A comparative analysis of the ESG impact of payment instruments

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Introduction and executive summary

WHY ARE WE DOING THIS?

The rise of Environmental, Social, and Governance (ESG) issues reflects a growing awareness of the impact of commercial activities on the broader world. Incorporating ESG concerns into business practices is becoming increasingly important to both firms and consumers. While payments are probably not the first industry that comes to mind when one thinks of environmental or social concerns, they do play a significant role. This whitepaper examines the ESG impacts of the most commonly used payment instruments within Europe using existing Life Cycle Analyses (LCA), assessing the environmental impact of instrument production, processing, and end-of-life phases for electronic and non-electronic payment types.[1] Aspects of social importance, such as access to formal financial products as well as governance concerns, are also addressed. The paper ends with high-level recommendations on what can be done to improve ESG concerns in the future.

> This whitepaper examines the ESG impacts of the most commonly used payment instruments within Europe using existing Life Cycle Analyses (LCA).

An examination of the environmental impacts of payment methods is needed; payment technology has advanced significantly for payment types such as cards, instant payments, and digital currencies and they have grown considerably in popularity. Now is the time to conduct an assessment of the ESG impacts as businesses and consumers embrace these technological advancements. Many studies look at the environmental or social impacts of just one or two payment types in isolation, but a comprehensive study analyzing a wide range of payment methods regarding their environmental, social, and governance concerns is lacking. This paper offers an analysis of the broader ESG impacts of digital currencies, cards, cash, cheques, instant payments, batch-processed credit transfers and direct debits.

It is hoped that this paper will foster dialogue and increase awareness of ESG topics among payment experts, industry decision-makers, and regulators. Increased awareness can improve environmental sustainability, increase access to electronic payments (which brings about larger social benefits), and encourage good governance of payment systems across Europe. In addition, this paper provides relevant information for decision-makers about the use of payment instruments with ESG considerations in mind. We encourage PSPs to integrate ESG metrics into their assessments of payment instruments and hope this paper contributes to ESG scholarship. A series of recommendations are included for practitioners on how to improve the ESG impact of payments. This research seeks to empower stakeholders to embrace sustainability and social responsibility as a force for positive change by fostering dialogue, raising awareness, and offering actionable recommendations.

[1] This paper used a compilation of existing LCAs from previous studies and summarised them rather than conducting a new analysis.

CONCLUSIONS

Our study ranks the environmental impact of the payment instruments examined through a combination of desk research and expert interviews and provides a relative ranking of the environmental impact of various payment methods based on qualitative and quantitative data (see Table 1 below). **Our research found digital currency to be the least environmentally friendly payment instrument, followed by cash, cheques, and cards. Batch payments (e.g. SCTs and SDDs) were found to have the lowest environmental impact followed by instant payments.** Promoting the migration away from 'dirty' methods should be discussed, though complete discontinuation can lead to lower financial inclusion, creating knock-on social effects. This demonstrates the importance of thorough data-based policy discussions. The payments industry needs to do more to positively contribute to this discussion.

We conclude that **appropriate governance aspects, such as inclusive decision-making, standardised data collection and reporting, and thoughtful weighing of the various options and consequences can limit the environmental impact of payment methods and promote social inclusion.**

	Rank	Instrument	Energy consumption per transaction in KWh
More environmentally friendly	1	**Batch payments** (credit transfers have lower energy usage than direct debits)	0.0063
	2	**Instant payments**	>0.0063*
	3	**Cards** (credit & debit)	0.01714
	4	**Cheques**	0.072
	5	**Cash**	0.222
Less environmentally friendly	6	**Traditional cryptocurrencies**	1,777.11 (Bitcoin) 125.36 (Ethereum)

*While our study did not find exact quantitative data for IP and RTGS, from the information gathered it can be concluded that per transaction IPs consume more energy than batch payments and less than cards.

Table 1 Environmental impact ranking Source: Lipis Advisors

RECOMMENDATIONS

Our study highlights several recommendations for industry stakeholders to promote ESG considerations across the payments ecosystem.

Recommendations
National policymakers should support and encourage the use of electronic payment methods because they are more environmentally friendly and are socially beneficial (i.e. combat money laundering and other nefarious practices) while maintaining access to cash for social reasons, such as financial inclusion.
Batch and instant payments are the most environmentally friendly payment methods and their use should be encouraged and promoted.
Payment system operators have a responsibility to make the payment services they offer as environmentally friendly as possible. This means switching to hardware stacks that last longer (i.e. switching to solid-state drives), ensuring that hardware is recycled whenever possible, and sourcing electricity that is produced sustainably.

Making good decisions requires accurate and up-to-date data, so industry associations should standardise and improve the monitoring and reporting of ESG data to ensure accurate and comparable data is collected.
Industry stakeholders should enhance coordination around ESG concerns to promote sustainable practices through knowledge-sharing and collective efforts, ensure that social issues are taken into consideration prior to making decisions, and endeavour to make decision-making inclusive.
Some digital currencies were found to be very harmful from an environmental perspective. Any future digital currency initiatives need to take emissions seriously and be designed in environmentally friendly ways.
Existing payment methods that include a physical component, such as cards, cash, and cheques, should look for ways to make the manufacture and transportation of physical components less dependent upon environmentally damaging substances such as plastic, metals, and fossil fuels. Using virtual payment methods should be encouraged where possible, though inclusion concerns should be taken into account.

Table 2 List of recommendations Source: Lipis Advisors

OUTLINE OF THE PAPER

This paper begins with an overview of our methodology, namely why we chose to collate and summarise existing Life-Cycle-Analyses. We then present the payment instrument LCAs in order from least to most environmentally friendly. The methodology section finishes with our analysis of the social and governance aspects of these payment instruments. The paper ends with our detailed recommendations as to how ESG considerations in payments could be improved.

Instrument	Definition	Classification
Account-to-account payments	Refers to both batch and instant payments for the purposes of this paper. E.g. SCT, SDD Core, SDD B2B, SCT Inst	Electronic
Batch payments	Refers to ACH-processed credit transfers and direct debits. Transactions that are transmitted to and processed by an ACH in groups of related payment instructions (aka batches) at distinct intervals of time. E.g. SCT & SDD Core	Electronic
Card	A payment card issued to a person for purchasing goods and services, presenting value against a line of credit established by an issuer or directly charged to funds on the payer's account at a depository institution.	Electronic
Cash	Physical, legal tender in the form of banknotes or coins issued by a central bank.	Paper-based
Cheques	A retail payment instrument consisting of a written order from one party (the drawer) to another party (the drawee, normally a bank) requiring the drawee to pay a specified sum on demand to the drawer or to a third party specified by the drawer	Paper-based, occasionally electronic
Traditional cryptocurrencies	A digital asset that can be traded on a blockchain or other distributed ledger. E.g. Bitcoin or Ethereum	Electronic
Instant payments	Payments that are posted to the beneficiary's account on an individual basis (rather than in a batch file) at the time instructions are received (usually within seconds) by the payment system rather than at some later time. E.g. SCT Inst.	Electronic

Table 3 Definition of payment instruments analysed Source: BIS, U.S. Federal Reserve

METHODOLOGY

WHAT IS LIFE CYCLE ANALYSIS AND WHY DID WE CHOOSE THIS METHOD?

Life cycle analysis (LCA) is a systematic study of a product or service's environmental impact throughout its entire life cycle.[2] In the context of payment instruments, LCA breaks down the payment process from the manufacturing of the hardware it requires to be initiated, processed, and received (e.g. initiation tool, data centers, ATM, POS machine, raw materials for coins and bills, etc.) through its transportation to and from customers, retailers and banks, the energy consumed during these processes, and end-of-life management.

We utilised existing LCAs because the environmental impact of payments accounts for the largest share of quantifiable ESG implications. Using existing LCAs enabled a partial breakdown of the different payment instruments' life cycles and allowed them to be grouped in a comparable way without spending considerable resources conducting a new study. LCA allows for the inclusion of quantitative and qualitative data, which is essential due to the complexities of comparing seven payment instruments and because comprehensive quantitative data is not available to the same degree for all instruments in all stages.

The Life Cycle Analyses that appear in the body of this paper are a summary of the full LCA for each payment method that can be found in Appendix II.

HOW DID WE COLLECT AND ORGANISE THE QUANTITATIVE DATA?

We drafted a general framework for an instrument's life cycle that could be applied to all payment methods. The framework has a three-stage structure following the instruments' production, operation, and end-of-life phases. Each phase was broken up into smaller components to account for the differing steps each instrument goes through. All information found was put in this framework to properly break down each instrument's life cycle.

This study relied on multiple sources to get as close to a comprehensive analysis of the life cycle of different payment instruments as possible. Qualitative data sources were collected through desk research and put into our LCA framework for each payment method. Due to the lack of publicly available data, we had to supplement quantitative data with qualitative data, which we obtained through expert interviews.
A full literature review broken by down by payment method can be found in Appendix I.

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EXPERT INTERVIEWS

While the desk research was successful in populating the majority of our framework, there were some gaps left to fill once the available sources were exhausted. We conducted interviews with payment processors to fill these gaps; each processor interviewed processes batch payments while some also process card and cheque payments. The information gathered in these interviews not only filled many of the gaps in the LCA framework but added "color" to the raw quantitative data. One good example is the consideration of not just the average life cycle of a server within a data center, but the differing lifespans based on the technology used as well as how the same hardware can be used for various processes – including, but not limited to – electronic payment processing.

DIFFICULTIES IN COMPARING DATA

Our study encountered challenges in comparing quantitative and qualitative data due to the paper's scope, spanning multiple payment instruments and data sources. Different (and often hard to compare) metrics were used across studies, transparent and comparable data was scarce, and differing factors of assessment for each LCA were present. Furthermore, drawing comparisons for LCA stages across markets was difficult due to differing hardware components and end-of-life management practices. Drawing comparisons across instant payments and batch payments also proved challenging, as these functions are often run off the same hardware, which may support back office functions or other value-added services not directly related to payment processing itself. Finally, separating the connection of payments from other industries was another challenge. For example, when examining payment method LCAs it becomes difficult to know where to draw the line i.e. at

[2] Sphera. (2020). "What is Life Cycle Assessment". https://sphera.com/glossary/what-is-a-life-cycle-assessment-lca/

what point is the mining involved in producing a metal coin more about the mining industry than the payments industry? These various issues combined made creating a single environmental cost for any given payment cost difficult. In spite of these difficulties, we are confident in the broad conclusions which we have been able to reach from our analyses.

LIFE CYCLE ANALYSIS

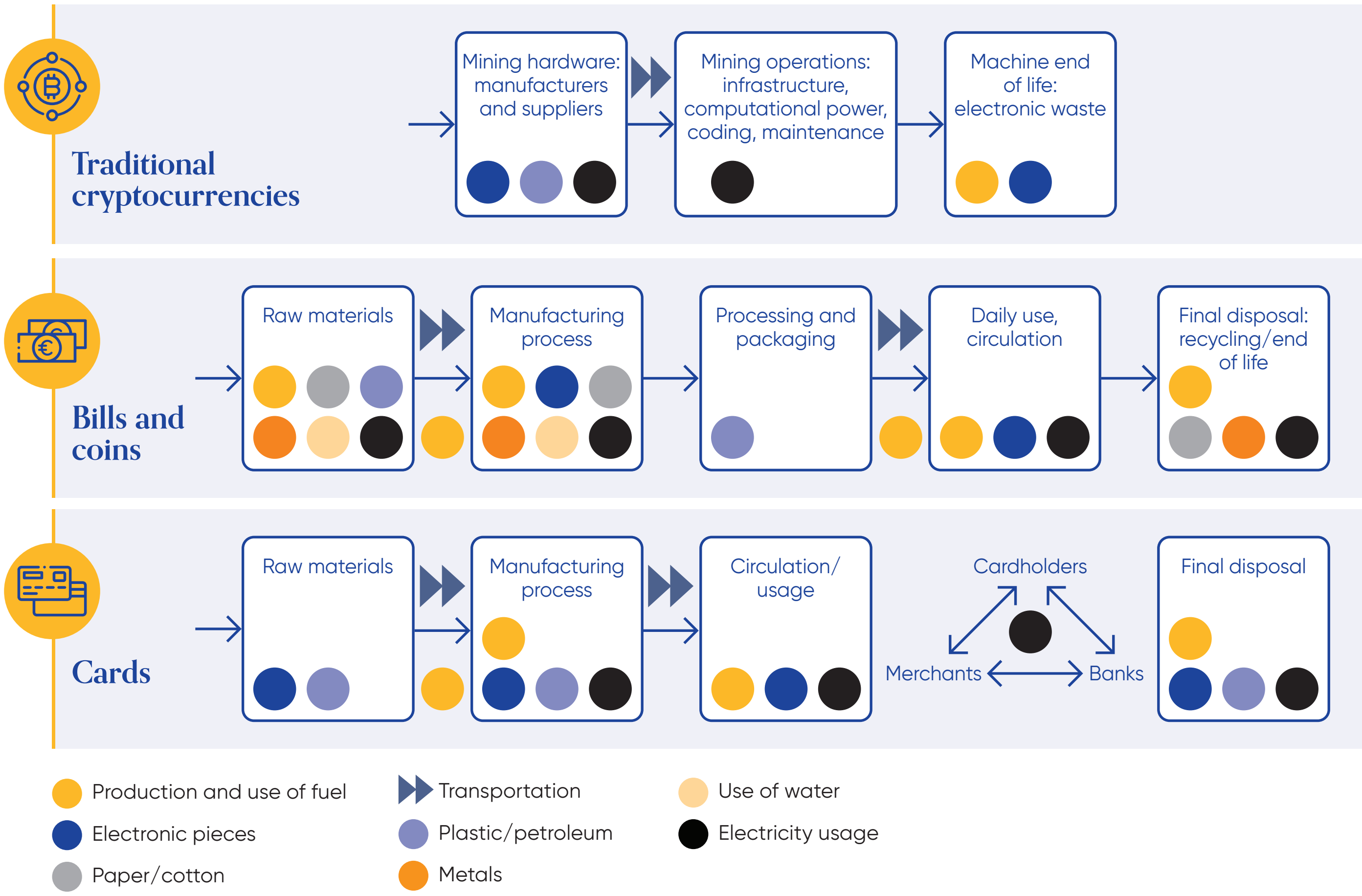

Figure 1 Visual representation of the LCAs of cryptocurrencies, conventional currencies and cards
Source: Pagone et al. 2023 with alterations by Lipis Advisors

ANALYSIS OF PAYMENT INSTRUMENTS

DIGITAL CURRENCIES

The digital currencies LCA focused on Bitcoin due to its prominence and the wealth of literature examining it in comparison to other digital currencies. Bitcoin mining is characterised by energy-intensive mining processes inherent to its Proof of Work mechanism. This process relies on specialised data centres and advanced computers, and consumes vast amounts of electricity, equivalent to the energy usage of countries such as Belgium or Poland while generating substantial e-waste due to rapid hardware obsolescence (typically within 1-3 years). Bitcoin's environmental impact is staggering, with significant carbon emissions, electricity usage, e-waste generation, and resource extraction, ranking it the most environmentally harmful out of all payment instruments examined as a part of this study. Another negative aspect for Bitcoin is the fact that it is primarily used for speculation and rarely as an actual payment instrument. It may also facilitate illegal, black-market payments and money laundering.

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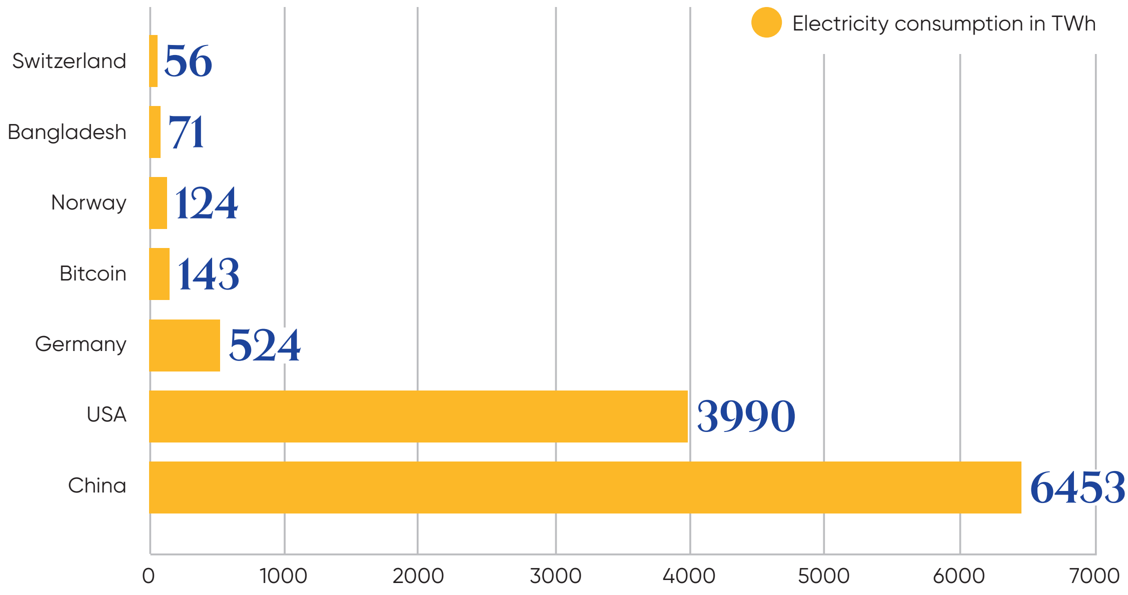

Figure 2 Bitcoin energy usage in comparison to nation-states in 2021 Source: Statista

CASH

The LCA on cash relied on the work of the Dutch National Bank in its investigation of the environmental impact of Euro banknotes in the Netherlands. The production phase requires sourcing materials such as cotton, various metals, thread, foil, and ink, with this phase making up the largest portion of cash's total environmental impact. Cotton is sourced from outside of Europe, requiring transoceanic shipping, as are the metals needed for coins, creating significant impact due to resource depletion and the mining process. The operational stage for cash encompasses transportation, ATM utilisation, and cash handling. Transportation-related environmental impacts make the operational stage the most costly part of the cash life cycle, accounting for 64% of the instrument's total impact. In comparison to the production and operational phases, cash's end-of-life stage is negligible in terms of its environmental impact due to cash's long life cycle and the simple disposal processes. Cash still came out as the second most environmentally unfriendly payment instrument after digital currencies primarily due to the metal mining required for coin production (32% of the total LCA impact) and the operational energy requirements for ATM utilisation and cash transportation (64% of the total environmental impact).

> **Cash still came out as the second most environmentally unfriendly payment instrument after digital currencies primarily due to the metal mining required for coin production and the operational energy requirements for ATM utilisation and cash transportation.**

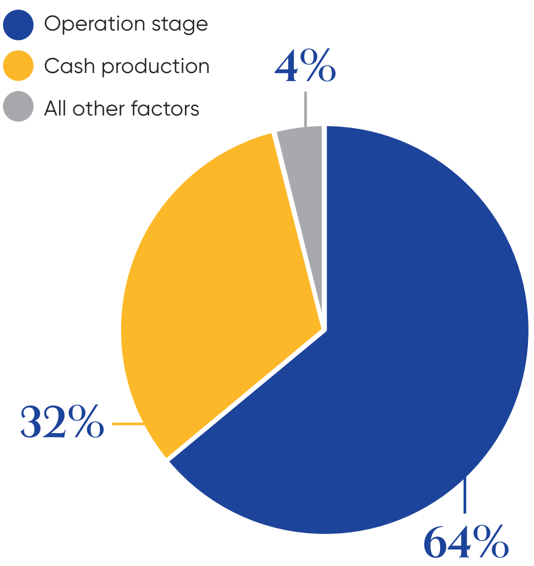

Figure 3 Analysis of cash LCA environmental impact
Source: DNB study: Hanegraaf et al. 2018

[3] At least when compared to disposing of electronic equipment.

CARDS

The LCA for cards benefited from the work of the Dutch National Bank and its assessment of the environmental impact of cards. The production phase for cards encompasses materials and transportation for card initiation tools, cards, terminals, and data centres, contributing 57.7% of the total impact. Energy consumption at data centres and card terminals plays a significant role during the operational phase, constituting 26.8% of the total impact, primarily due to electricity consumption. Disposing of plastic cards at the end of their 3-5 year life span poses long-term environmental concerns; despite recycling initiatives, most cards end up incinerated with general waste or in landfills, adding challenges to environmental assessment and contributing to total emissions. As a result, cards are ranked as the third least environmentally friendly, due to their shorter lifespan, significant production costs, and the electricity needed for the operational phase.

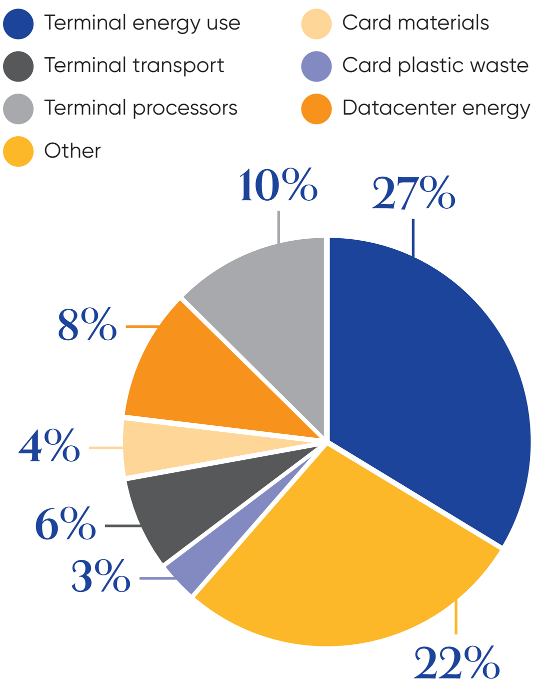

Figure 4 Analysis of a debit card transaction environmental impact
Source: DNB study: Lindgreen et al. 2017

CHEQUES

Cheque usage, though declining in Europe, remains notable in countries like France, Ireland, and the UK, necessitating their scrutiny as a part of this study. The production stage involves sourcing paper from wood pulp and ink from various metallic pigments, binders, and solvents, contributing to deforestation and environmental impacts from pigment mining and processing. Transportation to banks adds carbon emissions. Cheque processing is performed almost exclusively electronically for lower value payments, cutting down significantly on environmental impacts, but still requiring considerations for energy consumption and electronic waste generated by the machines used to process them. After their one-time usage, cheques require disposal or recycling, typically involving shredding or burning, incurring carbon emissions. Cheques came out as more environmentally friendly than cards.

INSTANT PAYMENTS

Instant payments and batch payments share significant portions of their production phases and, in some cases, both are processed using the same hardware stack. Production requires the manufacturing of significant hardware components for operators and the FIs that facilitate these transactions. Operational differences in energy usage emerge, however, as each instant payments require, on average, three times as much electricity as batch payments due to the individual nature of the transactions during processing (i.e. message-by-message versus batch). End-of-life considerations are also crucial, with hardware typically only lasting 3-5 years before decommissioning, repurposing, or recycling, though challenges remain in managing e-waste generation and recycling processes. Instant payments were ranked very high in terms of environmental friendliness, second only to batch payments (i.e. SCT and SDD).

Instant payments were ranked very high in terms of environmental friendliness, second only to batch payments.

BATCH PAYMENTS

The production phase requires hardware like servers, routers, and PCs, contributing to resource depletion and environmental degradation, with greenhouse gas emissions generated during production, transportation, and installation. In the operational stage, ACH operators often utilise the same hardware stack for instant systems, leading to complexities in separating environmental impacts, though batch payments offer processing efficiency compared to individual transactions.

Cooling requirements, outdated software, and variations in payment types also influence energy consumption, with cooling alone accounting for up to 60% of energy usage. End-of-life considerations involve periodic maintenance cycles and varied hardware lifespans, necessitating efficient resource management and responsible disposal practices to minimise environmental impact and enhance sustainability.

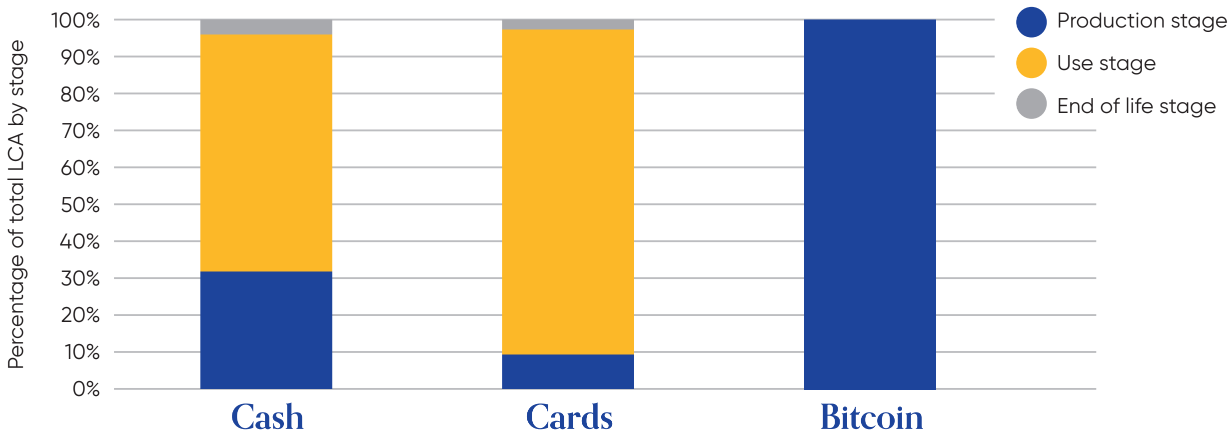

Figure 5 Environmental impact of payment instruments by LCA stage
Source: Lipis Advisors analysis, Lindgreen et al. 2017; Hanegraaf et al. 2018 Rybarczyk et al. 2021

SOCIAL CONSIDERATIONS

Widespread access to payments has a number of social benefits, including promoting financial inclusion, increasing security, greater economic growth, and social well-being.[4] Most European markets already boast relatively high wealth and impressive financial inclusion rates, with bank account penetration exceeding 90% in many countries.[5] Improved access to electronic payments can still provide benefits by fostering social cohesion and incentivising formal economic participation, especially among marginalised groups. Although the effects may not be as stark as in regions with lower financial inclusion rates, such as sub-Saharan Africa or South and Southeast Asia, access to electronic payments are integral to promoting social inclusion and economic development in Europe.

Our interviews with EACHA members shed some light on quantifying the social impacts of access to electronic payments in Europe. Particularly in countries surveyed with high immigrant populations (France, Spain, Denmark), access to convenient and accessible means of making payments incentivises individuals to obtain bank accounts, which reduces barriers to other financial products and services. Marginalised communities are integrated into the formal economy, enabling participation in economic activities and enhancing overall financial resilience. Our interviews revealed that immigrants from regions with lower financial literacy levels find themselves quickly incorporated into the formal financial system, as having a bank account is a necessity for participation in everyday life.

Improved access to electronic payments can still provide benefits by fostering social cohesion and incentivising formal economic participation, especially among marginalised groups.

Another notable social impact of access to payment systems revolves around digital illiteracy, particularly among senior citizens. Despite digital advancement and high degrees of digital literacy, a significant portion of Europe's over 60 population still prefers traditional methods for bill payments. This reliance on non-digital alternatives can lead to feelings of exclusion and marginalisation. To negate this potential exclusionary effect of digitalisation, non-digital payment alternatives are still provided for those who are unable or unwilling to make the digital leap in the interest of preventing social exclusion. While difficult to quantify, the social impacts of access to payment systems in Europe are still observable from a number of different perspectives. This is a significant point given the rapid aging of Europe's population.

[4] Beck, T., Demirgüç-Kunt, A., & Levine, R. (2007). Finance, inequality and the poor. B Bolzani, J. (2022). Leading the Way in Payments: How Central Banks Are Using Innovation to Promote Financial Inclusion and Reshape Competition.
[5] See: https://www.worldbank.org/en/publication/globalfindex

This last point demonstrates the importance of choice: end users should not be forced to use one payment method over another, but should have as much choice as possible, lessening exclusion. While understanding the environmental impact is important, any gains from either eliminating or limiting the use of "dirty" payment methods could have counteracting effects in other areas which should be taken into consideration.

GOVERNANCE

Good governance is increasingly becoming a topic of public and political debate, whether in financial services, manufacturing, or other industries. As businesses are increasingly seen as profit-driven organisations with a societal responsibility, good governance naturally rises in importance. Good governance can help ensure business ethics are adhered to, improve an organisation's reputation, attract talent, boost employee engagement, instill customer confidence, and attract investment, positively impacting financial performance, employee loyalty and trust.

Corporate Social Responsibility (CSR) reports and/or ESG reporting is done by multiple ACHs[6] in Europe and card companies, though there is a lack of ESG-related data reporting standards and transparency within most of the payment industry. The cryptocurrency organisation Climate Crypto Accord has created its own ESG data reporting guidelines[7] to ensure transparency and accountability. The introduction of the CSR reporting directive from the European Commission in early 2023[8] forces larger companies (e.g. listed corporations and banks) to report on ESG-based European Sustainability Reporting Standards (ESRS). This directive could provide a common ground for the industry in terms of ESG performance reporting and prevent so-called greenwashing. The European Banking Authority (EBA) released a consultation[9] in early 2024 calling for suggestions on managing ESG risks and providing guidelines and minimum requirements for financial institutions to report and manage ESG risks.

Key players in the payment industry demonstrate their commitment to environmental sustainability through environmental studies and supplier selection aimed at mitigating climate change risks, responsibly managing climate resources, and conserving energy. The cash industry in the UK and Europe has showcased how the industry can work together to reduce the environmental footprint of cash. The Bank of England worked with cash producers, banks, and ATM suppliers to set up an industry initiative named the Cash Industry Environmental Charter (CIEC) to make commitments for the UK industry aiming to achieve a net-zero target for climate change. The European Payment Council (EPC) set up an industry working group called the Cash Efficiency Working Group (CEWG)[10] to formulate policies to recirculate Euro cash locally and reduce the transportation needs for cash.[11] On the crypto side, 250 cryptocurrency providers joined forces to establish the Crypto Climate Accord (CCA), supported by the United Nations Framework Convention on Climate Change (UNFCCC) Climate Champions. Their goal is to decarbonise cryptocurrencies in the industry to achieve net zero emissions.

Governance around payments extends to the European-wide, EU and national levels. The European Parliament has taken several strategic initiatives around increasing access to electronic payments. The recent European policy initiative on instant payments aims to enhance availability and access to euro transactions across EU and EEA countries while also ensuring low pricing on instant transfers for consumers.[12] Simultaneously, the broader EU Retail Payment

The European Parliament has taken several strategic initiatives around increasing access to electronic payments.

[6] One example is shown from an ACH in which the company has its own CSR team to provide a 5-year roadmap for integrating the ESG in its company operation. Such a roadmap, according to the ACH's plan, is their plan to make payment more sustainable.

[7] See https://cryptoclimate.org/

[8] See the announcement from the European Commission, larger companies such as listed companies and banks must apply the new rules for the first time in the 2024 financial year. See https://finance.ec.europa.eu/capital-markets-union-and-financial-markets/company-reporting-and-auditing/company-reporting/corporate-sustainability-reporting_en

[9] See https://www.eba.europa.eu/sites/default/files/2024-01/c94fd865-6990-4ba8-b74e-6d8ef73d8ea5/Consultation%20papaer%20on%20draft%20Guidelines%20on%20ESG%20risks%20management.pdf

[10] See https://www.europeanpaymentscouncil.eu/news-insights/insight/euro-cash-cycle-how-does-it-work-and-what-its-environmental-impact

[11] See https://www.europeanpaymentscouncil.eu/sites/default/files/kb/file/2019-10/EPC260-19%20Cash%20Recirculation%20Paper%20v1.0.pdf

[12] https://www.consilium.europa.eu/en/press/press-releases/2023/11/07/instant-payments-council-and-parliament-reach-provisional-agreement/

Strategy[13] emphasises the importance of digitalisation and innovation in payments, particularly in light of the acceleration of digital payments and e-commerce since the Covid pandemic. This strategy promotes the adoption of instant payments, supports the development of pan-European payment solutions, and explores further concepts like open finance to foster competition and innovation. Governance efforts around promoting ESG concerns reflect a concentrated effort to promote a more efficient and resilient payment ecosystem.

RECOMMENDATIONS

We believe there are several recommendations that industry stakeholders should consider to promote ESG issues across the payments ecosystem.

- Payment system operators have a responsibility to make the payment services they offer as environmentally-friendly as possible. This means switching to hardware stacks that last longer (i.e. switching to solid state drives), ensuring that hardware is recycled whenever possible, and sourcing electricity that is produced sustainably. Balancing these needs with social aspects (such as the need to keep certain payment methods active to ensure financial inclusion) and governance issues should not be forgotten.
- National policymakers should support the use of electronic payment methods because they are more environmental friendly and are socially beneficial (i.e. combat money laundering and other nefarious practices) while maintaining access to cash for social reasons, such as financial inclusion.
- Making good decisions requires accurate and up-to-date data, so industry associations should standardise and improve the monitoring and reporting of ESG data to ensure accurate and comparable data is collected. Standardising the collection and reporting electricity usage, e-waste generated, and carbon emissions across markets is important to the effective evaluation of ESG impacts. While any standardisation effort will inevitably meet some of the same challenges encountered in this paper, there are clearly areas that can be standardised.
- Industry stakeholders should enhance coordination around ESG to ensure shared sustainable practices through knowledge-sharing and collective efforts, ensure that social issues are taken into consideration prior to making decisions, and that decision-making be inclusive.
- Some digital currencies were found to be very harmful from an environmental perspective. Any future digital currency initiatives need to take emissions seriously and be designed in environmentally-friendly ways.
- Existing payment methods that include a physical component, such as cards, cash, and cheques, should look to ways to make the manufacture and transportation of physical components less dependent upon environmentally damaging substances such as plastic, metals, and fossil fuels.

There are other topics that should be considered, such as:

- "Instant as the new normal" may have environmental consequences given the current state of technology. As technology improves and technology stacks are modernised, the environmental gap between instant and batch payments could lessen, but this should not be assumed to be the case.
- The use of cloud computing for payment processing, both at the operator level and the financial institution level, as well as the use of mainframes versus distributed forms of computing all have arguments for and against them. Settling this debate from an ESG perspective requires better data collection and reporting requirements. We encourage industry stakeholders to take the necessary action to standardise and collect this data.
- European regulators have created a number of new payment types that have required supplementary regulation and the creation of new rulebooks. The effect that this has on environmental concerns is at best neutral and at worst negative due to the need to update core banking hardware. Regulators should consider the impact that new rulebooks and regulation could have on technology stacks as well as the creation of e-waste that comes with any modernisation effort. ■

[13] https://www.ecb.europa.eu/pub/pdf/other/ecb.eurosystemretailpaymentsstrategy~5a74eb9ac1.en.pdf

APPENDIX I

LITERATURE REVIEW

SOURCE MATERIAL

Many industry stakeholders address ESG concerns by including assessments of the environmental impact for various payment methods. However, much of the existing research focuses on measuring the environmental impact of individual payment instruments rather than comparing multiple methods. Cash and digital currencies have received the most attention, followed by cards. Cheques, account-to-account payments (both batch and instant) have not been extensively studied.

This section examines existing literature, including industry reports, scientific research, journals, governmental and international organisational reports, and business intelligence sources. We discuss the methodologies employed by these sources to evaluate the environmental impact of different payment methods, the factors considered, and their findings. We then identify research gaps and discuss how they are addressed through alternative approaches, primarily through interviews with industry experts. This section also provides a discussion of the challenges associated with comparing data.

CASH

Several studies on cash utilise life cycle analysis (LCA) to evaluate environmental impact. These studies typically break down cash's life cycle into raw materials, production, operation and distribution, and end-of-life phases. Adopting a consistent approach across studies proves challenging. The European Central Bank (ECB) conducted LCAs for the first and second series of euro banknotes in separate studies in 2005[14] and 2023.[15] The 2023 study diverged from the previous methodology, opting for the European Commission's Product Environmental Footprint (PEF) methodology. The Dutch National Bank (DNB)[16] and a joint report from the French Banking Federation,[17] EY, and Bio Intelligence conducted studies using the ReCiPe endpoint (H) impact method while the Bank of England[18] (BOE) utilised carbon footprint, certified by the Carbon Trust Environmental Standard.

Various studies conducted by central banks primarily focused on the environmental impact of banknotes, neglecting the consideration of coins. This includes working papers from both the European Central Bank (ECB) in 2005 and 2023 as well as the Swiss National Bank (SNB) in 2022,[19] which examined the environmental impact of different series of euro banknotes and Swiss banknotes, respectively. Notably, the ECB's 2023 study explicitly excludes consideration of the environmental impact of euro coins and electronic payments. The Bank of Canada (BOC) in 2011[20] and the BOE in 2013 and 2017[21] conducted research comparing the carbon footprint of cotton and polymer paper notes, assuming the lifespan of polymer banknotes to be approximately twice as long as that of cotton-made banknotes. They concluded that polymer banknotes generally have a lower environmental impact compared to those made from cotton, with the exception of photochemical ozone creation as highlighted in the BOE's 2013 study.

Comparing studies solely on cash payments is challenging because the results are expressed in various units. For example, the ECB and DNB present results in micropoints (µPt) alongside the Global Warming Potential (GWP) value in CO2 equivalents (CO2e), while the Bank of England and Pagone et al[22] provide results in terms of carbon footprint. The Swiss National Bank uses a Swiss-based unit of measurement called environmental impact points (EIP) to assess the environmental impact of Swiss banknotes. The problem of differing methods of measurement being used to assess environmental impact across studies was prevalent across the various payment methods examined in this study.

[14] ECB, (2005), "LCA of Euro Banknotes 2003: Final Report. Confidential report" by E2 Management Consulting AG, in cooperation with PRé Consultants.
[15] See https://www.ecb.europa.eu/pub/pdf/other/ecb.pefreport202312~81e945e7aa.en.pdf
[16] See https://www.dnb.nl/media/3bndnaql/610-life-cycle-assessment-of-cash-payments.pdf
[17] French Banking Federation, Ernst and Young, Bio Intelligence Service, (2011), "Environmental footprint of payment methods"
[18] See https://www.sciencedirect.com/science/article/pii/S221282712300094X
[19] See https://www.snb.ch/dam/jcr:7b5c4c08-c96d-4507-ac78-c92729724e51/life_cycle_assessment.en.pdf
[20] See https://www.bankofcanada.ca/wp-content/uploads/2011/06/Life-Cycle-Assessment-of-Polymer-and-Cotton-Paper-Bank-Notes_opt.pdf
[21] See https://www.bankofengland.co.uk/-/media/boe/files/banknotes/polymer/lca-of-paper-and-polymer-bank-notes.pdf
[22] See https://www.sciencedirect.com/science/article/pii/S221282712300094X

The study by the Dutch National Bank (DNB) in 2018 and the report from the French Banking Federation, EY, and Bio Intelligence in 2011 examined coins, banknotes, and debit cards. The DNB study is particularly relevant as it offers a detailed analysis of the environmental impact of multiple payment instruments within the Euro area. These studies indicate that the operation of ATMs and the circulation of coins and banknotes have the most significant environmental impact, surpassing other stages of cash's life cycle such as production and end-of-life disposal. When comparing coins and banknotes, the DNB study demonstrates that coins have a greater environmental impact due to metal depletion.

CARDS

The Dutch National Bank (DNB) in 2017,[23] Pagone et al in 2023, and a YouGov study from 2022[24] each used different LCA approaches. They gathered data covering the entire life cycle of card payments, including raw materials, production, card usage, and end-of-life disposal. Researchers use benchmarks such as functional units and set parameters in their studies to establish clear goals and scope. The DNB study (2017) used an average debit card transaction of EUR 28.68 at the point-of-sale as the functional unit whereas Pagone et al. (2023) and the YouGov study (2022) set parameters on the card's lifespan, composition, weight, production volume, and annual number of payments.

The results from Pagone et al and the DNB study suggest that card payments are slightly more environmentally friendly than both coin and banknote payments due to the environmental impact caused by the production and transportation of cash. According to the DNB, the majority of the environmental impact stems from the use of payment terminals and their materials, which account for 75% of the card's entire environmental impact. The remainder is attributed to card production and data centers.

DIGITAL CURRENCIES

Researchers assess the environmental impact of digital currencies differently than with cash and cards. Instead of conducting an LCA, most studies, such as Pagone et al (2023), the Cambridge Bitcoin Electricity Consumption Index (CBECI),[25] and the International Monetary Fund (IMF, 2022)[26] focus on energy consumption. In Table 2, Pagone et al. present a framework illustrating the differences in assessment between cryptocurrencies and fiat currencies (encompassing cash and cards). Alex De Vries,[27] the founder of the Digiconomist website, takes the energy cost into consideration when determining the overall energy consumption of Bitcoin. Notably, this analysis excludes the materials of hardware and any associated production costs. A study by the Business Intelligence Agency Reconnaissance group suggests that this omission is likely due to the difficulty in quantifying the carbon footprint of digital payments, including hardware and software, as well as energy consumption for payment data processing, data management, and payment devices accessed via the internet or mobile phones.

Besides the assessment consideration, two key factors determining digital currencies' energy consumption are the type of consensus mechanism used for network agreement and the level of control for validation within the network. The International Monetary Fund (2022) highlights Bitcoin as an example of the proof-of-work (PoW) consensus mechanism, revealing that the annual energy consumption of the Bitcoin network equals that of Austria and Finland combined. In contrast, non-PoW mechanisms, being permissionless, consume less energy since they do not necessitate a robust core processing infrastructure.

Alex De Vries' study (2023) on Ethereum, another cryptocurrency, illustrates this point by demonstrating a significant increase in energy efficiency when Ethereum transitioned its consensus mechanism from PoW to proof-of-stake (PoS) in September 2022. PoS, a non-PoW mechanism, uses less energy. The IMF suggests that this could be a crucial factor in the design of Central Bank Digital Currencies (CBDCs) in the future, which was echoed by the World Bank and the European Central Bank (ECB). Since most

[23] See https://www.dnb.nl/media/a3sk2oob/574-evaluating-the-environmental-impact-of-debit-card-payments.pdf
[24] See https://assets.ctfassets.net/40w0m41bmydz/1knB1JoEFasAZ1a6l4MRCk/4eec8644092674ed4c28c2e42efa9095/Payments__plastics__people_and_the_planet.pdf
[25] See https://ccaf.io/cbnsi/cbeci/methodology
[26] See https://www.imf.org/en/Publications/fintech-notes/Issues/2022/06/07/Digital-Currencies-and-Energy-Consumption-517866
[27] See https://digiconomist.net/bitcoin-energy-consumption

CBDCs are either in development or were only recently launched, research on their environmental impacts largely relies on estimations of intended design. This paper prioritises observable past actions over statements of intention.

Many authors tend to compare the environmental impact of Bitcoin with other payment instruments. Despite Bitcoin's relatively uncommon usage as a form of payment, Deloitte[28] estimated that approximately 2,352 businesses in the United States accept Bitcoin out of over 33 million in total.[29] Apart from the study conducted by Pagone et al, de Vries compares a single Bitcoin and Visa card transaction on his website Digiconomist, asserting the carbon footprint of one Bitcoin transaction is equivalent to 959,395 Visa card transactions. It is also worth noting that electronic waste emissions from retired mining hardware pose a concern, with Alex de Vries and Christian Stoll (2021)[30] attributing this issue to the short lifespan of mining hardware.

CHEQUES

A study conducted by the French Banking Federation (FBF) in 2011 compared the environmental impact of cheques, cash, and card payments, revealing that card payments generated the lowest amount of greenhouse gases, followed by cheque and cash payments; however,there is insufficient public information available from the FBF regarding how they quantify the environmental impact of these payment methods. It is challenging to ascertain how exactly the environmental impact is measured due to research gaps concerning cheque payments.

For a deeper understanding of cheque usage, data from the European Central Bank's 2022 Payment Statistics[31] indicates that cheques account for less than 2% of all payment services in the Euro area. Despite France having the highest number of cheque transactions in 2021,[32] only 1.8% of cheques in France were processed physically as of 2012,[33] indicating a shift towards electronic cheque processing and a reduction in environmental impact.

BATCH AND INSTANT PAYMENTS

Most studies compare the environmental impact of cash, cards, and digital currencies, with only a few including account-to-account (A2A[34]) payments. YouGov (2022) conducted a comparison between the energy consumption of a fintech's A2A payments model and card payments, indicating that A2A payments can enhance energy efficiency and reduce energy consumption by 75% compared to card payments. This improvement is attributed to the simplified two-step process versus the eight-step payment process involved in card payments. A2A payments result in lower energy consumption by reducing the number of messages during payment processing. The entire life cycle of a card is not explicitly considered in these calculations, although the study does discuss the production and end-of-life cycle of cards.

Regarding instant payments, the Bank of Italy (2021[35]) conducted a comparison of the environmental impact of the ECB's instant payment system, TIPS, with other instant payment systems (such as Sweden's BiR) and Bitcoin, using an LCA approach. The assessment's scope encompasses the energy used for server production, transportation, and installation as well as TIPS usage and end-of-life cycle management of hardware. The study finds that the carbon footprint of TIPS in 2019 is approximately 40,000 times less than that of Bitcoin, though it is important to note that this is the only study focusing on the environmental impact of instant payments.

The scarcity of sources addressing A2A payments in this field highlights a significant research gap. This study aims to bridge this gap via multiple interviews with Automated Clearing Houses (ACH), enabling qualitative insights for analysis.

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[28] See https://www2.deloitte.com/content/dam/Deloitte/us/Documents/audit/us-corporates-using-crypto-pov.pdf based on Maddie Sheperd, "How many businesses accept bitcoin? Full list," Fundera, October 10, 2022.

[29] See: https://www.uschamber.com/small-business/state-of-small-business-now

[30] See https://www.bbc.com/news/technology-58572385

[31] See https://www.ecb.europa.eu/press/pr/stats/paysec/html/ecb.pis2022~8bb6cc08f4.en.html

[32] See https://data.ecb.europa.eu/sites/default/files/2023-09/Payment%20Statistics%20%28full%20report%29.pdf

[33] According to the Bank of International Settlement and Banque de France. For more information please see https://www.banque-france.fr/system/files/2023-04/819029_livre_chapitre_2_en.pdf

[34] Account-to-account payments refer to batch and instant payments.

[35] See https://www.bancaditalia.it/pubblicazioni/mercati-infrastrutture-e-sistemi-di-pagamento/approfondimenti/2021-005/N.5-MISP.pdf?language_id=1

APPENDIX II

LIFE CYCLE ANALYSIS: DIGITAL CURRENCY

We focused on Bitcoin when assessing the environmental impact of digital currencies due to its status as one of the world's most widely held digital currencies. There is a substantial body of research examining Bitcoin's environmental impact, including energy consumption, carbon emissions, and overall ecological impact. The combination of its age, prominence, and the abundance of research make using Bitcoin suitable for understanding the broader environmental impact of digital currencies. We are aware, however, of potential criticism that Bitcoin may not be representative of other digital currencies. While that is a fair assertion, there are very few digital fiat currencies that have moved beyond the pilot stage or are being used in contexts comparable to Europe where the digital Euro is expected to be created (such as the Sand Dollar in the Bahamas).

PRODUCTION AND USAGE STAGES

We combined the production and usage stages due to how Bitcoin's system works; the production and processing of Bitcoin transactions cannot be separated. Bitcoins are produced as a part of the verification and processing of transactions on the Bitcoin ledger, a type of blockchain. Information storage is decentralised within the blockchain network, with each participant ('node') having an entire copy of the transaction history. Bitcoin "miners" are network participants who compete to solve cryptographic puzzles to verify these transactions and add a block to the chain of transactions. Miners are rewarded for lending their processing capacity with a certain amount of newly generated Bitcoin.

This is a part of Bitcoin's "proof-of-work" (PoW) mechanism, which differs from the "proof-of-stake" (PoS) process used by other cryptocurrencies where a network participant is chosen to verify/create new blocks based on the amount of crypto that they stake as collateral. While Bitcoin's PoW mechanism is the basis for the networks security and decentralisation, it is also the cause of its considerable environmental footprint because the energy consumed and the hardware required are considerable and very inefficient. The various mining facilities competing to verify transactions first multiply the total amount of energy required to process a transaction. The actual storage of transaction information after the mining/PoW process, however, only requires a minimal amount of electricity.[36]

Mining operations typically happen at specialised data centres using many highly advanced computers with application-specific chips. These computers have no alternative use beyond Bitcoin mining and require expensive materials that require extraction and processing,[37] increasing their environmental impact. The demand for this hardware has even played a role in disrupting the global semiconductor trade.[38] Looking at Bitcoin's total environmental impact, mining represents the largest output and source of inefficiencies within the life cycle. The resulting carbon impact is the equivalent to the output of individual countries such as Belgium,[38] Poland,[39] or Sri Lanka,[40] while mining takes up 99.8% of all electricity used throughout the Bitcoin life cycle.[41] The draw on power grids is enormous, with the mining process consuming over 113.88 TWh a year for the entire Bitcoin network[42] without accounting for the cooling process, which is also energy-intensive. Other studies have pointed to per-transaction energy consumption within the range of 786.81 KWh, roughly the overall consumption of a U.S. household for a month.[43]

END-OF-LIFE STAGE

Bitcoin's end-of-life stage contributes significantly to its environmental inefficiencies, though more in the way of electronic waste (e-waste) than any other metric. With an average lifespan of merely 1.3 years,[44] mining hardware becomes quickly

[36] Croman et al.: On scaling decentralized blockchains. 2016
[37] De Vries, Alex, and Christian Stoll (2021). „Bitcoin's growing e-waste problem." https://www.sciencedirect.com/science/article/pii/S0921344921005103
[38] DeVries, A. (2020). Bitcoin's energy consumption is underestimated: A market dynamics approach.
[39] CBECI (2023c). Greenhouse Gases Emissions, Index. Cambridge Center for Alternative Finance. University of Cambridge. Available online at https://ccaf.io/cbnsi/cbeci/ghg
[40] Stoll,C.,Klaaßen,L., andGallersd¨orfer,U. (2019). The carbon footprint of bitcoin
[41] Rachel Rybarczyk et al. 2021 On Bitcoin's Energy Consumption: A quantitative approach to a subject question.
[42] Rybarczyk et al. 2021
[43] https://digiconomist.net/bitcoin-energy-consumption
[44] De Vries, Alex, and Christian Stoll (2021). „Bitcoin's growing e-waste problem." https://www.sciencedirect.com/science/article/pii/S0921344921005103

unprofitable and necessitates replacement, generating substantial e-waste. The hyper-specialisation of Bitcoin mining computers coupled with their inability to be used for any other purpose accelerates the cycle of obsolescence, resulting in a rapid turnover of powerful and short-lived devices. The annual e-waste generated for Bitcoin was estimated in one study to be over 30,000 tons in 2021, equivalent to the e-waste generated in the Netherlands.[45] When broken down on a transaction basis, 272 grams of e-waste, the equivalent of two iPhones, is generated for each transaction.[46] Further exacerbating this is the state of e-waste recycling, as only 17% of all e-waste is recycled[47] coupled with the fact that a significant portion of Bitcoin mining takes place in jurisdictions with little regulatory oversight on e-waste recycling. Bitcoin production represents a staggering environmental impact, contributing greatly to carbon emissions, electricity consumption, e-waste, and resource extraction for a payment instrument used by a fraction of the population and seldom used for anything other than speculation.[48]

LIFE CYCLE ANALYSIS: CASH

For a life cycle analysis on the ESG impacts of cash payments, our paper borrows heavily from the work of the Dutch National Bank and its investigation into the environmental impacts of Euro banknotes and coins in 2016 in the Netherlands.[49]

PRODUCTION STAGE

This paper accounts for the materials and transportation required to produce Euro banknotes and coins. Euro banknote production requires cotton, thread, foil, and ink, and mixes cotton, additives, chemicals, and water into a pulp, which is turned into security paper on which the notes are printed. Cotton is sourced from outside of Europe, requiring transoceanic shipping and transport to minting locations via trucks, resulting in a higher environmental impact than if the cotton was produced locally. The energy used by the machines for to print the the notes was approximately 232 megawatts (2015) in the Netherlands alone. Coin production is divided into blank production and the actual minting process. The production of coin blanks requires non-recycled quantities of steel, aluminium, nickel, zinc, and tin as well as a mixture of recycled and non-recycled copper, leading to resource depletion and environmental impact from mining and minting. Banknote production makes up less than 5% of the total environmental impact while coin production makes up 32%, according to the DNB study.

OPERATIONAL STAGE

The operational phase for cash encompasses various processes that can be broken down into transportation, ATM utilisation, and cash handling. Transportation involves moving the cash from where it is produced to national banks before being sent to distribution centres to be put into circulation. Distribution includes refilling ATMs and services that facilitate the transportation of cash between distribution centres and companies. Transportation in most European countries is facilitated by armored diesel trucks, with the resulting emissions adding to the total environmental impact. ATM and cash recycling machines also play a pivotal role in facilitating cash usage, though they also have an environmental impact due to electricity usage and the corresponding CO2 emissions. Energy usage by bank ATM networks was 10.1 GWh in 2015 in the Netherlands. Cash handling in distribution centres also imposes environmental concerns, with the paper referencing energy usage estimates around 752 MWh in 2015 in the Netherlands. Due to the transportation required and the need to maintain the ATM network, cash's operational phase accounts for 64% of the total environmental impact.[50]

END OF LIFE STAGE

Compared to the production and operational stages, cash's end-of-life stage is negligible due to the disposal processes and rather long life span of banknotes (roughly 4 years for

[45] Ibid.
[46] See: https://www.theguardian.com/technology/2021/sep/17/waste-from-one-bitcoin-transaction-like-binning-two-iphones#:~:text=In%202020%20the%20bitcoin%20network%20processed%20112.5m%20transactions%20(compared,272g%20of%20e%2Dwaste%E2%80%9D.
[47] https://www.bbc.com/news/technology-58572385
[48] Ulbrich Bindseil & Jürgen Schaaf: Bitcoin's last stand. 2022 https://www.ecb.europa.eu/press/blog/date/2022/html/ecb.blog221130~5301eecd19.en.html
[49] Life cycle assessment of cash payments: Hanegraaf et al. 2016
[50] Ibid.

smaller denominations and 10 years for larger denominations[51]) and coins (roughly 30 years[52]). Banknotes within the Eurozone are generally shredded once they are considered unfit for circulation, after which they are granulated, packed into bags, and sent to waste control centres for incineration. 1,800 KWh in energy is expended for each ton of banknotes incinerated, with 105 tons being incinerated in the Netherlands in 2015. The long lifespan of coins means that very few need to be decommissioned. Coins are transported to a melting company to be recycled into other products. The environmental impact for this stage is therefore miniscule compared to the production and operation phases, accounting for less than 0.01% of cash's total environmental impact.

LIFE CYCLE ANALYSIS: CARDS

Cards are one of the most widely used payment methods and have a complex lifecycle; the need for an intitiation tool, i.e. a terminal, adds additional layers to the analysis of the production and end-of-life stages. This study used a working paper from the Dutch National Bank as the main source because it was deemed the most comprehensive qualitative analysis among all related sources.[53] This paper has focused on conditions in the Netherlands, making a number of assumptions to simplify calculations without compromising the accuracy of the end results. While the results were published in grams of CO2 emitted, these were converted to kWh to enable comparisons with other instruments, using the generation emission factor for grid electricity of the UK government in 2023.[54]

PRODUCTION STAGE

We included several different factors in the production phase, but focused on initiation devices, cards, card terminals, and the data centres used to process card payments. Our study excluded the implications of mobile and desktop-initiated card payments because initiating payments is only a very small part of what they do, making it is impossible to define total emission shares related to card payments. The analysis of the production phase includes materials used for cards and chips, raw materials used for card terminals and data centres, the main manufacturing steps for all hardware, and the transportation of cards and terminals to customers and retailers.

Our quantitative results are taken from the aforementioned DNB working paper, though it does not provide a complete breakdown of the different components' share of total emissions from card payments. For materials used in the card and chip, manufacturing and transportation emissions (from manufacturing to customisation centres, from there to customers, and from them to waste management facilities) result in 0.00249 kWh emissions, 14.7% of the total. Terminal materials, manufacturing, and their transportation emissions (from manufacturing to retailers) result in 0.0069 kWh, 41.1% of the total. Materials for data centre components and their manufacturing result in 0.00031 kWh, 1.86% of the total. This figure includes emissions from terminals, but not from incinerating cards.

The following components are excluded from the calculations for simplicity: transportation of data centre components, emissions from the packaging of cards and terminals, and emissions from the manufacturing of data centre components (the latter excluded due to lack of data). The production phase accounts for 57.66% of the total emissions of a card transaction.

OPERATION STAGE

The energy usage during payment processing is the focus of the operation stage. Card processing requires ATMs (withdrawals), POS terminals for initiation, and data centres for clearing and settlement. ATMs have been omitted from the calculations as they have a number of other use cases and we were unable to find data that breaks down ATM energy consumption based on services. Bank branch emissions, which are part of a card payment life cycle in multiple ways (distributing cards, maintaining ATMs and managing card replacements), have also been omitted because, similarly to ATMs, they are responsible for numerous

[51] https://www.geld-und-geldpolitik.de/en/cash-chapter-2.html#:~:text=The%20lifespan%20of%20a%20banknote,than%20ten%20years%20in%20circulation.
[52] Life cycle assessment of cash payments: Hanegraaf et al. 2016
[53] Lindgreen, Erik Roos, et al. (2017). „Evaluating the environmental impact of debit card payments". https://www.dnb.nl/en/publications/research-publications/working-paper-2017/evaluating-the-environmental-impact-of-debit-card-payments/
[54] UK Department for Energy Security and Net Zero. (2023). "Conversion factors 2023 condensed set". https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2023

services and it is impossible to identify the exact share of card emissions. The maintenance of data terminals that payment processors apply for card payments are often responsible for processing multiple payment types and cannot separate the usage for card payment exactly. This was confirmed in multiple interviews we conducted with payment processors that manage the processing of multiple payment methods.

The energy consumption of data centres' payment processing is 0.00148 kWh, 8.84% of the total, while the energy consumed by card terminal operations results in 0.0045 kWh, 26.8% of total emissions. It is important to note that the authors of the DNB paper assumed that retailers follow the suggestion of POS system developers to always keep the machines connected to an outlet for system updates to go through at all times, for security reasons. In real life, however, there is no way to know the exact operating hours of all POS machines, even in a controlled environment.

END-OF-LIFE STAGE

The end-of-life phase for cards is multifaceted because cards require various hardware to operate. Cards, POS machines, and data centres all have plastic components that take hundreds of years to decay, adding serious ESG implications. In most cases, customers dispose of their cards through municipal waste, although recently there have been numerous initiatives to collect and recycle cards from customers and businesses upon expiration, such as Mastercard's used card recycling program in the UK.[55] Nevertheless, this is a new development and most payment cards are still incinerated with other general waste, making it tough to identify the exact environmental implications from payment cards. The DNB working paper accounted for incineration emissions by consulting with a company that processes electronic waste and used their insights on the waste management of key components from cards and POS terminals to calculate emissions. These were determined to be 14.7% and 41.1% of collective emission results stated in the production phase, respectively. While the transportation of cards from customers to waste management facilities was also included in the 14.7% share stated in the production phase, the transportation of terminals from retailers to the waste management facilities was not, which came out to 0.00067 kWh or 4.03% of total emissions.

The DNB paper investigated what happens with cards that are incorrectly ordered or mistakes in manufacturing or personalization, and estimate the energy generated from their incineration on a yearly basis. The DNB considered this as an offset, but our study found no significant evidence of this in other markets, so we added back the 2% reduction, arriving at a total of 0.01714 kWh as the total environmental impact of a card transaction.

LIFE CYCLE ANALYSIS: CHEQUES

PRODUCTION STAGE

Cheque usage has been declining across Europe and has disappeared completely in some markets. Countries such as France, Ireland, and the UK still use them in significant numbers,[56] necessitating their examination for this study. While parsing out the overall impact of cheque payments is not feasible on a European level, independent studies by the French Banking Federation have estimated that the per-transaction environmental impact of this payment instrument is roughly 0.072 KWH or 15 g of CO2.[57]

Cheques require paper and ink; paper is typically sourced from wood pulp, while ink comes from a variety of pigments, solvents, and special oxide particles for magnetic ink. The production of paper for cheques entails logging and processing timber for paper, contributing to deforestation. the extraction of materials for ink production involves mining and processing pigments, raising environmental concerns. The manufacturing of paper is marked by its resource-intensive nature, with mills responsible for pulp processing demanding significant energy. After the cheques are produced, they must be packaged and transported to banks for distribution via truck or car, increasing carbon emissions.

OPERATIONAL STAGE

Cheques are most often used for B2B, C2B, and occasionally P2P payments. Most cheque processing in Europe is performed electronically,

[55] Bhalla, Ajay. (2023). " Shredding a myth about recycling: It's time to tackle first-use plastic cards". https://www.mastercard.com/news/perspectives/2023/shredding-a-myth-about-recycling-it-s-time-to-tackle-first-use-plastic-cards/
[56] ECB report 2022
[57] Federation Bancaire Francaise: Development Durable 2021.

cutting out the need for overnight flights or the use of trains or trucks for transport, as was formerly the case.[58] The advent of electronic check processing represents a significant shift in the ESG impacts of cheque processing because it involves the transformation of paper cheques into electronic images, cutting out the need for transportation for processing and mitigating the environmental impact associated with transportation, storage, and disposal of cheques. Electronic processing also introduces new considerations such as energy consumption and electronic waste associated with the required technological infrastructure. Within Europe, processing procedures vary, but generally, low-value checks (under €6,000 in Germany, for example) are scanned and sent electronically to a clearing house by receiving banks. The clearing house then forwards cheque images to the paying bank or a designated office to decide whether it should be honored and processed.[59] This process entails electricity usage and carbon images generated from data transmission, storage, and security measures. Each cheques can only be used once, greatly increasing their environmental impact.

END-OF-LIFE STAGE

Cheques require disposal or recycling. Physical cheques are usually destroyed after being processed by banks, with the waste ending up at recycling centres or in landfills. The destruction process involves shredding or burning. The devices used for cheque destruction can include shredding machines and/or furnaces, both of which are associated with their own environmental costs due to carbon emissions and electricity usage. Practices vary from bank to bank and between nations, making an easy generalisation of the ESG impacts difficult to quantify on the European level. The factors involved in the life cycle of a cheque allow us to rank it as one of the more unsustainable payment instruments on a per-transaction basis, especially due to the single-use nature of the instrument.

LIFE CYCLE ANALYSIS: INSTANT PAYMENTS

PRODUCTION STAGE

The production stage for instant payments has significant similarities with batch payments, as revealed by our survey of relevant literature and our interviews with EACHA members. Operators responsible for both batch and instant payments commonly utilise the same hardware stack for processing both types of transactions, underscoring the overlap in environmental implications between the two payment methods. The production process involves the manufacturing of significant hardware components for both the operators and the financial institutions that facilitate these transactions. The extraction and processing of raw materials to produce this equipment has significant environmental impacts, as does the transportation and installation of this hardware.

OPERATIONAL STAGE

Despite the similarities in the production stage, the operational stage differs to some degree from batch payments due to the message-by-message nature of transaction processing. Unlike batch processing, where payments are grouped and processed collectively, instant payments are handled individually. Our interviews with EACHA members indicate that instant payments require approximately three times more energy and processing power compared to batch payments. This heightened energy consumption is attributed to the increased CPU power needed to facilitate each transaction, imposing burdens both on the system operator and the banks responsible for processing payments. It is worth noting that outdated software and coding can significantly impact energy consumption; using modern software can increase energy efficiency as can transitioning away from using physical servers to cloud-based servers.

END-OF-LIFE STAGE

The disposal and recycling of hardware components play a crucial role in overall environmental impact. As with batch payments, the lifespan of servers and other hardware varies among operators, as it is often the same equipment. Upon reaching the end of its lifespan (generally 3-5 years), equipment goes through the decommissioning process, with some components repurposed for secondary use (servers from a European system operator were repurposed by local hospitals for their IT systems) while other components are recycled through specialised companies. Hardware disposal can pose environmental challenges due to the

[58] https://www.digitalcheck.com/check-21-environmental-impact/
[59] https://www.bundesbank.de/en/tasks/payment-systems/rps/national-cheque-processing/national-cheque-processing-626586#:~:text=The%20clearing%20house%20forwards%20these,effected%20through%20the%20clearing%20house.

generation of e-waste. Efforts to responsibly manage end-of-life considerations are seen through adherence to recycling protocols, though this is not possible for all hardware components. Advancements in technology, such as the usage of hardware with a longer lifespan, help reduce the environmental impact.

LIFE CYCLE ANALYSIS: BATCH PAYMENTS

PRODUCTION STAGE

Though little analysis exists and our interviewees were unable to reveal exact metrics for the impact of the production of ACH infrastructure used for batch payments, this stage still entails significant environmental implications. The production of the infrastructure required to process batch payment involves the manufacturing of hardware such as servers, routers, PCs, and cables, as well as the computers and servers needed by banks and end users to initiate these transactions. These devices are composed of raw materials sourced through mining and manufacturing, contributing to resource depletion and environmental degradation. The production of servers generates greenhouse gas emissions and consumes energy alongside the transportation and installation of this hardware.

OPERATIONAL STAGE

In cases where the ACH operator also operates the real-time system, these systems will often be run from the same hardware. These servers often facilitate VAS such as fraud detection, confirmation-of-payee, and other services, such as back-off processing in addition to standard transaction processing. As a result, measuring the environmental impact of batch payments alone can be quite difficult between markets where the ACHs do not necessarily offer the same services nor can the usage by these services be separated from the pure transaction process. The bundled nature of batch payments, in which payments are processed in batches rather than individually allows for more efficiency in processing by both the operator and the individual banks receiving payment messages. The difference in energy consumption between an instant payment and a standard credit transfer is roughly 3:1, according to our interviews with five European Automated Clearing House Association (EACHA) members.

Another significant draw on the energy consumption is the cooling required to ensure hardware does not overheat, which can represent up to 60% of the energy used by ACHs as a whole.[60] There is a significant difference between different types of batch payments in terms of energy usage, with direct debits being more inefficient than credit transfers due to the additional payment messages that must be sent via the infrastructure and the relative amount of exceptions handling. Outdated software and coding can have a much larger impact on energy consumption than actual payment volumes processed. Batch payments are likely to become even more efficient than other payment instruments over time as technology progresses.

END-OF-LIFE STAGE

The end-of-life stage for ACH hardware encompasses various considerations stemming from the lifespan of ACH hardware and component parts. Operators often adhere to periodic maintenance cycles in which servers are evaluated and/or upgraded every 3-4 years to maintain capacity and efficiency, which is when transitions to newer technology take place, such as to cloud-based services. The lifespan of individual server components, such as CPUs, disks, and memory, further complicates the evaluation of the end-of-life process. For example, operators using solid-state disks in their hardware stacks need only to replace them every 10-15 years whereas older hardware may be replaced within 5 years.[61]

The lifespan of ACH hardware varies, even among members of EACHA. In some markets, hardware needs to be replaced every 3-5 years while in other markets hardware stacks have a lifespan of up to 15 years. The process for disposal of e-waste at the end of the equipment's life cycle involves outdated equipment being sent to specialised hardware disposal companies for recycling, though not all equipment is recyclable. The end-of-life stage for ACH equipment underscores the importance of efficient resource management and responsible disposal practices to minimise environmental impact and maximise the sustainability of ACH infrastructure.

[60] Interview with EACHA members, 2024
[61] Ibid.

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About EACHA

The European Automated Clearing House Association (EACHA) is the technical cooperation forum of European ACHs. Its membership, currently comprising 27 institutions, gathers twice a year to discuss European developments in retail payments. The philosophy of EACHA is that healthy competition also means teamwork. This is why EACHA believes firmly in developing a common vision for the future, and favouring harmonious implementation of European policies and schemes including interoperability based on open standards.

EACHA aims to:

- be a forum enabling its members to share information
- advance the views of its members on issues of general interest
- resolve specific issues by, for instance, developing common guidelines for the clearing and settlement of SEPA payments

For more information, see **www.eacha.org**

About Lipis Advisors

Lipis Advisors is a leading strategy consultancy specializing in the payment sector. Lipis Advisors staff are experts on payment systems, services, and strategy, as well as the underlying technologies that support payment infrastructures. Lipis Advisors advises on all forms of payments, including ACH payments, real-time payments, card payments, cheques, mobile payments, online payments, and RTGS/wire payments.

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