna.

Along with the cards, the other product systems involved in this payment type are the payment terminal and the data center.

Mobile Payments

Mobile payments are comprised of:

1. Tap Payment (Tap NFC[8])
2. Quick Response (QR codes) Payments

The mobile tap payment method includes a complete life cycle assessment of a smartphone, the payment terminal, and the data center. A smartphone has several common applications that use various amounts of energy stored in the battery. This white paper uses a derived factor to generate the calculation linked to each smartphone's energy use when initiating a transfer for either of the two mobile payment options.

Since the number of transactions for the Merchant Presented Method (MPM[9]) and the

[7] An integrated circuit (IC), sometimes called a chip, microchip or microelectronic circuit, is a semiconductor wafer on which thousands or millions of tiny resistors, capacitors, diodes and transistors are fabricated. A card with an embedded IC (Integrated Circuit) is called an IC card.

[8] A wireless communication technology that enables the exchange of data between devices over a short distance, commonly used for contactless payments.

[9] Merchant-Presented Mode (MPM) is one of two types of unified QR codes and barcodes, in which the user's smartphone reads a QR code indicated by the store, and the user enters the amount of payment.

Customer Presented Method (CPM[10]) was not available, the total CO_2e emission from all QR code transactions was calculated instead of the CO_2e emission per QR code transaction..

The product systems involved in this method of QR code payment are the smartphone, the electronic device (payment terminal), and the data center.

In the CPM, the customer produces a QR code on their smartphone, which is then scanned by the merchant using an electronic device (assumed to be similar in components to the payment terminal). The product systems considered to calculate the impact of a CPM QR code transaction are the smartphone, the electronic device (payment terminal), and the data center.

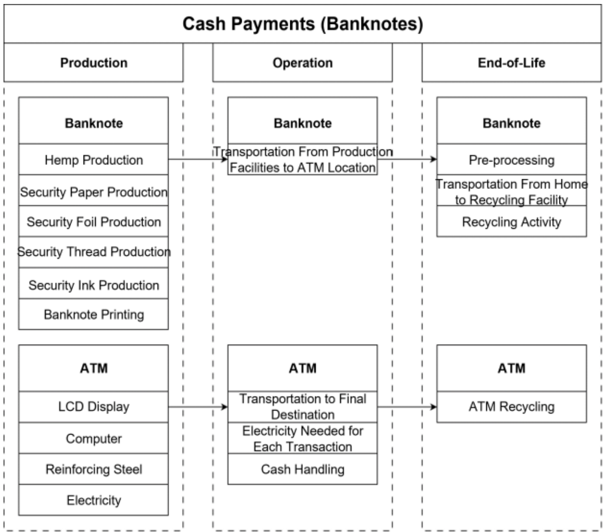
System Boundary[11] for the Data Inventory Utilized

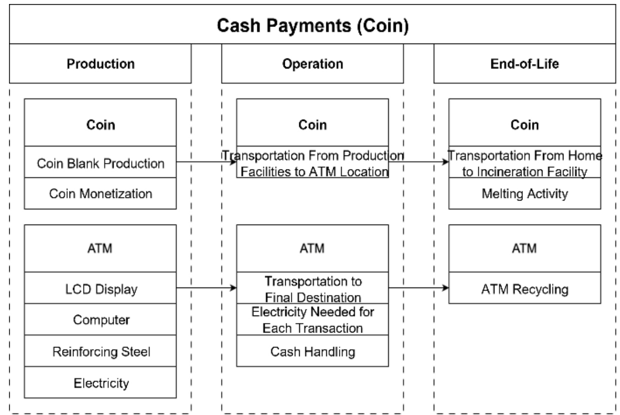
The System Boundary Diagram at Figure 1 serves as a conceptual map, illustrating the boundaries of the system under consideration and identifying key elements that contribute to the carbon impact associated with different payment options.

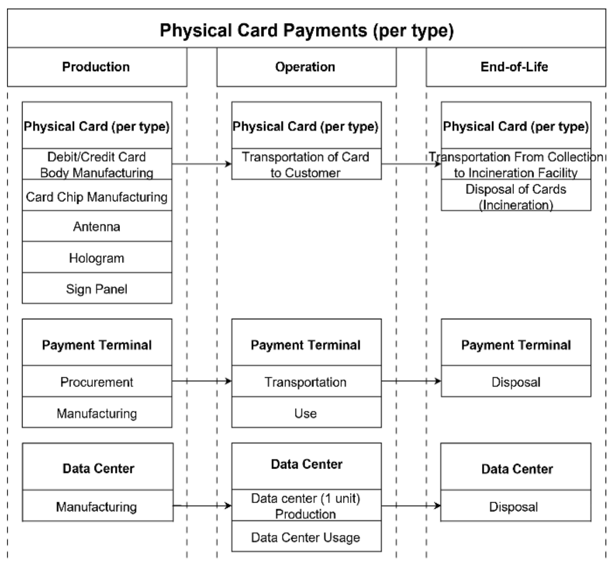
This diagram not only aids in identifying the primary processes and components within the payment methods but also highlights the interconnected relationships between them. By visually representing the system boundaries, stakeholders can gain insights into the carbon impact of each payment method, from traditional card transactions to emerging technologies like mobile payments.

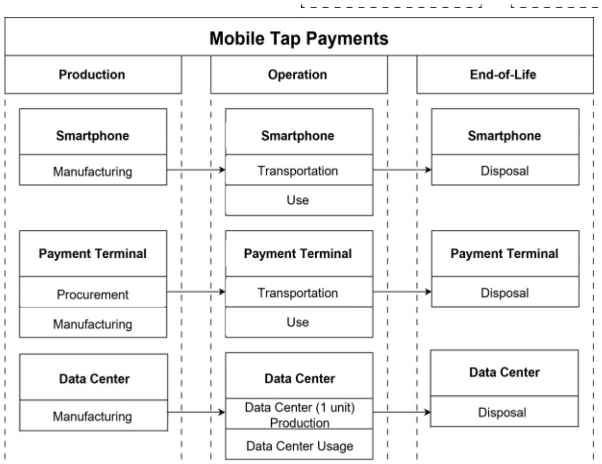
[10] Consumer-Presented Mode (CPM) is one of two types of unified QR codes and barcodes, in which a user displays a QR code or barcode on the smartphone and asks the store to read it for payment.

[11] System Boundary refers to the limits that are defined around a product system being assessed. The system boundary outlines the scope of the assessment and identifies what processes and activities are included or excluded from the analysis. A clear system boundary ensures that the assessment is relevant, consistent, and transparent.


Cash Payments (Banknotes)
Production
Operation
End-of-Life
Banknote
Hemp Production
Security Paper Production
Security Foil Production
Security Thread Production
Security Ink Production
Banknote Printing
Banknote
Transportation From Production Facilities to ATM Location
Banknote
Pre-processing
Transportation From Home to Recycling Facility
Recycling Activity
ATM
LCD Display
Computer
Reinforcing Steel
Electricity
ATM
Transportation to Final Destination
Electricity Needed for Each Transaction
Cash Handling
ATM
ATM Recycling


Cash Payments (Coin)
Production
Operation
End-of-Life
Coin
Coin Blank Production
Coin Monetization
Coin
Transportation From Production Facilities to ATM Location
Coin
Transportation From Home to Incineration Facility
Melting Activity
ATM
LCD Display
Computer
Reinforcing Steel
Electricity
ATM
Transportation to Final Destination
Electricity Needed for Each Transaction
Cash Handling
ATM
ATM Recycling


Physical Card Payments (per type)
Production
Operation
End-of-Life
Physical Card (per type)
Debit/Credit Card Body Manufacturing
Card Chip Manufacturing
Antenna
Hologram
Sign Panel
Physical Card (per type)
Transportation of Card to Customer
Physical Card (per type)
Transportation From Collection to Incineration Facility
Disposal of Cards (Incineration)
Payment Terminal
Procurement
Manufacturing
Payment Terminal
Transportation
Use
Payment Terminal
Disposal
Data Center
Manufacturing
Data Center
Data center (1 unit) Production
Data Center Usage
Data Center
Disposal


Mobile Tap Payments
Production
Operation
End-of-Life
Smartphone
Manufacturing
Smartphone
Transportation
Use
Smartphone
Disposal
Payment Terminal
Procurement
Manufacturing
Payment Terminal
Transportation
Use
Payment Terminal
Disposal
Data Center
Manufacturing
Data Center
Data Center (1 unit) Production
Data Center Usage
Data Center
Disposal

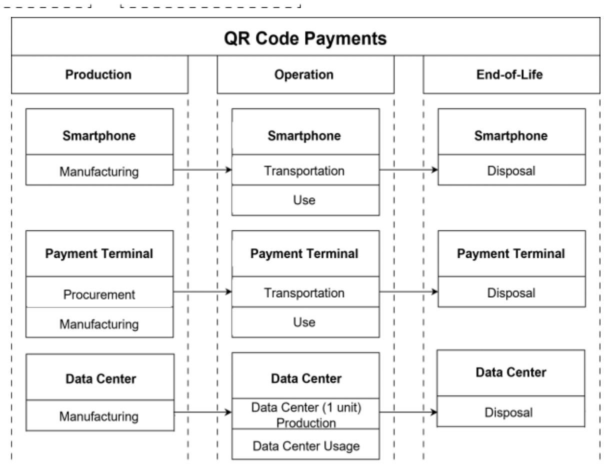

QR Code Payments
Production
Operation
End-of-Life
Smartphone
Manufacturing
Smartphone
Transportation
Use
Smartphone
Disposal
Payment Terminal
Procurement
Manufacturing
Payment Terminal
Transportation
Use
Payment Terminal
Disposal
Data Center
Manufacturing
Data Center
Data Center (1 unit) Production
Data Center Usage
Data Center
Disposal

Figure 1. High Level Logic and System Boundary for the Data Inventory Utilised in this White Paper.

Table 1 lists all activities, and the data sources for each, included in the scope of the calculation performed in this white paper.

Since the data center is used for both the card payment method and the mobile payment method, the carbon impact of the whole lifecycle stages for the data center including production and end-of-life[12] was initially calculated and then applied to each payment method.

<table>
<tr><th>Payment Method</th><th>Type</th><th>Lifecycle Stage</th><th>Component</th><th>Source for Input Data</th></tr>
<tr><td rowspan="13">Cash Payments (Banknote)</td><td rowspan="11">Banknote</td><td rowspan="6">Production</td><td>Hemp Production</td><td>Secondary Data</td></tr>
<tr><td>Security Paper Production</td><td>Secondary Data</td></tr>
<tr><td>Security Foil Production</td><td>Secondary Data</td></tr>
<tr><td>Security Thread Production</td><td>Secondary Data</td></tr>
<tr><td>Security Ink Production</td><td>Secondary Data</td></tr>
<tr><td>Banknote Printing</td><td>Secondary Data</td></tr>
<tr><td>Operation</td><td>Transportation from Production Facilities to ATM</td><td>Secondary Data (Calculated by Arbor based on public data)</td></tr>
<tr><td rowspan="3">End-of-Life</td><td>Pre-processing</td><td>Secondary Data</td></tr>
<tr><td>Transportation From Home to Recycling Facility</td><td>Secondary Data (Calculated by Arbor based on public data)</td></tr>
<tr><td>Recycling Activity</td><td>Secondary Data</td></tr>
<tr><td rowspan="2">ATM</td><td rowspan="2">Production</td><td>LCD Display</td><td>Secondary Data</td></tr>
<tr><td>Computer</td><td>Secondary Data</td></tr>
</table>

[12] A stage in a product's life cycle which includes the recycling, re-use, or disposal of a product.

			Reinforcing Steel	Secondary Data
			Electricity	Secondary Data
		Operation	Transportation to Final Destination	Secondary Data
			Electricity Needed for Each Transaction	Primary Data (Domestic ATM Manufacturers)
			Cash Handling	Secondary Data
		End-of-Life	ATM Recycling	Secondary Data
Cash Payments (Coin)	Coin	Production	Coin Blank Production	Primary Data (Calculated by JCB based on publicly available resources through the Japan Mint)
			Coin Monetization	Secondary Data
		Operation	Transportation from Production Facility to ATM	Primary Data (Calculated by JCB together with Arbor based on public data)
		End-of-Life	Transportation from Home to Recycling Facility	Primary Data (Calculated by JCB together with Arbor based on public data)
			Melting Activity	Secondary Data
	ATM	Production	LCD Display	Secondary Data
			Computer	Secondary Data
			Reinforcing Steel	Secondary Data
			Electricity	Secondary Data
		Operation	Transportation to Final Destination	Secondary Data
			Electricity Needed for Each Transaction	Primary Data (Domestic ATM Manufacturers)
			Cash Handling	Secondary Data
		End-of-Life	ATM Recycling	Secondary Data
Physical Card Payments	Physical Card	Production	Debit/Credit Card Body Manufacturing	Primary Data (TOPPAN Edge Inc., Dai Nippon Printing Co., Ltd.)

(per types)	(per types)		Card Chip Manufacturing	Primary Data (TOPPAN Edge Inc., Dai Nippon Printing Co., Ltd.)
			Antenna	Primary Data (TOPPAN Edge Inc., Dai Nippon Printing Co., Ltd.)
			Hologram	Primary Data (TOPPAN Edge Inc., Dai Nippon Printing Co., Ltd.)
			Sign Panel	Primary Data (TOPPAN Edge Inc., Dai Nippon Printing Co., Ltd.)
		Operation	Transportation of Card to Customer	Primary Data (Calculated by JCB together with Arbor based on public data)
			Payment Terminal (Cradle-to-Grave LCA)	Primary Data (Panasonic Connect Co., Ltd.)
			Data Center (1 unit) Production	Secondary Data
			Data Center Electricity Usage	Primary Data (TIS Inc.)
		End-of-Life	Transportation From Collection to Incineration Facility	Primary Data (Calculated by JCB together with Arbor based on public data)
			Disposal of Cards (Incineration)	Secondary Data
	Payment Terminal	Production	Procurement	Primary Data (Panasonic Connect Co., Ltd.)
			Manufacturing	Primary Data (Panasonic Connect Co., Ltd.)
		Operation	Transportation	Primary Data (Panasonic Connect Co., Ltd.)
			Use	Primary Data (Panasonic Connect Co., Ltd.)
		End-of-Life	Disposal	Primary Data (Panasonic Connect Co., Ltd.)
	Data Center	Operation	Data Center (1 unit) Production	Secondary Data
			Data Center Usage	Primary Data (TIS Inc.)
Mobile Tap	Smartphon	Production	Manufacturing	Primary Data (Apple Inc.)

Payments	e	Operation	Transportation	Primary Data (Apple Inc.)
			Use	Primary Data (Apple Inc.)
		End-of-Life	Disposal	Primary Data (Apple Inc.)
	Payment Terminal	Production	Procurement	Primary Data (Panasonic Connect Co., Ltd.)
			Manufacturing	Primary Data (Panasonic Connect Co., Ltd.)
		Operation	Transportation	Primary Data (Panasonic Connect Co., Ltd.)
			Use	Primary Data (Panasonic Connect Co., Ltd.)
		End-of-Life	Disposal	Primary Data (Panasonic Connect Co., Ltd.)
	Data Center	Operation	Data Center (1 unit) Production	Secondary Data
			Data Center Usage	Primary Data (TIS Inc.)
QR Code Payments	Smartphon e	Production	Manufacturing	Primary Data (Apple Inc.)
		Operation	Transportation	Primary Data (Apple Inc.)
			Use	Primary Data (Apple Inc.)
		End-of-Life	Disposal	Primary Data (Apple Inc.)
	Payment Terminal	Production	Procurement	Primary Data (Panasonic Connect Co., Ltd.)
			Manufacturing	Primary Data (Panasonic Connect Co., Ltd.)
		Operation	Transportation	Primary Data (Panasonic Connect Co., Ltd.)
			Use	Primary Data (Panasonic Connect Co., Ltd.)
		End-of-Life	Disposal	Primary Data (Panasonic Connect Co., Ltd.)
	Data Center	Operation	Data Center (1 unit) Production	Secondary Data
			Data Center Usage	Primary Data (TIS Inc.)

Table 1. Calculation Scope.

Information on production processes, energy consumption, bill of materials, and other relevant factors have been gathered based on the following categories to ensure completeness and accurate representation.

- Primary Data: Refers to quantified values obtained directly from public sources, government, industry associations, or corporations, for the specific purpose of their study, including quantified values calculated using data acquired from the aforementioned entities, within the product system.
- Secondary Data: Refers to data that does not meet the strict requirements to be qualified as primary data and is instead, quantified values from external life cycle databases[13], scientific papers and proxy data including average values calculated using data obtained from the aforementioned sources.

- Supplementary Data: Refers to data gathered to fill in data gaps in the primary data regarding input amounts, and values used for allocating the inputs to a comparative functional unit. This includes scientific literature, publicly available industry reports, and up-to-date databases.

[13] A comprehensive collection of data used in Life Cycle Assessment (LCA) that provides detailed information about the environmental impacts associated with materials, processes, and products over their entire life cycle. This database includes inputs and outputs, such as raw material extraction, energy use, waste generation, and emission data.

To produce accurate impact estimations for each payment method, primary data is collected where possible. In order to guide data collection through a number of unknowns, the following sets of principles were considered, in the following order of priority, when collecting primary data for each of the payment methods:

1. Prioritise data gathering for a specific target device if it exceeds a market share of at least 50% in Japan.
2. If there are multiple products, either individually or collectively, with a market share of at least 50%, collect data for those products and compute the averages.

Calculation Steps & Results

Methodology and Approach

The data methodology used in this white paper involves several components to measure the carbon impact, across its entire life cycle, from cradle-to-grave[14], for each payment option. The data methodologies, frameworks, and sources used in this white paper simulate supply chain steps to determine environmental impacts[15].

This white paper covers the entire life cycle of each payment method, including manufacturing, distribution, usage, and disposal. Following the ISO 14040 standard, this white paper uses a comprehensive life cycle model for each payment method, mapping out the stages from raw material extraction to disposal, while assigning energy consumption and emission factors to each stage. The stages of the payment methods have been divided into 3 sub-systems: Production Phase, Operation Phase, and End-of-Life (EOL) phase.

The ISO 14040 standard offers principles for conducting an LCA, outlining a set of international criteria for GHG accounting and reporting. The standard also addresses quantitative assessment methods for evaluating the environmental impacts of a product or service in the stages of its entire life cycle. It is an overarching standard encompassing all three phases of LCA (Production, Operation, EOL) and provides a comprehensive view. The defined framework covers requirements and terminology for an LCA and provides guidance on four main phases: goal and scope definition, inventory analysis, impact assessment, and interpretation. ISO 14040/44 aims to ensure consistency, transparency, and reliability of LCA studies, and to facilitate comparison and communication of LCA results.

[14] Cradle-to-Grave is a model used in the scientific footprint method Life Cycle Assessments (LCA). It assesses the complete environmental footprint of products. From raw material extraction, production, and product use, until the end of its life.
[15] Environmental impacts in the LCA context refer to adverse impacts on the areas of concern such as ecosystem, human health, and natural resources.

The attributional LCA method[16] was chosen in this white paper, characterised by its emphasis on enabling direct comparisons between the carbon impact of products. This method helps identify aspects within a product's life cycle that have the most significant environmental impact. The raw data collected during the life cycle inventory collection phase is converted to environmental impact numbers using life cycle impact assessment methods (LCIA[17]). The LCIA method applied in this white paper is "Environmental Footprint v3.0 no LT"[18] and the GWP results are calculated to represent the environmental impact of a transaction as a single carbon impact score, measured in grams of CO_2e (g CO_2e).

Secondary and supplementary data was used to fill data gaps in the calculations that existed where:

1. Materials and processes involved in various payment methods were confidential due to security reasons.
2. Unavailability of primary data, for numerous reasons such as IP protection, and uncertainty in data provided by the stakeholder.
3. Data was difficult to access due to organisational constraints or complexity of supply chains.

The data collection and calculations have been conducted by Arbor, a Global Reporting Initiative (GRI) licensed carbon management platform.

GRI, the world's most widely used sustainability reporting standard is used throughout this white paper to display data, allocations, and results. The standards used in this report are related to emissions, energy, and waste to create calculation inputs and outputs while

[16] A set of procedures and conventions for conducting a life cycle assessment, encompassing all stages from goal definition, data collection, impact assessment to interpretation.
[17] Life cycle impact assessment (LCIA) is the method for converting inventory data from a life cycle assessment into a set of potential impacts. This enables practitioners and decision makers to better understand the damage caused by resource use and emissions.
[18] Environmental Footprint v3.0 (EF v3.0) is the Environmental Footprint method that is maintained by the European Commission. It is a midpoint method assessing several impact categories.

the supplier analysis standard is used to verify validity and conduct normalisation of data provided through stakeholders.

Allocation of Assumptions

Usage patterns amongst different payment methods can vary greatly. To ensure fair comparisons, this white paper uses a functional unit of “per transaction” for each payment method to allocate, aggregate, and compare the CO_2e impact across payment methods.

Cash Payments

The number of transactions and the average transaction value for Cash Payments were estimated based on the number of transactions and the average transaction value for Cashless Payments because the data for Cash Payments is not available. The number of transactions for Cash Payments was calculated from the number of transactions for Cashless Payments in 2022[19] and the ratio of Cashless Payments in 2022[20] on the assumption that the transaction value for Cash Payments can be calculated by subtracting the transaction value for Cashless Payments in 2022[21] from the Private Consumption Expenditure in 2022 as seen in Table 2. The average transaction value of 3,762 Yen for Cashless Payments was also used for Cash Payments on the assumption that the amount is equivalent.

Cashless Payments

Physical Card Payments

To measure the impact from the raw material production, transportation, and EOL for a single card transaction, the number of times an average card is used throughout its lifetime is utilised. This value is estimated using primary data on the number of card transactions in 2022, and

[19] Calculated based on publicly available resources through the Bank of Japan, the Japan Consumer Credit Association, and the Japanese Cashless Promotion Association.
[20] Calculated based on publicly available resources through the METI.
[21] Calculated based on publicly available resources through the Bank of Japan, the Japan Consumer Credit Association, and the Japanese Cashless Promotion Association.

supplementary data on the number of active credit and debit cards used in Japan in 2022 ("The Japan Consumer Credit Association" and "the Bank of Japan"). Most of the issued credit cards have a validity period of 3-7 years. Since the data by validity period was not available, the worst case lifetime was chosen which is 3 years as per the guidelines in the LCA methodology.

Payment Terminal

The cradle-to-grave impact for the payment terminal was measured using the total number of transactions that a terminal can handle over its lifetime. The total number of transactions was estimated using the assumption of 50 transactions handled per day. This number is calculated by dividing the total number of Cashless Transactions listed in Table 2 (29,513,171,105) by the number of Payment Terminals (including point-of-sale (POS[22]) and CCT[23]) shipped over the last five years, 2018 through and including 2022 (1,623,774[24]). This ratio is defined as the operational count of terminals, for a lifetime of 6 years. This assumption is derived from the LCA study conducted by the payment terminal manufacturer.

Smartphone

The cradle-to-grave analysis on a reference smartphone was used to estimate the carbon impact resulting from the smartphone's contribution to a single transaction.

Data Center

The impact of the operation of the data center to process transactions forms a major part of the total impact of the data center. The impact amount for this stage is collected from primary data. To measure the impact coming from the raw material production of the data center, primary data on the number of transactions processed by the data center was used.

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[22] The point at which a retail transaction is completed, involving the necessary software and hardware to process payments.

[23] Credit Center Terminal that is installed at a merchant and connected with credit card companies, enabling an online validity check and authorization approval.

[24] Any tablets or smartphones procured by merchants themselves are not included.

The purpose of this white paper is to measure and analyse the CO_2e emissions associated with payment methods utilised in the Japanese economy. Therefore, the measurements and analysis take into account region-specific variations in energy sources, trade, and infrastructure. This enables a more accurate representation of the carbon footprint[25] based on the location of the study.

[25] The total amount of greenhouse gas emissions (primarily carbon dioxide) generated by a product or activity, expressed in units of carbon dioxide equivalents (CO_2e).

The number of transactions per payment method for 2022 are detailed in Table 2 below.

Payment Type	Payment Method	Number of Transactions in 2022 (Count)	Data Source	Transaction Amount in 2022 (Yen)	Source Type
Cash	Banknotes	52,504,618,545	Calculated by JCB based on the number of transactions for Cashless Payment and primary data obtained from METI[26]	197,513,717,000,000	Calculated by JCB based on the transaction value for Cashless Payment and primary data obtained from Cabinet Office[27]
	Coins				
Cashless	Credit Card	15,849,197,105	Japan Consumer Credit Association[28]	93,792,600,000,000	Japan Consumer Credit Association[29]
	Debit Card	742,000,000	Bank of Japan[30]	3,219,000,000,000	Bank of Japan[31]
	Mobile Tap	5,882,000,000	Bank of Japan[32]	6,083,900,000,000	Bank of Japan[33]
	QR Code Payment	7,039,974,000	Japanese Cashless Promotion Association[34]	7,928,183,000,000	Japanese Cashless Promotion Association[35]

[26] Calculated based on "The ratio of Cashless Payment in 2022" published by the METI
[27] Calculated based on "SNA (National Accounts of Japan)" published by the Cabinet Office
[28] Calculated based on "Dynamic Research Survey on Credit Card Transactions" published by the Japan Consumer Credit Association
[29] Calculated based on "Statistics on Japan Credit" published by the Japan Consumer Credit Association
[30] Calculated based on "Payment and Settlement Statistics" published by the Bank of Japan
[31] Same as above
[32] Same as above
[33] Same as above
[34] Calculated based on "Statistics on Code Payment" published by the Japanese Cashless Promotion Association
[35] Same as above

Total	=	82,017,789,650	Calculated by JCB based on the number of transactions for Cashless Payments	308,537,400,000,000	Cabinet Office[36]

Table 2. Transaction Data per Payment Method for 2022.

[36] Calculated based on “SNA (National Accounts of Japan)” published by the Cabinet Office

1. Cash (Banknotes & Coins)

The total environmental impact of a single transaction of 3,762 Yen is considered in this white paper. This amount is calculated on the assumption that the value is the same as Cashless Payments.

Variable	Amount	Source
Amount of Annual Cash Payment	¥197,513,717,000,000	Calculated by JCB based on the transaction value for Cashless Payment and primary data obtained from Cabinet Office
Number of Annual Cash Payment Transactions	52,504,618,545	Calculated by JCB based on the number of transactions for Cashless Payment and primary data obtained from METI
Average Single Transaction	¥3,762	Assumed the average transaction value for Cash Payment is same as that for Cashless Payment

Table 3. Breakdown of a Single Transaction for Cash Payments.

1.1 Banknotes

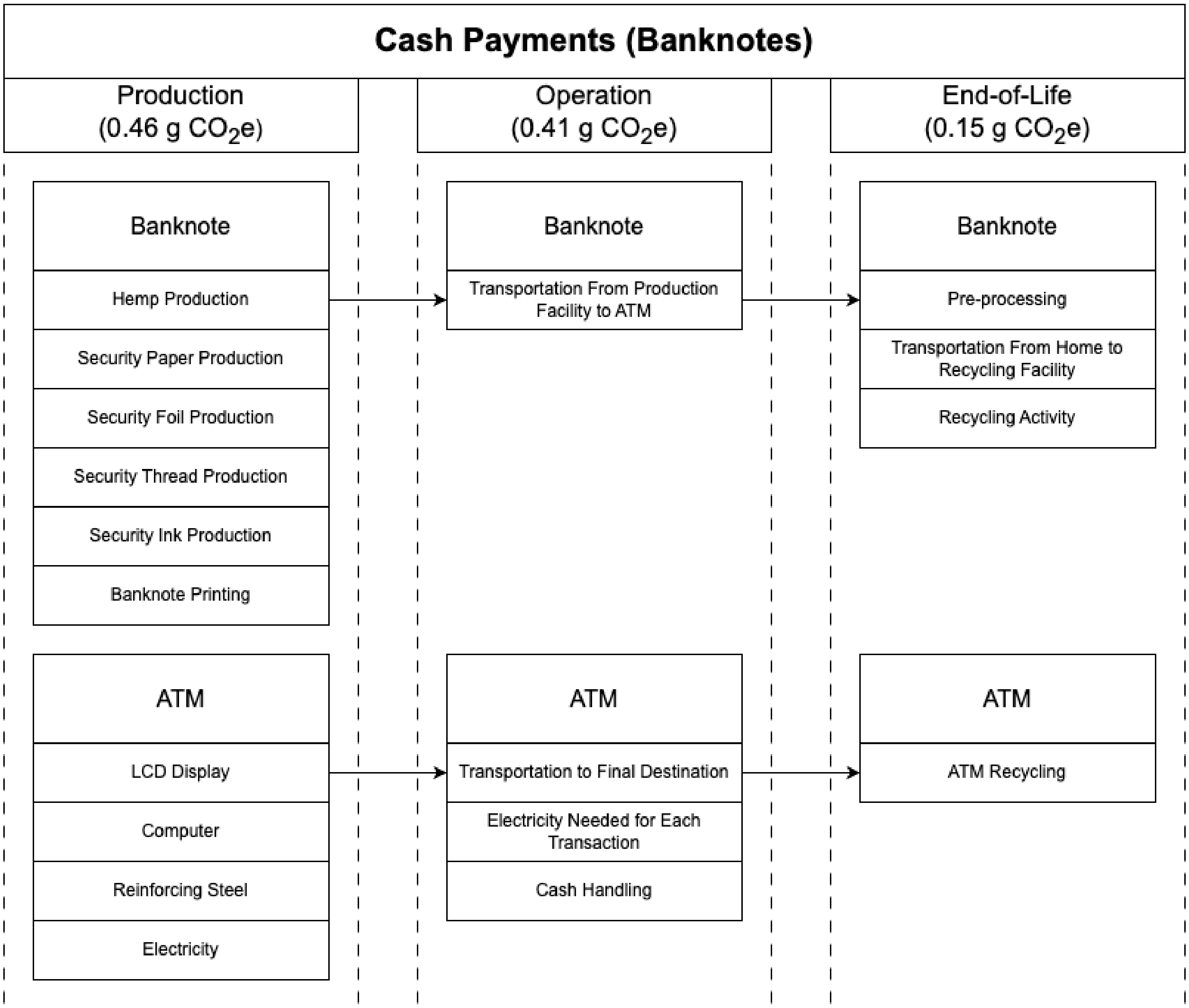

Figure 2a. Cash Payments Process Flow Diagram.

$$\underbrace{0.46 \text{ g } CO_2e}_{\text{Production}} + \underbrace{0.41 \text{ g } CO_2e}_{\text{Operation}} + \underbrace{0.15 \text{ g } CO_2e}_{\text{End-of-Life}} = \underbrace{1.01 \text{ g } CO_2e}_{\text{Per Transaction}}$$ [37]

[37] All numerical values in this paper have been rounded to two decimal places for the purpose of presentation. Intermediate calculations were performed using the full precision of the original data to minimise rounding errors. As a result, the displayed values may exhibit slight discrepancies in their summation due to the applied rounding methods.

Figure 3. Summary for Banknotes Calculation.

1.1.1 Production

The production of banknotes involves four main materials - manila hemp, thread, foil, and ink, which are combined in different processes, i.e., security paper production and banknote printing. The inventory data for the raw materials used in the production of banknotes has been estimated using publicly available resources through the National Printing Bureau and supplementary data from literature (Hanegraaf et al.). Collecting primary data around the production of banknotes is challenging due to security purposes. The raw materials in the production process are outlined in Table 20.

Raw Material Production

To model the weight, this white paper considers the average weights of the banknote materials, being manila hemp, thread, foil, and ink, based on the denominations used.

Security Paper Production

Security paper is created by blending fibre, enhancers, substances, and an abundant amount of water (99%) into a fibrous mixture. Throughout the production procedure, the majority of the water is transformed into vapour (Hanegraaf et al.). Since there was a lack of primary data concerning the fabrication of security paper, comparable processes from life cycle databases were employed to estimate the ecological consequences linked to security paper manufacturing, see Table 20.

Security Foil and Thread Production

The foil is structured using comparable proportions of polyester, resin, and aluminium, while the thread encompasses polyester and aluminium components. Additionally, plastic spools are employed to package both the foil and thread. The packaging has not been included. See Table 20 for inventory used in the calculation.

Security Ink Production

The ingredients used in the manufacturing of security ink are strictly confidential and unobtainable. Therefore, the ecological influence of security ink was estimated through reference to regular ink. Amounts of ink employed in creating banknotes, along with the energy consumption of the printing machinery, were modelled using supplementary data (Hanegraaf et al.).

Banknote Printing

The production process of banknotes involves the implementation of distinct printing phases. During these printing steps, polyethylene terephthalate (PET[38]) printing plates and chrome-nickel printing plates are used. The operating life of the printing plates and their carbon implications have been integrated into the assessment. Additionally, the utilisation of a cleansing solution has also been factored into the analysis.

1.1.2 Operation

Transportation from Production Facilities to ATM Location

The weighted average transportation distance was used to calculate the distance from The National Printing Bureau to every listed town and city in Japan[39] via the Bank of Japan. The distance is weighted by the population relative to the total Japanese population[40] to derive an average of the respective town or city. A trucking distance of 382.4 km between the production facilities and the ATM location was calculated.

[38] Polyethylene terephthalate (PET or PETE), a strong, stiff synthetic fibre and resin and a member of the polyester family of polymers.
[39] Source: Geospatial Information Authority of Japan website (https://terras.gsi.go.jp/)
[40] Source: Portal Site of Official Statistics of Japan website (https://www.e-stat.go.jp/)

1.1.3 End-of-Life

Transport to Recycling Facility

Following pre-processing (shredding), EOL banknotes are transported to a recycling facility where they are recycled. The distance transported from the user to the recycling facility is estimated to be 382.4 km. The distance of 382.4 km is used again, assuming that recycling occurs at the same location as the banknote manufacturing.

Recycling

The impact from the treatment of the banknote is then modelled using data derived from life cycle databases.

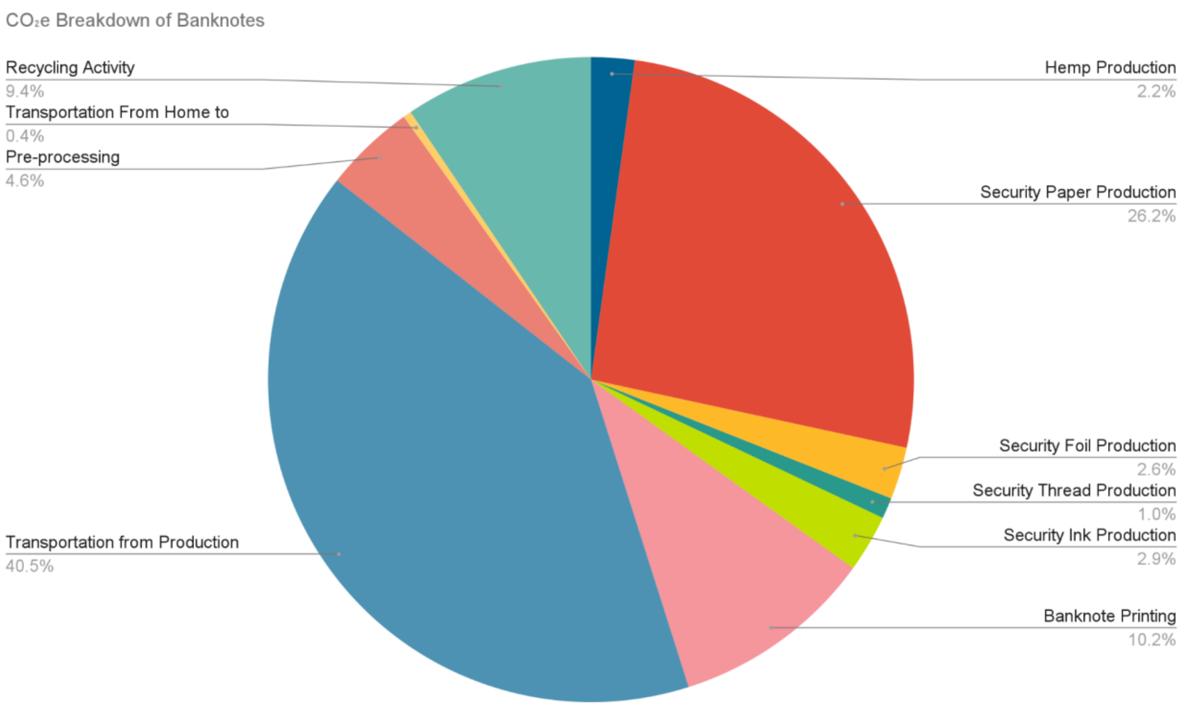

Figure 4. CO_2e Breakdown of Banknotes.

CO_2e Breakdown of Banknotes			
Lifecycle stage	**Component**	**Impact (g CO_2e)**	**Impact Percentage**

Production	Hemp Production	0.02	2.17%
	Security Paper Production	0.27	26.22%
	Security Foil Production	0.03	2.62%
	Security Thread Production	0.01	1.05%
	Security Ink Production	0.03	2.88%
	Banknote Printing	0.10	10.18%
Operation	Transportation from Production Facilities to ATM	0.41	40.48%
End-of-Life	Pre-processing	0.05	4.56%
	Transportation From Home to Recycling Facility	<0.01	0.41%
	Recycling Activity	0.10	9.44%

Table 4. CO_2e Breakdown of Banknotes.

1.2 Coins

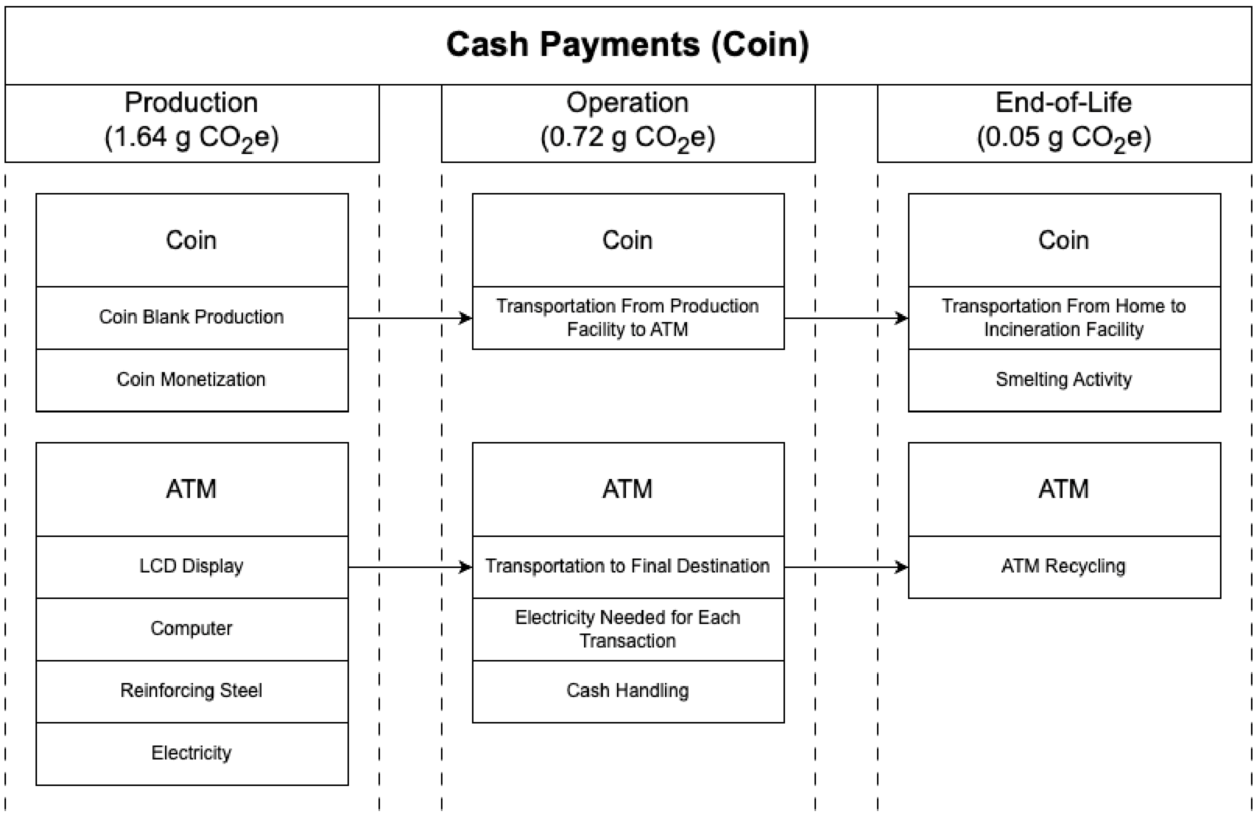

Figure 2b. Cash Payments Process Flow Diagram.

1.64 g CO_2e	+	0.72 g CO_2e	+	0.05 g CO_2e	=	2.41 g CO_2e
Production		Operation		End-of-Life		Per Transaction

Figure 5. Summary for Coins Calculation.

Coins have been integral to commerce for centuries. From the selection of materials to the intricate minting techniques, understanding the essence of coin production provides insights into the CO_2e impact associated with this traditional payment option.

It is worth noting that material selection can vary from coin to coin, and even though they are minted for long time circulation, the transaction value is relatively small in comparison to all other payment methods.

1.2.1 Production

The production of coins has been divided into two sub-processes: the production of coin blanks and the monetizing of coins. Coins typically have a long lifespan, which we have assumed to be 30 years[41] to account for the impact from the production of coins (Hanegraaf et al.). The raw materials, and the amounts required to produce a coin, is estimated using primary data from Table 1.

Coin Blank Production

This procedure encompasses the refinement, pressing, blanking, annealing, and upsetting of metals (Hanegraaf et al.).

Coin Monetization

The inputs needed for coin monetization were derived using existing literature and the source of inputs for electricity production was collected from secondary data (Hanegraaf et al.). It is assumed that monetization occurs in the same facility as the coin blank production.

1.2.2 Operation

Transportation From Production Facilities to ATM Location

The weighted average transportation distance was used to calculate the distance from The Japan Mint's factory in Osaka to every listed town and city in Japan[42] via the Bank of Japan. The distance is weighted by the population relative to the total Japanese population[43] to derive an average of the respective town or city. A trucking distance of 357.6 km was used for the coin transportation.

[41] Based on publicly available resources through the Japan Mint
[42] Source: Geospatial Information Authority of Japan website (https://terras.gsi.go.jp/)
[43] Source: Portal Site of Official Statistics of Japan website (https://www.e-stat.go.jp/)

1.2.3 End-of-Life

Transport to Recycling Facility

The distance travelled by coins from the user to the recycling facility is estimated to be 357.6 km. The distance of 357.6 km is used again, assuming that recycling occurs at the same location as the coin manufacturing.

Recycling

For the EOL phase, it is assumed that the coins are demonetized and then recycled to produce new coins. Since the coins are recycled to form new coins, the impact for recycling is modelled using the inputs for minting the coin.

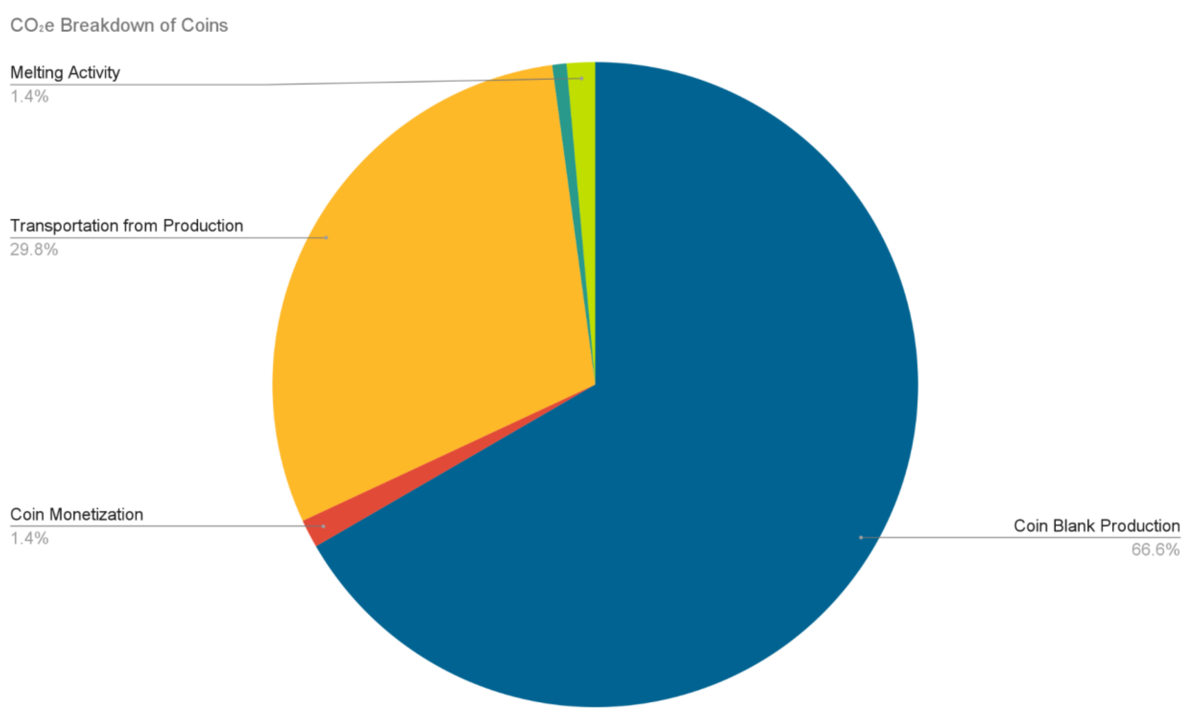

Figure 6. CO_2e Breakdown of Coins.

CO_2e Breakdown of Coins			
Lifecycle stage	**Component**	**Impact (g CO_2e)**	**Impact Percentage**
Production	Coin Blank Production	1.61	66.64%

	Coin Monetization	0.03	1.42%
Operation	Transportation from Production Facility to ATM	0.72	29.81%
End-of-Life	Transportation from Home to Recycling Facility	0.02	0.72%
	Melting Activity	0.03	1.42%

Table 5. CO_2e Breakdown of Coins.

1.3 ATM

$$\underbrace{5.08 \text{ g } CO_2e}_{\text{Production}} + \underbrace{1.96 \text{ g } CO_2e}_{\text{Operation}} + \underbrace{0.10 \text{ g } CO_2e}_{\text{End-of-Life}} = \underbrace{7.14 \text{ g } CO_2e}_{\text{Per Transaction}}$$

Figure 7. Summary for ATM Calculation.

1.3.1 Production

To model the impact from the production of an ATM, supplementary data from LCA studies were used (Hanegraaf et al.). The components utilised in constructing an ATM can be summarised as follows: one personal computer, one screen, and approximately 700 kg of reinforced steel over an assumed average lifespan of ten years.

1.3.2 Operation

1.3.2.1 ATM Usage

It is assumed that the ATM is transported 1,200 km by truck to its final destination as per PEFCR. A one-time transportation impact is calculated for the ATM’s lifetime, after which it stays in use.

Along with transportation, the energy consumption of ATMs has been considered. The energy consumption, in watt-hours (Wh), can be divided into two categories: idle energy consumption (184.67 Wh) and active energy consumption (650 Wh). The energy consumption for these two categories are averages derived using primary data from multiple ATM makers in Japan. It is assumed that ATMs remain online, using idle energy consumption, when not actively used. It is estimated that an ATM machine processes approximately 137 transactions per day. This is calculated using the total number of daily transactions for domestic convenience store ATMs in 2022 by applying the "average daily usage per ATM" data published in Seven Bank's 2021 and 2022 IR materials by prorating the data based on the estimated number of ATMs in all domestic convenience stores and the proportion of Seven Bank's ATMs. The total daily transaction numbers for bank ATMs and Japan Post Bank ATMs for the year 2022 were estimated using the ratio of the number of bank ATMs and Japan Post Bank ATMs to the number of domestic convenience store ATMs, as published by the Japanese Bankers Association. Using this information, the total number of daily transactions for domestic ATMs was calculated. These use phase values were collected via primary data collection, as seen in Table 1.

1.3.2.2 Cash Handling

This white paper accounts for the cradle-to-grave impact of the cash handling machines. Data regarding the energy usage of counting machines, deployed for the verification and validation of banknotes, amounts to 207.6 kilowatt-hours (kWh[44]) per one million units of banknotes. As information around the energy consumption of similar machines is not accessible, it is presumed that the energy usage of the counting apparatus is similar to that of the equipment used by the printing facilities. This assumption was grounded in the observation that there are a limited number of counting machine versions accessible, all of which operate in a comparable manner.

[44] A measure of electricity defined as a unit of work or energy, measured as 1 kilowatt (1,000watts) of power expended for 1 hour.

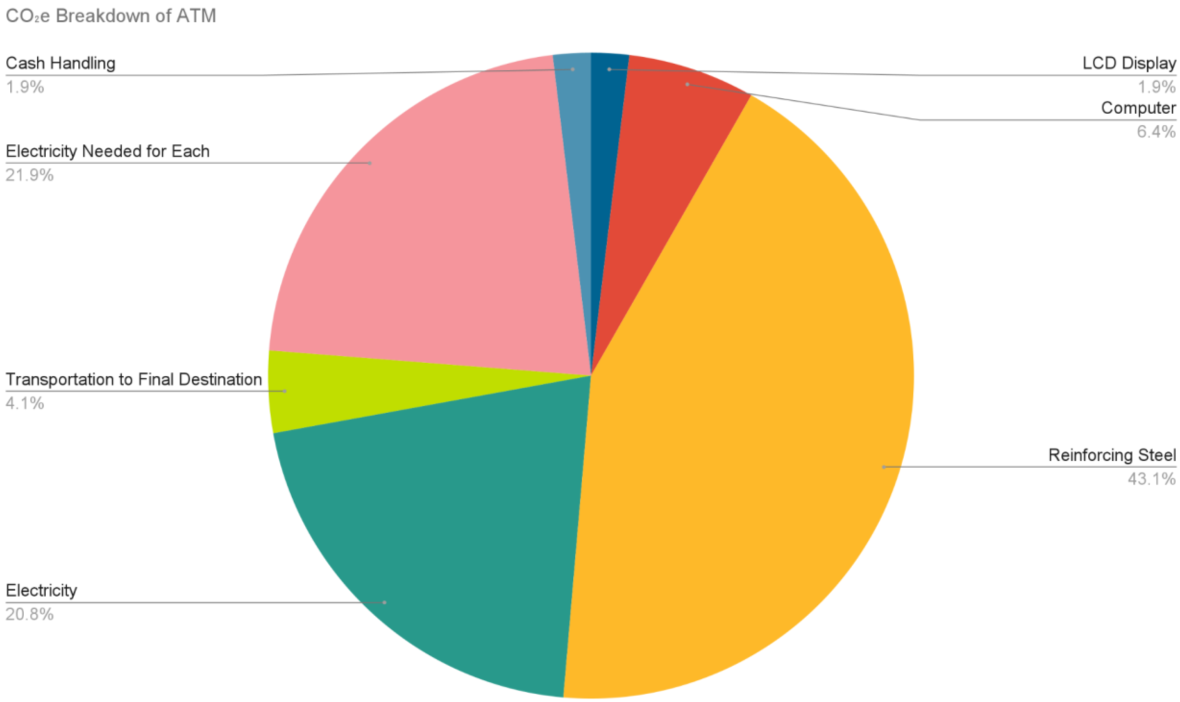

Figure 8. CO_2e Breakdown of ATM.

CO_2e Breakdown of the ATM			
Lifecycle Stage	**Component**	**Impact (g CO_2e)**	**Impact Percentage**
	LCD Display	0.13	1.87%
	Computer	0.45	6.28%
	Reinforcing Steel	3.04	42.50%
Production	Electricity	1.46	20.49%
	Transportation to Final Destination	0.29	4.04%
Operation	Electricity Needed for Each Transaction	1.54	21.55%
	Cash Handling	0.13	1.87%
End-of-Life	ATM Recycling	0.10	1.39%

Table 6. CO_2e Breakdown of the ATM.

1.4. Cash Based Payment Results

Cash transactions have a carbon impact of 10.57 g CO_2e per transaction. Based on market share of the amount of banknotes and coins in circulation in Japan for the year 2022, the functional unit was divided to be allocated in both product systems. Among the inventory inputs, the production and operational phases of the ATM influence the carbon impact of the cash payment method the most at 66.67% of the total carbon impact per transaction, followed by the cradle-to-grave impact of coins at 22.82%. Figure 9 provides a breakdown of the CO_2e associated with each cash transaction.

7.18 g CO_2e	+	3.09 g CO_2e	+	0.30 g CO_2e	=	10.57 g CO_2e
Production		Operation		End-of-Life		Per Transaction

Figure 9. Summary for Cash Calculation.

Data Inventory

Table 7 provides a high-level overview of the sources of key carbon intensive activities associated with the Cash payment option. The in-depth inventory breakdown per payment method is attached in the appendix.

Production Phase			
Payment Method	**Component**	**Unit**	**Input Activity**
Banknote	Security Paper Production	kg	Market for Sulfate Pulp, Bleached, RoW
		kg	Chemi-thermomechanical Pulp Production, RoW
		kg	Paper Production, Newsprint, Virgin, RoW
		kg	Corrugated Board Box Production, RoW
		kg	Polyethylene Terephthalate Production, Granulate, Amorphous, RoW
		MWh	Market for Electricity, Low Voltage, Japan

Coin	Coin Blank Production	g	Copper Production, Cathode, Solvent Extraction and Electrowinning Process, GLO
		g	Aluminium Production, Primary, Ingot,RoW
		g	Primary Zinc Production from Concentrate, RoW
		g	Tin Production, RoW
		g	Market for Nickel Concentrate, 16% Ni, GLO
		tkm	Transport, Freight, Lorry 16-32 metric ton, EURO4, RoW
Operation Phase			
Banknote & Coin	ATM	kWh	Market for Electricity, Low Voltage, Japan
End-of-Life Phase			
Coin	Melting	kWh	Electricity Production, Oil, Japan

Table 7. Key Carbon Intensive Activities Inventory Breakdown.

2. Cashless (Card and Mobile Payments)

2.1 Card Payments

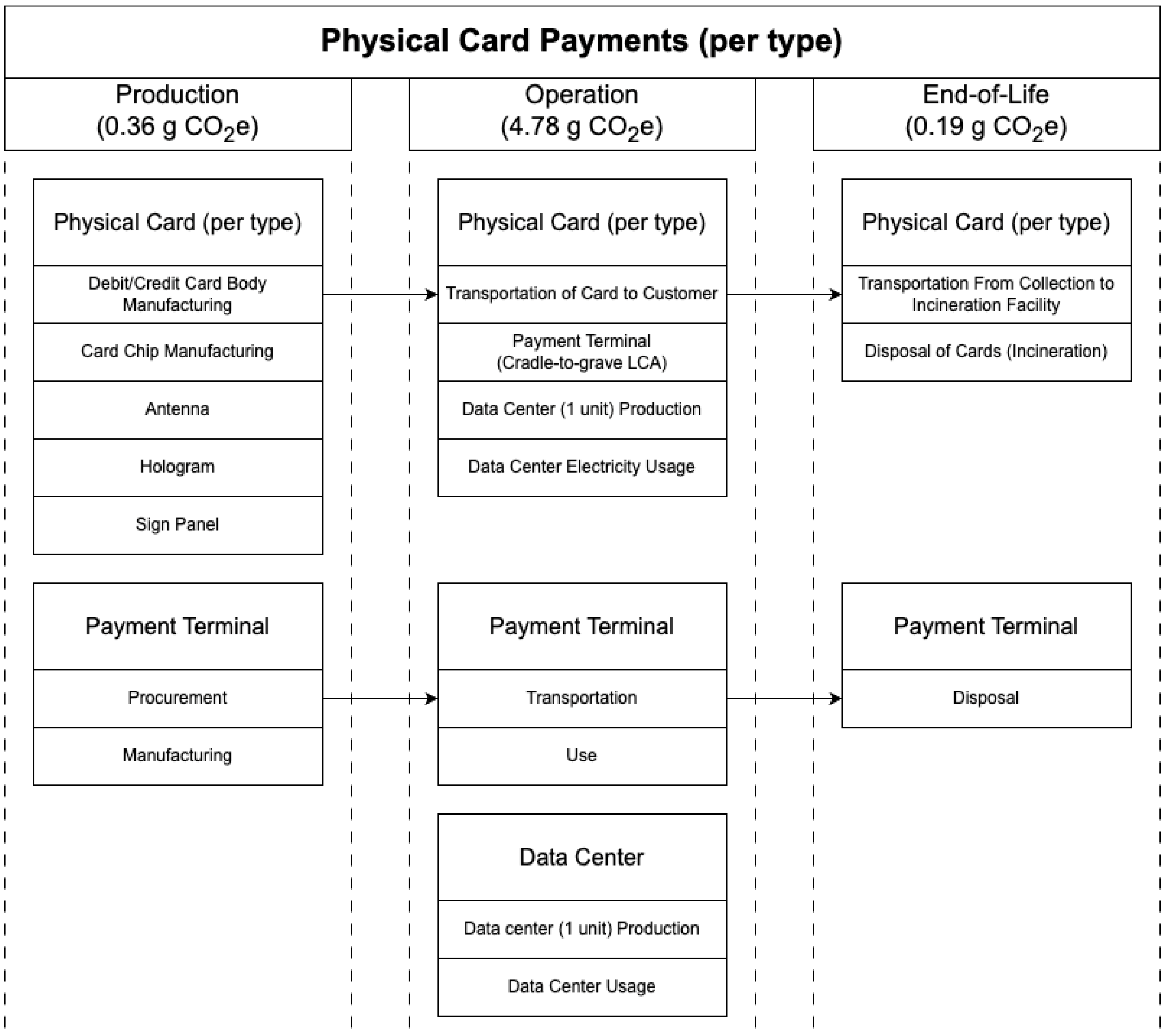

Figure 10. Card Payments Process Flow Diagram.

$$\underbrace{0.35\ \text{g}\ CO_2e}_{\text{Production}} + \underbrace{4.78\ \text{g}\ CO_2e}_{\text{Operation}} + \underbrace{0.19\ \text{g}\ CO_2e}_{\text{End-of-Life}} = \underbrace{5.32\ \text{g}\ CO_2e}_{\text{Per Transaction}}$$

Figure 11. Summary for IC Chip Only Card Calculation.

$$\underbrace{0.38\ \text{g}\ CO_2e}_{\text{Production}} + \underbrace{4.78\ \text{g}\ CO_2e}_{\text{Operation}} + \underbrace{0.19\ \text{g}\ CO_2e}_{\text{End-of-Life}} = \underbrace{5.34\ \text{g}\ CO_2e}_{\text{Per Transaction}}$$

Figure 12. Summary for IC Chip + Type F Card Calculation.

$$\underbrace{0.36\ \text{g}\ CO_2e}_{\text{Production}} + \underbrace{4.78\ \text{g}\ CO_2e}_{\text{Operation}} + \underbrace{0.19\ \text{g}\ CO_2e}_{\text{End-of-Life}} = \underbrace{5.33\ \text{g}\ CO_2e}_{\text{Per Transaction}}$$

Figure 13. Summary for IC Chip + Type A/B Card Calculation.

$$\underbrace{0.37\ \text{g}\ CO_2e}_{\text{Production}} + \underbrace{4.78\ \text{g}\ CO_2e}_{\text{Operation}} + \underbrace{0.19\ \text{g}\ CO_2e}_{\text{End-of-Life}} = \underbrace{5.34\ \text{g}\ CO_2e}_{\text{Per Transaction}}$$

Figure 14. Summary for IC Chip + Type A/B/F Card Calculation.

2.1.1 Production

The production of cards is modelled using primary data from Table 1 for the following card components: the card body, the chip module, the antenna, the hologram, and the signature panel. The number of transactions made by each card throughout its estimated lifetime has been used to allocate the impact of production, transportation, and disposal of the card. The most important material by weight in a card is usually Polyvinyl Chloride (PVC[45]) for its body, and other components mainly consist of metal conductors (Lindgreen et al.). An average impact from the four different cards was estimated to represent the impact of a general card used in Japan for the year 2022. It is observed that the only difference in card types arises in the raw materials used in the cards' makeup.

2.1.2 Operation

Transportation

To model the transportation of raw materials from the production facility to the end customer, a distance of 447.7 km by truck was used based on the weighted average (by population) of distance from the manufacturing factory to all cities in Japan. The distances between the manufacturing facilities and the distribution center provided by TOPPAN Edge Inc. and Dai Nippon Printing Co., Ltd.

The weighted average transportation distance was used to calculate the distance from the manufacturing factory to every listed town and city in Japan[46]. The distance is weighted by the population relative to the total Japanese population[47] to derive an average of the respective town or city.

[45] Polymerization of vinyl chloride (monomer) results in the production of polyvinyl chloride or PVC. PVC is a high-strength thermoplastic material.
[46] Source: Geospatial Information Authority of Japan website (https://terras.gsi.go.jp/)
[47] Source: Portal Site of Official Statistics of Japan website (https://www.e-stat.go.jp/)

Payment Terminal

Primary data inputs from an LCA study conducted by Panasonic Connect Co., Ltd. were used to derive the Japanese-specific impact of a payment terminal. To allocate this impact to a single calculation, the total cradle-to-grave impact was divided by the total number of transactions handled by a terminal in its lifetime.

Data Center

Electronic payment transactions are handled by data centers, involving a two-step process: the initial authorization phase, followed by the subsequent stage of payment, clearing, and settlement. The data collected includes the breakdown of components and input quantities within data centers responsible for processing electronic payment transactions. Supplementary data was used for the materials utilised in certain aspects of a data center such as chillers, pump racks, computer components, and infrastructural elements (Oliveira). These elements are then quantified in kilograms. Additionally, this white paper accounts for material input from IT equipment and power equipment (Whitehead et al.).

Comprehensive details, including estimated lifetimes of all the components utilised were considered using supplementary data ("Data Center Life Cycle"). To model the impact of the processes, this white paper leveraged inputs from the Ecoinvent database v3.8[48].

The impact data regarding the use phase of a data center, specifically for JCB card transactions, is collected from primary data from the relevant data centers. Data provided by Cardnet was used to estimate Acquiring (ACQ) impact. When a cardholder initiates a payment at a merchant, the transaction data undergoes a series of steps to reach the card issuer. The process involves the following stages:

1. Merchant to Credit Card Network (e.g. Japan Card Network)

[48] The ecoinvent Database is a leading Life Cycle Inventory (LCI) database that supports various types of sustainability assessments by providing in-depth information on product processes, production systems, and services in terms of their environmental impacts.

2. Japan Card Network to Acquirer[49] (e.g. JCB)
3. Acquirer to Credit Card Network
4. Credit Card Network to Card Issuer (e.g. JCB)

Regarding the data center, emissions data is calculated based on the total CO_2e emissions data obtained from Japan Card Network and TIS Inc., a contractor for the maintenance and operation of JCB's data centers.

The CO_2e emissions per transaction is then calculated by dividing the total emissions by the annual transaction volume. This comprehensive approach ensures a thorough assessment of the carbon impact associated with each transaction stage in the data center.

2.1.3. End-of-Life

To model the EOL impact of cards, it is assumed that the cards are incinerated and disposed of as municipal trash. The transportation form collection to the incineration or recycling facility data was unavailable and therefore the distance travelled from the customer to the disposal site is assumed to be 101 km as per PEFCR.

The impact from the EOL phase is estimated using secondary data from the Ecoinvent database v3.8.

2.1.4. Results

The average carbon impact per card transaction for an average card type as noted below amounts to 5.33 g of CO_2e. Figure 15 provides a breakdown of the CO_2e associated with each card transaction.

[49] Acquirer (ACQ) typically relates to merchant acquiring services. These services involve processing payments and transactions for merchants.

Average Card Impact per transaction: 5.33 g CO_2e

a. IC Chip only: 5.32 g CO_2e

b. IC Chip + Type F: 5.34 g CO_2e

c. IC Chip + Type A/B: 5.33 g CO_2e

d. IC Chip + Type A/B/F: 5.34 g CO_2e

Figure 15. CO_2e Breakdown Cards Compared.[50]

[50] Among the Payment Terminal, the paper rolls required during use phase are the most significant CO_2e contributor, accounting for 70.4% of the payment terminal's impact.

CO_2e Breakdown Cards Compared					
Lifecycle Stage	**Component**	**IC Chip Cards**	**IC Chip + Type F Cards**	**IC Chip + Type A/B Cards**	**IC Chip + Type A/B/F Cards**
Production	Debit/Credit Card Body Manufacturing	5.64%	5.61%	5.62%	5.61%
	Card Chip Manufacturing	0.90%	1.21%	0.90%	0.90%
	Antenna	<0.01%	0.22%	0.22%	0.43%
	Hologram	<0.01%	<0.01%	<0.01%	<0.01%
	Sign Panel	0.01%	0.01%	0.01%	0.01%
Operation	Transportation of Card to Customer	0.11%	0.11%	0.11%	0.12%
	Payment Terminal (Cradle-to-Grave LCA)[51]	76.35%	75.94%	76.18%	76.01%
	Data Center (1 unit) Production	0.36%	0.36%	0.36%	0.36%
	Data Center Electricity Usage	13.14%	13.07%	13.11%	13.09%
End-of-Life	Transportation From Collection to Incineration Facility	0.02%	0.02%	0.02%	0.02%
	Disposal of Cards (Incineration)	3.46%	3.44%	3.45%	3.45%

Table 8. CO_2e Breakdown of Card Payments.

Data Inventory

Table 9 provides a high-level overview of the key carbon intensive activities and the data source associated with the card payment method. The inventory breakdown per payment method can be seen in Table 23.

Production Phase			
Payment Method	**Component**	**Unit**	**Input Activity**

[51] Same as above

Card	Card Body	g	Polyvinyl Chloride Production, Suspension Polymerisation, RoW + Injection Moulding, RoW
		g	Copper Production, Cathode, Solvent Extraction and Electrowinning Process, GLO + Wire Drawing, Copper, RoW
Operation Phase			
Card	Data Center Usage	kWh	Market for Electricity, Low Voltage, Japan
End-of-Life Phase			
Card	Disposal of Cards	kg	Treatment of Waste Plastic, Mixture, Municipal Incineration, RoW

Table 9. Key Carbon Intensive Activities Inventory Breakdown in Card Payments.

2.2. Mobile Payments (Mobile Tap & QR Code)

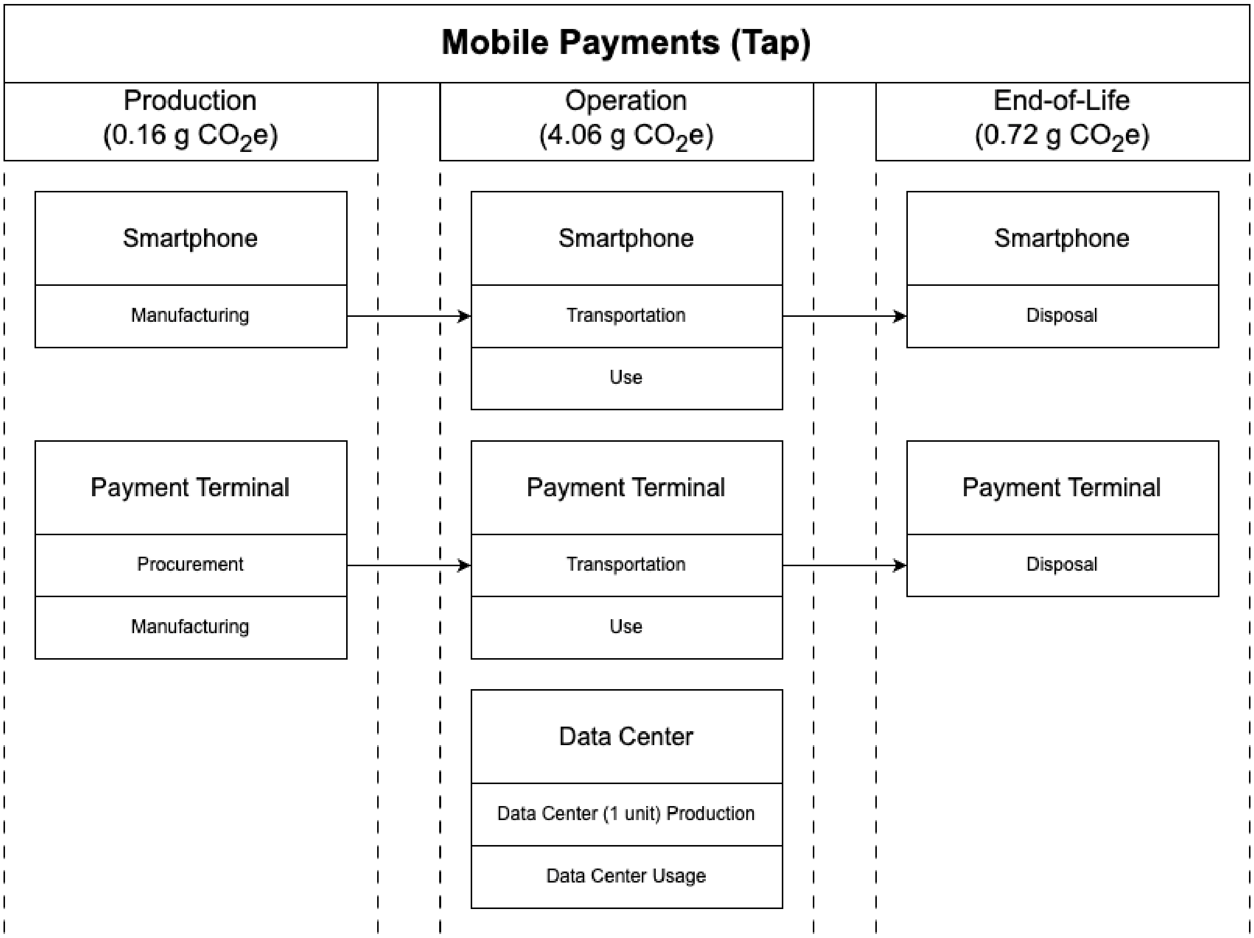

Figure 16a. Mobile Tap Payment Process Flow Diagram.

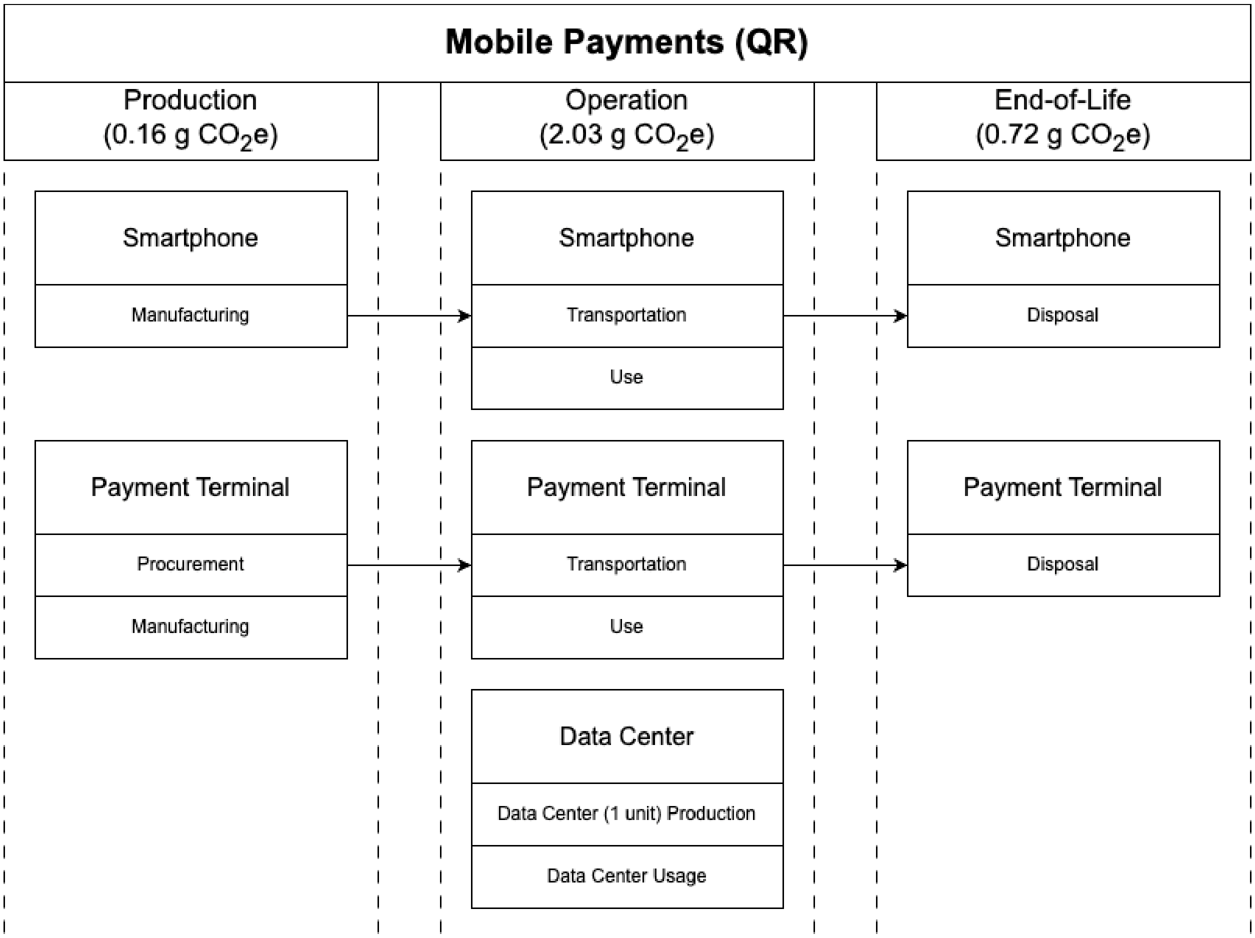

Figure 16b. Mobile Payment (QR Code) Process Flow Diagram.

This section of the white paper delves into the realm of mobile payments, shedding light on two prominent methods: Mobile Tap and QR Code Payments.

2.2.1 Mobile Tap Payment

Tap NFC payments harness the potential of proximity-based communication technology to facilitate swift and secure transactions. By utilising NFC chips embedded in smartphones and payment terminals, users can initiate transactions by simply tapping their devices near the terminal.

To estimate the carbon impact associated with mobile tap payment systems, three main resource intensive components are considered: the smartphone, the payment terminal, and the data center.

2.2.1.1 Smartphone

For the impact of the smartphone, supplementary data was used from the cradle-to-grave LCA study by Apple on the Apple iPhone 13 pro max 1TB. This assumption is in line with the data selection criteria set forth in the methodology section. The carbon impact for this product was estimated in the LCA study as 117 kg CO_2e ("Product Environmental Report"). To allocate this impact to one transaction, the overall impact was multiplied by a factor which represents the amount of a phone's total impact attributed to a single transaction. This factor is calculated by dividing the electricity needed to make a single transaction by the total energy consumed by an average smartphone throughout its lifetime.

2.2.1.2 Payment Terminal

The payment terminal used for mobile tap payments is the same device used for card payments, and therefore the impact calculations used for the payment terminal portion of the aforementioned card payment type are used for mobile tap payments, outlined in section 2.1.2 - Payment Terminal, above.

2.2.1.3 Data Center

The impact from the data center was estimated in the same manner as for the aforementioned card payment type, outlined section 2.1.2 - Data Center, above.

2.2.1.4 Results for the Mobile Tap Payment System

Mobile tap payments have a carbon impact of 4.93 g of CO_2e per transaction. Figure 17 presents the relative contributions of each unit process to the overall CO_2e.

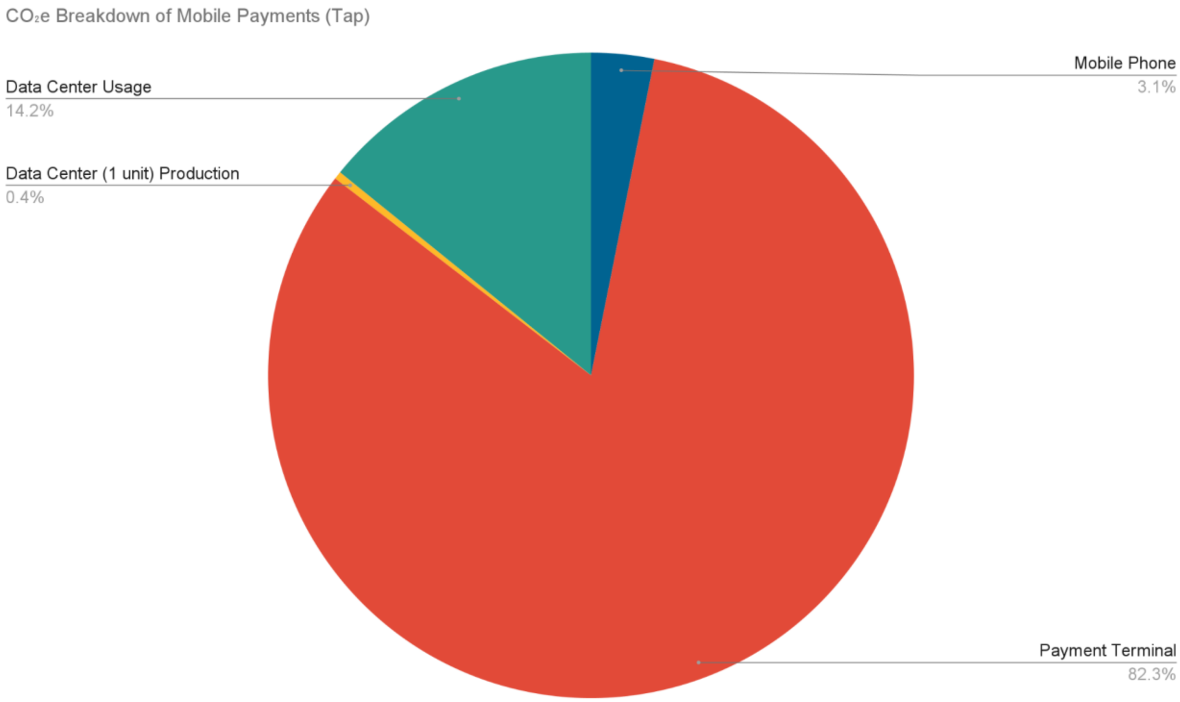

Figure 17. CO_2e Breakdown of Mobile Tap Payments.

CO_2e Breakdown of Mobile Tap Payments			
Lifecycle Stage	**Component**	**Impact (g CO_2e)**	**Impact Percentage**
Production	Smartphone	0.16	3.15%
Operation	Payment Terminal	4.06	82.30%
End-of-Life	Data Center (1 unit) Production	0.02	0.39%
	Data Center Usage	0.70	14.17%

Table 10. CO_2e Breakdown of Mobile Tap Payments.

Data Inventory

Table 11 provides a high-level overview of the sources of key carbon intensive activities associated with the Mobile Tap payment method. The inventory breakdown per payment method is attached in Table 24.

Payment Terminal		
Component	**Unit**	**Input Activity**
Payment Terminal	Unit	Payment Terminal Cradle-to-Grave

Table 11. Key Carbon Intensive Activities Inventory Breakdown.

2.2.2 QR Code Payments

Since the number of each CPM and MPM transaction was not available, the total CO_2e emission from all QR code payment transactions was calculated on the assumption that the number of CPM transactions and that of MPM transactions are same.

2.2.2.1 Customer Presented Method (CPM)

In this white paper, the carbon impact for CPM was estimated by using a CCT terminal instead of a POS system as the POS system is used for other purposes. Major components involved in the CPM method are the smartphone (consumer), a payment terminal to scan the QR code (merchant), and the data center. The impact from the smartphone was estimated in the same way as section 2.2.1.1 – Smartphone, by multiplying the electricity needed to make a single QR code payment transaction by the total number of CPM transactions (half of the total QR code payment transactions). Meanwhile, the impact from a payment terminal and the data center was estimated in the same way as section 2.2.1 – Mobile Tap Payment, above.

2.2.2.2 Merchant Presented Method (MPM)

For the MPM method, the major components involved are the smartphone (consumer) and the data center. The impact from the printed piece of paper is not considered due to its negligible impact, considering the number of transactions it is used to process. The impact of the smartphone and the data center was estimated using the same methodology as mentioned in sections - 2.2.2.1 - CPM, above.

2.2.2.3 Results of the QR Code Payment System

QR code transactions have a carbon impact of 20431.9 g CO_2e from all transactions.

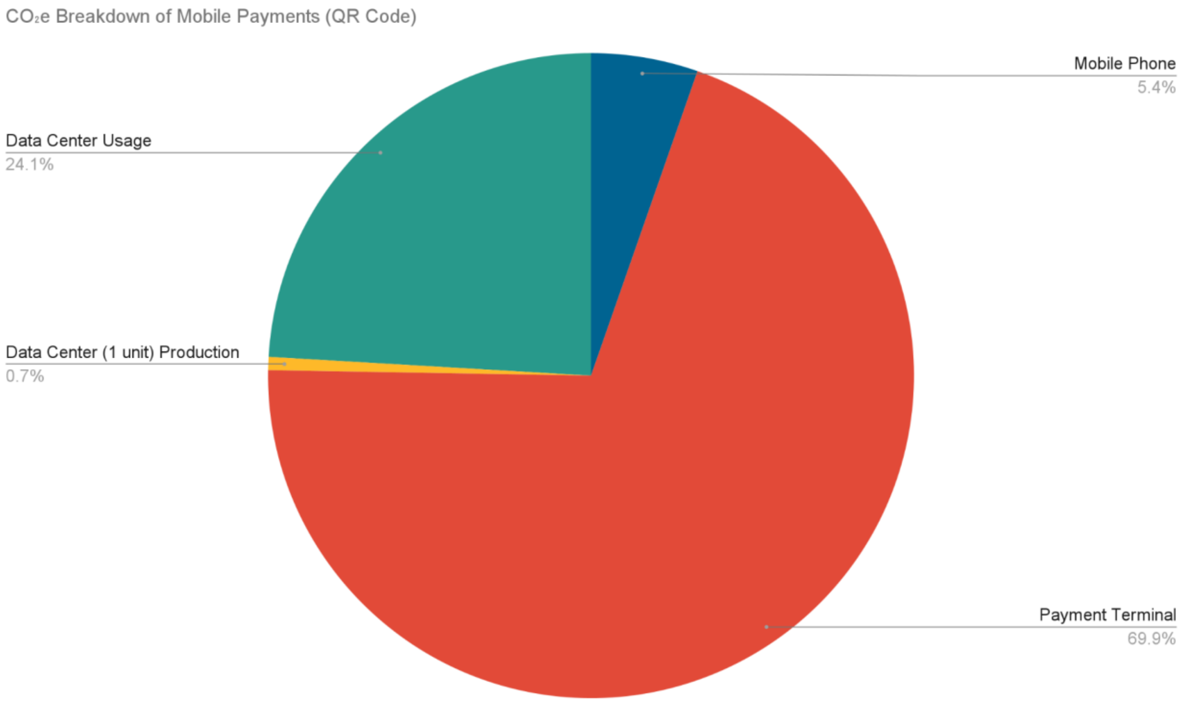

Figure 18. CO_2e Breakdown of QR Code Payments.

CO_2e Breakdown of QR Code Payments.			
Lifecycle Stage	**Component**	**Impact (g CO_2e)**	**Impact Percentage**
Production to End-of-Life	Smartphone	1093.11	5.35%
	Payment Terminal	14285.98	69.92%
	Data Center (1 unit) Production	134.85	0.66%
	Data Center Usage	4917.96	24.07%

Table 12. CO_2e Breakdown of QR Code Payments.

Data Inventory

Table 13 provides a high-level overview of the sources of key carbon intensive activities associated with the QR code payment method. The inventory breakdown per payment method is attached in Table 25.

Payment Terminal		
Component	**Unit**	**Input Activity**
Payment Terminal	Unit	Payment Terminal Cradle-to-Grave

Table 13. Key Carbon Intensive Activities Inventory Breakdown in QR Code Payments.

Analysis and Discussion

Key Findings

In today's world there are many different payment options, and it is important to understand each option's environmental impact. This analysis examines and compares the CO_2e impact associated with each payment method, including traditional cash transactions, card payments, and mobile payments. The goal is to measure and compare the environmental footprint for each type of transaction. By doing so, this white paper aims to provide useful information for businesses and individuals in Japan who wish to make more informed and environmentally-aligned decisions in their everyday financial transactions. The chart below summarises the key results associated with each type of payment method, per transaction.

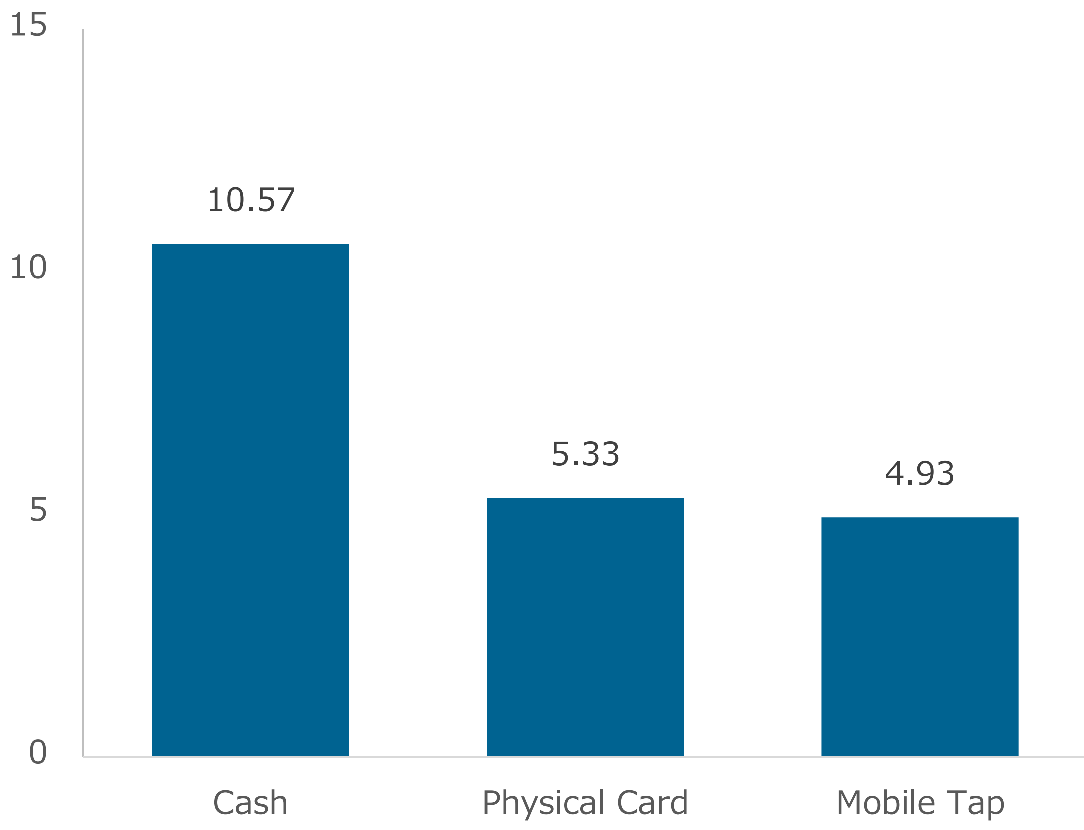

Figure 19. Carbon Impact (g CO_2e) per Transaction, per Payment Method in 2022.

Impact (g CO_2e) per Transaction		
Type	**Payment Method**	**Impact (g CO_2e)**
Cash	Banknotes & Coins	10.57
Cashless	Physical Card	5.35
	Mobile Tap	4.93

Table 14. Carbon Impact (g CO_2e) per Transaction per Payment Method in 2022.

The chart below shows the total impact generated by each payment method in the year 2022. This was calculated by multiplying the CO_2e impact per transaction and per payment method by the number of annual transactions in 2022 shown in Table 2.

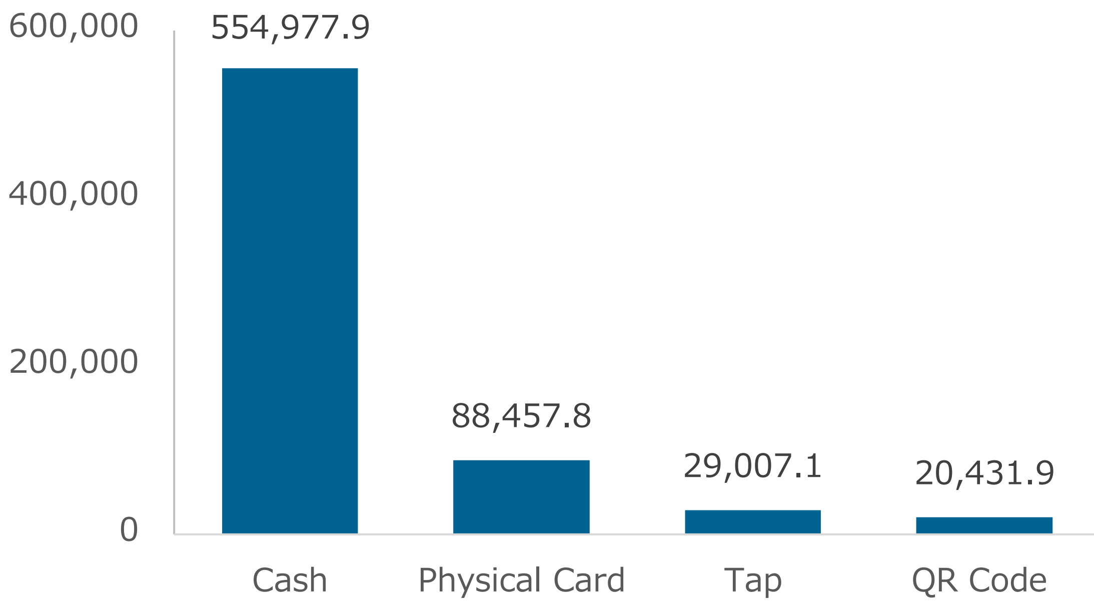

Figure 20. Impact (t CO_2e) From All Transactions Per Payment Method in 2022.

Impact of Transactions per Payment Method (2022)		
Payment Method	**Total impact From All Transactions (t CO_2e)**	**Impact Percentage**
Cash	554977.9	80.10%
Physical Card	88457.8	12.77%
Mobile Tap	29007.1	4.19%
QR Code	20431.9	2.95%

Table 15. Impact (t CO_2e) From All Transactions Per Payment Method in 2022.

Uncertainty Analysis

Due to the variable nature of the data sources and types, an uncertainty analysis is vital to examine the impact of varying input parameters on the overall results of this white paper.

Therefore, through this uncertainty analysis, we aim to identify the potential fluctuation of such inputs in the quantification process if we were to directly adopt the numbers from LCA studies. This analysis illustrates how the final values for each transaction can fluctuate when the preconditions or the LCA data inputs utilised from these studies change, highlighting the need for careful consideration and adjustment.

Calculation of Cashless Payment Ratio

This white paper used the existing ratio of cashless payment calculated by the current calculation method, meanwhile the METI has been reviewing this calculation method and a draft of the guideline revision has been disclosed in "the Report compiled by the Study Group on the Future Direction of Cashless Payment (Outline)", published by the METI in March 2023. This phase of the uncertainty analysis illustrates the impact of the variations on the total carbon footprint from all transactions by using the ratio of cashless payment calculated based on the draft of the guideline revision.

Calculation Formula for Cashless Payment Ratio based on the draft of the guideline revision.

$$\text{Cashless Payment Ratio} = \frac{\text{Payment amount by direct debit + Payment amount by credit card + Payment amount by debit card + Payment amount by prepaid payment + Payment amount by fund transfer}}{\text{Final consumption expenditure of households − Imputed rent of owner-occupied dwellings}}$$

	Input data	Values based on the current guideline	Values based on the new draft guideline
Numerator	Payment Amount by Direct Debit	0	Approximately 18.6 trillion Yen *Source: Japanese Bankers Association

	Payment Amount by Credit Card	93.8 trillion Yen	93.8 trillion Yen *Source: Japan Consumer Credit Association
	Payment Amount by Debit Card	3.2 trillion Yen	3.2 trillion Yen *Source: Bank of Japan
	Payment Amount by Prepaid Payment [52] + Payment Amount by Fund Transfer[53]	14.0 trillion Yen	35.1 trillion Yen *Source: Japan Payment Service Association
Denominator	Final Consumption Expenditure of Households	308.5 trillion	303.1 trillion *Source: Cabinet Office
	Imputed Rent of Owner-occupied Dwellings	Not considered	48.4 trillion *Source: Cabinet Office
Indicator	Cashless Payment Ratio	36.0%	59.2%

Table 16. Data Comparison between the current guideline and the new draft guideline.

Item	Amount
Annual Transaction Value 2022	103.9 trillion Yen
Annual Number of Transactions 2022	27.62 billion

Table 17. Transaction Value and Number of Transactions for Cash Payment calculated based on the new draft guideline.

[52] Obtained from “Changes in Payment Amount by Prepaid Payment" aggregated by the FSA and published by the Japan Payment Service Association

[53] Obtained from “Changes in Payment Amount by Fund Transfer” aggregated by the FSA and published by the Japan Payment Service Association. The amount for Peer-to-Peer money transfer is included.

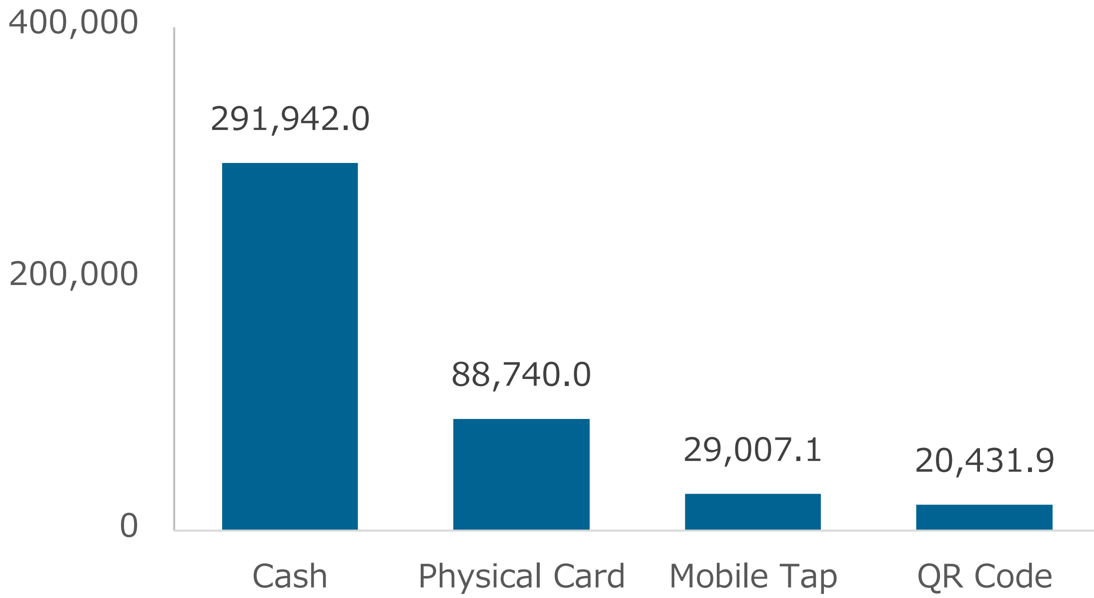

Figure 21. Carbon Impact (g CO_2e) from All Transactions, per Payment Method calculated based on the new draft guideline.[54]

Smartphone

In this segment of the uncertainty analysis, the cradle-to-grave CO_2e emission value derived from the iPhone 13 Pro max 1TB environmental footprint report is modified. The adjustment is made within a range of +/- 10%. Table 18 presents an overview of how these adjustments influence the carbon footprint per transaction associated with smartphone payment methods.

[54] The annual number of transactions for cash payment decreases as the ratio of cashless payment on the new draft guideline is higher than that on the current guideline. This resulted in an increase in the total CO_2e emission value from all cash payment transactions.

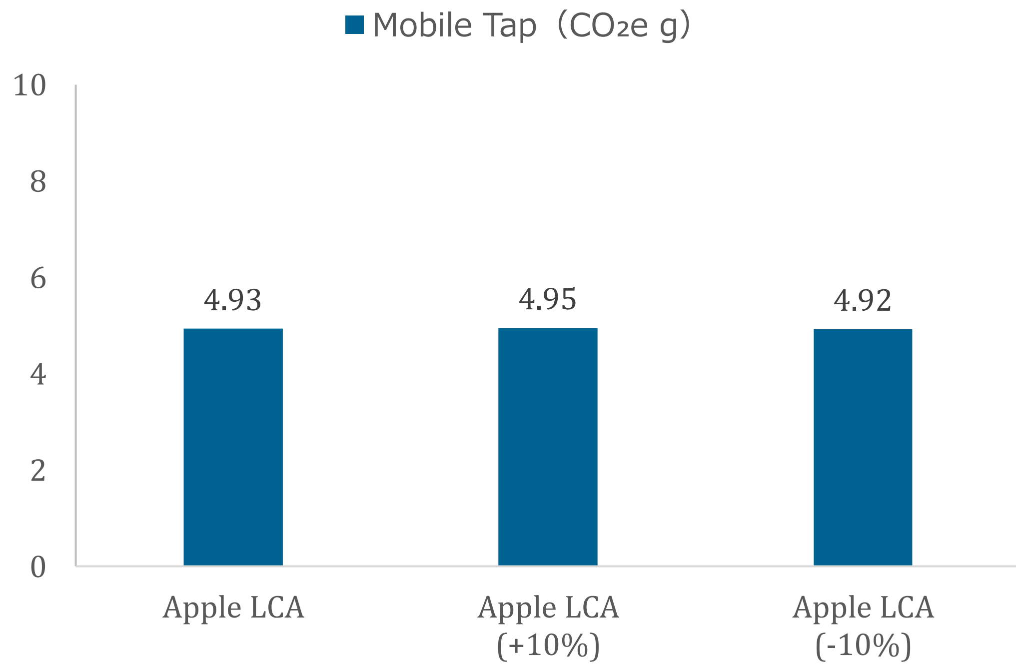

Figure 22. Apple Smartphone Uncertainty Analysis.

Uncertainty Analysis	
LCA Used	**Mobile Tap Payment (g CO_2e)**
Apple LCA	4.93
Apple LCA +10%	4.95
Apple LCA -10%	4.92

Table 18. Smartphone Uncertainty Analysis.

Transportation Distances

This white paper utilised weighted average transportation distances as inputs for calculating the CO_2e emissions for cash and physical card payments, meanwhile the guidelines in the LCA methodology advises that a data input in the worst case can be used if several data inputs are available. This phase of the uncertainty analysis illustrates the impact of the variation on the carbon footprint per transaction if the worst case transportation was used instead of the weighted average transportation values.

Payment Methods	Life Cycle Stage / Component	Weighted Average Transportation Distance	Worst-case Assumption Transportation Distance
Cash (Banknotes)	Transportation From Production Facilities to ATM Location	382.4 km	1,562km
	Transportation From Home to Recycling Facility	382.4 km	1,562km
Cash (Coin)	Transportation From Production Facilities to ATM Location	357.6 km	1,891km
	Transportation From Home to Recycling Facility	357.6 km	1,891km
Physical Card	Transportation of Card to Customer	447.7 km	1,621km
	Transportation From Collection to Incineration Facility	101 km	103km

Table 19. Data Comparison between the weighted average transportation distance and the farthest transportation distance.

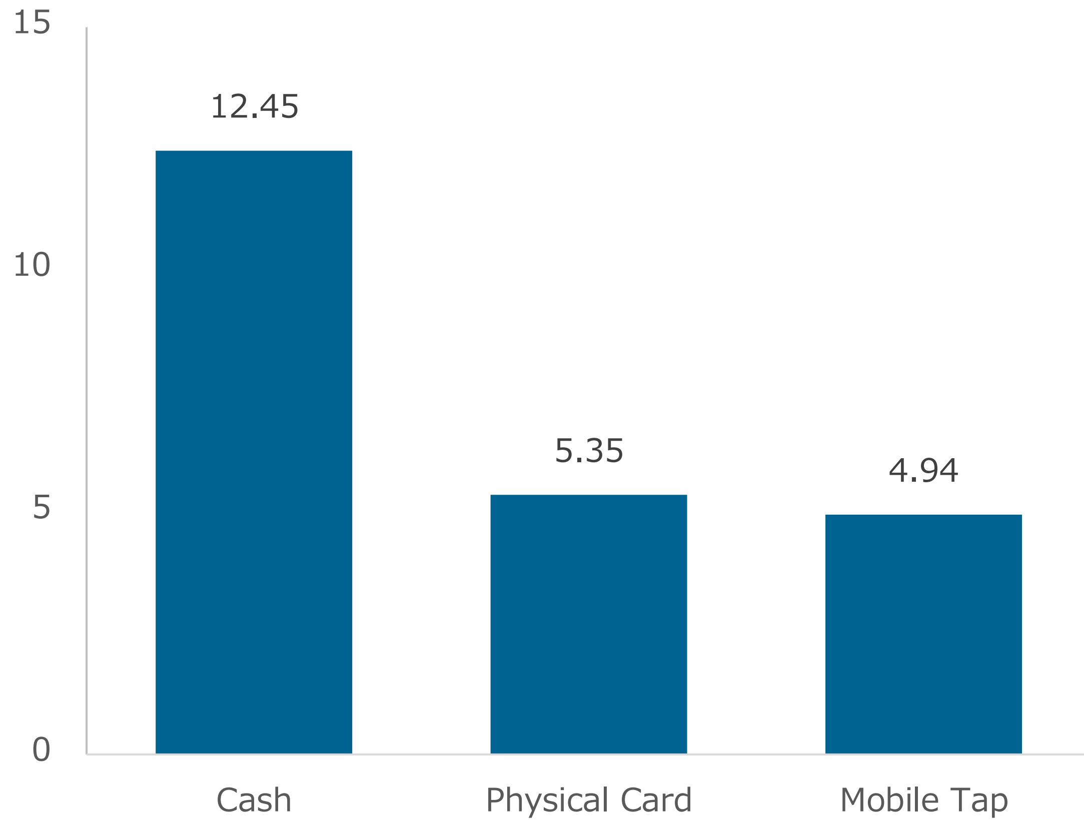

Figure 23. Impact (g CO_2e) per Transaction per Payment Method calculated based on the fartherst transportation distance.

Conclusion

This white paper, through its benchmark analysis and scenario-based assessments, offers a comprehensive understanding of the CO_2e impact of payment methods in Japan. By assessing the emissions linked to several payment systems, this paper serves as an important reminder to consider carbon emission impacts when choosing a payment method. As Japan aims for a greener transition, the insights from this paper can guide individuals in making choices that align with environmental objectives.

Carbon Emission Calculations for “Results from Research on the Carbon Impact of Cash and Cashless Payments in Japan”

The white paper report “Results from Research on Carbon Impact on Cash and Cashless Payments in Japan” has been prepared by JCB.

The carbon emissions were calculated using the Arbor Platform, a GRI Certified Software and Tool Partner. All calculations and outputs performed through the Arbor Platform are in accordance with GRI standards, and were done following guidelines set by the GHG Protocol, ISO 14040, and ISO 14044.

All primary data inputs used were collected and confirmed by JCB in collaboration with its partners. Based on these primary data inputs, Arbor calculated the carbon impact (CO_2e) for each of following payment methods:

- Cash Payment
  - Bank Note
  - Coin
- Cashless Payment
  - Physical Card
  - Mobile Tap (NFC)
  - QR Code

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Appendix A - Inventory of Banknotes

Production			
Component	**Material Input**	**Unit**	**Input Activity**
Hemp Production	Manila Hemp	kg	Sun Hemp Production
	Polyethylene Terephthalate Granulate	kg	Polyethylene Terephthalate Production, Granulate, Amorphous, RoW
	Electricity	MWh	Market for Electricity, Low Voltage, Japan
	Transport, Freight Lorry	tkm	Transport, Freight, Lorry 16-32 Metric Ton, EURO4, RoW
Security Paper Production	Sulfate Pulp	kg	Market for Sulfate Pulp, Bleached, RoW
	Chemi-thermomechanical Pulp	kg	Chemi-thermomechanical Pulp Production, RoW
	Paper	kg	Paper Production, Newsprint, Virgin, RoW
	Packaging, Corrugated Cardboard	kg	Corrugated Board Box Production, RoW
	Polyethylene Terephthalate Granulate	kg	Polyethylene Terephthalate Production, Granulate, Amorphous, RoW
	Electricity	MWh	Market for Electricity, Low Voltage, Japan
Security Foil Production	Polyester-biopolymer	kg	Polyester-complexed Starch Biopolymer Production,RoW
	Polyester-resin	kg	Polyester Resin Production, Unsaturated, RoW
	Aluminium	kg	Aluminium Production, Primary, Ingot,RoW
	Electricity	MWh	Market for Electricity, Low Voltage, Japan
	Heat, Natural Gas	MJ	Market Group for Heat, Central or Small-scale, Natural Gas, GLO
Security Thread Production	Polyester-biopolymer	kg	Polyester-complexed Starch Biopolymer Production, RoW
	Aluminium	kg	Aluminium Production, Primary, Ingot, RoW

	Electricity	MWh	Market for Electricity, Low Voltage, Japan
	Heat, Natural Gas	MJ	Market Group for Heat, Central or Small-scale, Natural Gas, GLO
Security Ink Production	Printing Ink	kg	Printing Ink Production, Offset, Product in 47.5% Solution State, RoW
	Transport, Freight, Lorry 16-32 metric ton	tkm	Transport, Freight, Lorry 16-32 Metric Ton, EURO4, RoW
Banknote Printing	Acetone	kg	Acetone Production, Liquid, RoW
	Waste Newspaper	kg	Paper Production, Newsprint, Virgin, RoW
	Polyethylene, Low Density, Granulate	kg	Polyethylene Production, Low Density, Granulate
	Polyethylene Terephthalate Granulate	kg	Polyethylene Terephthalate Production, Granulate, Amorphous, RoW
	Corrugated Cardboard	kg	Corrugated Board Box Production, RoW
	Nickel	kg	Market for Nickel Concentrate, 16% Ni, GLO
	Electricity	MWh	Market for Electricity, Low Voltage, Japan
Operation			
Transportation to ATM	Reinforcing Steel	kg	Reinforcing Steel Production, RoW
	Transport, Freight, Lorry 16-32 Metric Ton	tkm	Transport, Freight, Lorry 16-32 Metric Ton, EURO4, RoW
End-of-Life			
Pre-processing (Shredding, etc.)	Polyethylene Terephthalate	kg	Polyethylene Terephthalate Production, Granulate, Amorphous, RoW
	Electricity	MWh	Market for Electricity, Low Voltage, Japan
	Heat, Natural Gas	MJ	Market Group for Heat, Central or Small-scale, Natural Gas, GLO

Transport From Home to Recycling Facility	Transport, Car	tkm	Transport, Freight, Lorry 16-32 Metric Ton, EURO4, RoW
Recycling	Shredded Cash	kg	Paper Production, Newsprint, Recycled, RoW

Table 20. Inventory of Banknotes.

Appendix B - Inventory of Coins

Production			
Component	**Material Input**	**Unit**	**Input Activity**
Coin Blank Production	Copper	g	Copper Production, Cathode, Solvent Extraction and Electrowinning Process, GLO
	Aluminium, Ingot	g	Aluminium Production, Primary, Ingot, RoW
	Zinc	g	Primary Zinc Production From Concentrate, RoW
	Tin	g	Tin Production, RoW
	Nickel	g	Market for Nickel Concentrate, 16% Ni, GLO
	Transport	tkm	Transport, Freight, Lorry 16-32 Metric Ton, EURO4, RoW
Coin Monetization	Electricity	kWh	Electricity Production, Oil, Japan
Operation			
Transportation to ATM	Reinforcing Steel	kg	Reinforcing Steel Production, RoW
	Transport, Freight, Lorry 16-32 Metric Ton	tkm	Transport, Freight, Lorry 16-32 Metric Ton, EURO4, RoW
End-of-Life			
Transportation From Home to Recycling Facility	Transport, Freight, Lorry 16-32 Metric Ton	tkm	Transport, Freight, Lorry 16-32 Metric Ton, EURO4, RoW
Recycling	Electricity	kWh	Electricity Production, Oil, Japan

Table 21. Inventory of Coins.

Appendix C - Inventory of ATMs

Production			
Component	**Material Input**	**Unit**	**Input Activity**
ATM Manufacturing	Display, Liquid Crystal, 17 inches	1 unit	Liquid Crystal Display Production, Unmounted, GLO
	Computer, Desktop, Without Screen	1 unit	Computer Production, Desktop, Without Screen, GLO
	Reinforcing Steel	ton	Reinforcing Steel Production, RoW
	Electricity Needed for Manufacturing	kWh	Market for Electricity, Low Voltage, Japan
Operation			
Transportation to Final Destination	Transport, Freight, Lorry 16-32 Metric Ton	tkm	Transport, Freight, Lorry 16-32 Metric Ton, EURO4, Row
ATM Usage	Electricity Needed for Each Transaction	kWh	Market for Electricity, Low Voltage, Japan
Cash Handling (Counting)	Electricity	kWh	Market for Electricity, Low Voltage, Japan
	Paper	kg	Kraft Paper Production, RoW
End-of-Life			
ATM Recycling	Recycling Steel	kg	Market for Waste Reinforcement Steel, RoW
	Treatment of LCD	1 unit	Market for Used Liquid Crystal Display Module, RoW
	Treatment of Computer	1 unit	Market for Used Desktop Computer, GLO

Table 22. Inventory of ATMs.

Appendix D - Inventory of Cards

Production			
Component	**Material Input**	**Unit**	**Input Activity**
Card Body	PVC	g	Polyvinyl Chloride Production, Suspension Polymerisation, RoW + Injection Molding, RoW
	PVC Resin	g	Market for Polyester Resin, Unsaturated, RoW
Chip Module	Phosphor Bronze	g	Market for Copper, Cathode, GLO + Market for Tin, GLO + Market for Phosphorus, White, Liquid, GLO + Market for Metal Working, Average for Copper Product Manufacturing, GLO
	Epoxy Resin	g	Epoxy Resin Production, Liquid, RoW
	Silicon	g	Silicon Production, Electronics Grade, RoW
Antenna	Copper	g	Copper Production, Cathode, Solvent Extraction and Electrowinning Process, GLO + Metal Working, Average for Copper Product Manufacturing, RoW
Hologram	Polyester Film	g	Polyvinylchloride Production, Suspension Polymerisation, RoW + Injection Moulding, RoW
Sign Panel	Silk Printing Ink	g	Printing Ink Production, Offset, Product in 47.5% Solution State, RoW
Operation			
Transportation	Transport, Freight, Lorry 16-32 Metric Ton	tkm	Transport, Freight, Lorry 16-32 Metric Ton, EURO4, Row
Payment Terminal Cradle-to-Grave	Payment Terminal	1 unit	LCA Study

Data Center (1 unit) Production	Cooling Equipment (Cooler, Pump Rack, Chiller, and Cooling Infrastructure)	1 unit	LCA Study
	Power Equipment (Switchgear, PDU, UPS, Generator and Batteries)	1 unit	LCA Study
	IT Equipments (Servers, Laptops/PCs, Storage)	1 unit	LCA Study
Data Center Usage	Electricity Consumption	kWh	Market for Electricity, Low Voltage, Japan
End-of-Life			
Transportation From Home to Incineration Facility	Transport, Freight, Lorry 16-32 Metric ton	tkm	Transport, Freight, Lorry 16-32 Metric Ton, EURO4, Row
Disposal of Cards	Card, Municipal Incineration	kg	Treatment of Waste Plastic, Mixture, Municipal Incineration, RoW

Table 23. Inventory of Cards.

Appendix E - Inventory of Mobile Tap Payments

Smartphone			
Component	**Material Input**	**Unit**	**Input Activity**
Smartphone Cradle-to-Grave	Apple iPhone 13 Pro Max 1TB	1 unit	LCA Study
Payment Terminal			
Payment Terminal Cradle-to-Grave	Payment Terminal	1 unit	LCA Study
Data Center			
Data Center (1 unit) Production	Cooling Equipment (Cooler, Pump Rack, Chiller, and Cooling Infrastructure)	1 unit	LCA Study
	Power Equipment (Switchgear, PDU, UPS, Generator and Batteries)	1 unit	LCA Study
	IT Equipments (Servers, Laptops/PCs, Storage)	1 unit	LCA Study
Data Center Usage	Electricity Consumption	kWh	Market for Electricity, Low Voltage, Japan

Table 24. Inventory of Mobile Tap Payments.

Appendix F - Inventory of Mobile QR Code Payments

Smartphone			
Component	**Material Input**	**Unit**	**Input Activity**
Smartphone Cradle-to-Grave	Apple iPhone 13 Pro Max 1TB	1 unit	LCA Study
Payment Terminal (Merchant Scanning device)			
Payment Terminal Cradle-to-Grave	Payment Terminal	1 unit	LCA Study
Data Center			
Data Center (1 unit) Production	Cooling Equipment (Cooler, Pump Rack, Chiller, and Cooling Infrastructure)	1 unit	LCA Study
	Power Equipment (Switchgear, PDU, UPS, Generator and Batteries)	1 unit	LCA Study
	IT Equipments (Servers, Laptops/PCs, Storage)	1 unit	LCA Study
Data Center Usage	Electricity Consumption	kWh	Market for Electricity, Low Voltage, Japan

Table 25. Inventory of Mobile QR Code Payments.

Appendix G - Materials Used by Weight or Volume

Material Used	Renewability	Amount	Unit
Manila Hemp per Banknote	Renewable	1.0100	g
Security foil per Banknote	Renewable	0.0610	g
Security ink per Banknote	Renewable	0.1020	g
Security Thread per Banknote	Renewable	0.0124	g
Copper per Coin	Renewable	4.5756	g
Nickel per Coin	Renewable	0.9183	g
Zinc per Coin	Renewable	0.5486	g
Tin per Coin	Renewable	0.0031	g
Aluminium per Coin	Renewable	0.0086	g
PVC per Card	Non-renewable	4.8800	g
PVC Resin per Card	Non-renewable	0.0200	g
Hologram per Card	Non-renewable	0.0010	g
Sign Panel per Card	Non-renewable	0.0100	g
IC Chip per Card	Non-renewable	0.1200	g
Type F Antenna per Card	Non-renewable	0.1000	g
Type A/B Antenna per Card	Non-renewable	0.1000	g

Table 26. Materials Used by Weight or Volume.

Item	Energy Source	Amount	Unit
Electricity for Banknote Production	Japanese electricity grid	0.0016	kWh
Electricity for Coin Production	Japanese electricity grid	0.0009	kWh
ATM Electricity Consumption per Transaction	Japanese electricity grid	0.0401	kWh
Electricity for Cash Handling	Japanese electricity grid	0.0002	kWh

Table 27. Energy Consumption Outside of the Organization.

Payment type	Impact Assessment Method	Emissions Intensity	Unit
Cash	EF 3.0 no LT	10.57	g CO_2e/Transaction
Physical Card	EF 3.0 no LT	5.33	g CO_2e/Transaction
Mobile Tap Payment	EF 3.0 no LT	4.93	g CO_2e/Transaction

Table 28. GHG Emissions Intensity.

Appendix H - GRI Content Index

GRI Standard	Location	Disclosure	Omission		
			Requirement(s) Omitted	Reason	Explanation
GRI 301: Materials (2016	Page 73 Table 26	301-1 Materials Used by Weight or Volume	X	X	X
GRI 302: Energy (2016)	Page 73 Table 27	302-2 Energy Consumption Outside of the Organization	X	X	X
GRI 305: Emissions (2016)	Page 74 Table 28	305-4 GHG Emissions Intensity	X	X	X

Table 29. GRI Content Index.

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