“ASSESSING THE CARBON FOOTPRINT OF THE PAYMENT SERVICES”

Research Paper

Olga Croft, Swiss School of Business and Management, DBA, Olga.Croft@protonmail.com

“Abstract”

The payments are an integral part of the business activities of any organization however its impact on the carbon footprint is not well understood and reported. The study explores the barriers for the realistic assessment of the indirect emissions from the payment services. Based on the systematic literature review the study provides the comparative analyses of the energy efficiency of the different payment types from cash and credit cards to cryptocurrency and digital currencies.

Keywords: Carbon footprint, payment services, indirect emissions

1 Introduction

Since the United Nations Kyoto Protocol agreement, countries and individual businesses have been adopting the carbon emission reduction targets as the sustainable development goal. The Green House Gas Protocol (GHGP) provides a framework for measuring and reporting carbon emissions, categorising them into different scopes based on activities and control levels. Scope 3 emissions, which are indirect emissions from an enterprise’s value chain, are particularly challenging to measure due to the lack of control and ownership over these emissions, difficulties in data collection and interpretation, and due to misconceptions about the service industries’ emissions. However, indirect emissions can represent the largest source of emissions for companies and offers the most significant opportunities to influence GHG reductions.

The value chain of any company encompasses the processing of incoming and outgoing payments through various methods and service providers, which must be considered as contributing activities to Scope 3 emissions. The carbon footprint of the payment services industry is the focal point of this article. It synthesises findings from the literature review and provides a comparative analysis of various payment methods. Beginning with the well-documented high energy consumption of cryptocurrencies, the analysis delves into the surprising statistics concerning more traditional payment methods such as cash, bank transfers, and credit cards. As one of the most innovative industries, payment services present an opportunity to investigate the key digitalisation trends that will influence energy consumption across all business sectors.

2 Literature Review Approach

The role of the finance industry in combating the climate change is well established, however the carbon footprint assessment of the financial services sector itself is greatly overlooked. The definition of the carbon footprint of the financial services and payments sector is not a very straightforward concept. The starting point of the literature review was the placement of the boundaries with the theoretical framework of the UN SDGs and the standards of the carbon emission measurement. The challenge was to determine what is applicable to the payment services industry. The energy consumption of modern financial services cannot be evaluated independently of its key enabler, the information technology and communication (ITC) industry; thus, it is essential to examine ITC trends and the dual impact of digitalization as both an energy efficiency optimizer and a catalyst for increased energy consumption.

The payments industry is undergoing the rapid transformation with the advance of new technologies, such as blockchain, and the continual introduction of new standards and regulations. Therefore, to ensure consistent results, it was essential to limit the review of literature to publications from the selected period up to the end of 2022. It means, that the initiatives, that were introduced in 2022 in the UK or internationally but not fully implemented were not included in the scope of the study.

To make the results comparable across the materially different payment systems such as cash and electronic payments, the assumption was made that the main contribution to the carbon emission is derived from the energy consumption. It limits the scopes of the environmental impact assessment by excluding the natural resources consumptions and the harmful effects of the manufacturing process on nature and human health, which were analysed as additional contributing factors.

Based on the initially collected insights, the systematic literature review was focused on all possible combinations of the following keywords:

- payment type: cryptocurrency, bitcoin, stablecoin, credit cards, mobile payments, central bank digital currency, cash, gold.
- sustainability: carbon footprint, energy consumption, environmental impact.
- digitalisation, payment systems, ICT.

The review highlighted that the cryptocurrencies, the bitcoin in particular, dominates the research on the subject of carbon footprint of the payment services. The following chat illustrates the statement with the statistics of number of publications by the payment type:

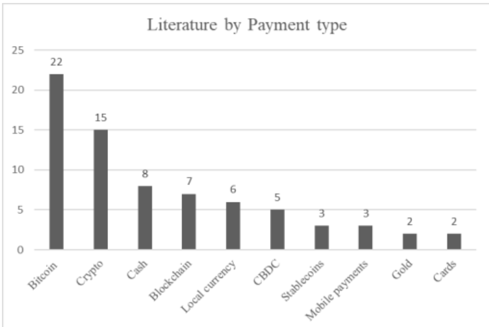

Figure 1. Research literature: number of publications by payment type

An analysis of the total number of citations for publications on various payment types indicates a growing interest in newly emerging payment methods, such as Local Bank Digital Currencies:

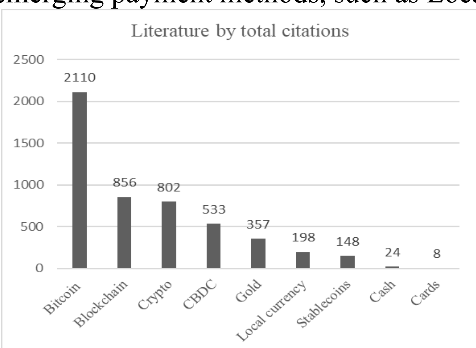

Figure 2. Research literature: total number of citations by payment type

The literture review confirmed that there is a lack of information and understanding of how to compare the carbon emission of the different types of payment within its entire value chain including the energy-consuming IT equipment, and the third-party providers of services or technology.

3 Assessing The Carbon Footprint of Payment Services

3.1 Carbon footprint: theoretical framework

The carbon footprint originates from the concept of ecological footprint, which is a measure of human demand on the Earth's ecosystems. The United Nations definition of the carbon footprint in the Climate Dictionary publication is "a measure of the greenhouse gas emissions released into the atmosphere by a particular person, organization, product, or activity" (UNDP, 2023).

The World Resource Institute (WRI) Green House Gas Protocol (GHGP) established a comprehensive global standardized framework to measure and manage greenhouse gas emissions from private and public sectors operations. The GHG Protocol categorizes emissions based on how directly they relate to a company's activities in Scope 1, 2 and 3. Thus Scope 3 is an indirect emission from the company value chain. The reporting standards for Scope 3 emissions are documented at the Corporate Value Chain Standard, that emphasises that 'Scope 3 emissions can represent the largest source of emissions for companies and present the most significant opportunities to influence GHG reductions and achieve a variety of GHG-related business objectives' (Callahan et al., 2011). According to the GHG protocol technical guidance Scope 3, the first category of indirect emission includes all upstream (i.e., cradle-to-gate) emissions from the production of products purchased or acquired, where a product is defined as either tangible goods or intangible services. Example of IT support is provided as a 'non-production-related-product' that can be categorised as purchased service.

GHG Technical guidance offers the various emission calculation methods relevant for each category. Thus, for Scope 3 purchased goods and services the recommended methods are the collecting the primary data from the suppliers or obtaining the secondary industry average or spend-data or using a hybrid method, which is combination of both. Carbon Disclosure Project (CDP) established that Scope 3 emissions represent the majority of emissions for many sectors, however identifying and reporting all relevant sources of Scope 3 emissions is often difficult. Thus, for financial services Scope 3 represents over 99% of total emission compared to about third for the transport services. The data related to the financial and payment services are very limited because only 35% of companies in the banking sector disclosed the carbon emissions in their annual reporting of 2021.

One of the key challenges is the data collection and the ambiguity of their interpretation, that leads to the tendency of the companies reporting the categories of emission that are easier to calculate, such as business air travel, rather the one that have the higher impact. Task Force on Climate-related Financial Disclosure (TCFD) statistics published in 2022 suggests that the Scope 3 emissions are on the rise of 7.5 % in 2020, compared to the direct Scope 1 and 2 emissions declining by about 1-2%. In 2020 the Scope 3 emissions, reported by the companies across all sectors, are 19 times higher than Scope 1 and 2 emissions combined.

Greenhouse Gas Emissions (*in Metric Tons CO2e)*	**2019**	**2021**	**YoY change %**
Gross scope 1 emissions	595,918	592,463	-0.58%
Gross scope 2 emissions (location-based)	713,995	697,565	-2.30%
Gross scope 3 emissions	23,277,49	25,026,53	7.51%

Table 1. TFCD Climate Related Metrics (*2022-TCFD-Status-Report*).

The TFCD statistics does not provide the explicit view of the financial industry and the payments sector contribution to the increasing Scope 3 emissions, however it indicates the alarming trend that requires further investigation. It is now widely accepted that Scope 3 greenhouse gas (GHG) emissions are a critical component of overall emissions in the financial services industry and are comparable to a company's Scope 1 and 2 emissions. The literature review provided the clear evidence that the payment services sector is the major contributor to the indirect emissions, that goes beyond the latest innovation such as cryptocurrencies.

3.2 Payment types: the basics

For avoidance of any miss-interpterion it is important to provide the definitions of money in its cash, electronic and digital forms.

The cash will imply the notes and coins issued by a national central bank for the circulation with the jurisdiction, and the local currencies, issues by the authorised regional authorities in the form of paper money for the circulation within the community, for example, Brixton pound in the UK. The major global government-issued currencies are not backed by any commodities such as gold or silver and therefore defined as fiat currencies based the value of each is backed by trust in the county government. The gold and silver coins and bullions also have the legal tender in most of the countries; therefore, it can be considered as means of cash payment for the benchmarking purpose.

The terms "electronic money" and "digital money" are often used interchangeably, but they can have vastly different connotations depending on the context. In this study, the distinction will be made based on the type of issuer. Thus, the electronic money or e-money refers to digital representations of money that are issued by the traditional banks or other regulated entities in the form of digital account balances, such as those associated with debit cards and checking account. For example, according to Bank of England 96% of money in the UK are hold electronically as bank deposits, with just 4% held in physical form as cash including banknotes and coins. As per International Monetary Fund (IMF) definition, e-money can include prepaid cards, mobile payment apps, and other electronic payment methods. Companies that provide electronic payment services, such as mobile payment apps e.g., Apple Pay, Google Pay, digital wallets e.g., PayPal, and prepaid cards, issue electronic money to users. These providers facilitate transactions and store users' digital funds.

For the clarity of the research boundaries, the digital currencies are defined as the newest form of money, which for the time of the study include the cryptocurrencies and Central Bank Digital Currencies (CBDC). According to IMF, cryptocurrency is ‘a private sector digital asset that depends primarily on cryptography and distributed ledger or similar technology. In contrast, CBDC is the central bank liability denominated in the existing unit of account, that differs from the reserves or settlement balances held by commercial banks at central bank. The technological solution of the CBDC is irrelevant to its status, it can be based on DLT but still can’t be categorised as cryptocurrencies.
The following chapters will summarise the available research of the carbon footprint of each type of payment.

3.2.1 Digital currencies

Cryptocurrencies, especially Bitcoin, high energy consumption attracted a lot of attention from scholars and industry experts since its inception in 2009. The ambiguity of such views lies in the limited usage of the cryptocurrencies as a mean of payments. The prevailing opinion is the treatment of Bitcoin as ‘digital gold’ – a hybrid between the commodity and currency (Badea and Mungiu-Pupazan, 2021). As the history of Bitcoin since its inception demonstrates, the cryptocurrencies can co-exist with the conventional fiat currencies. The number of various cryptocurrencies was steadily risen, and the pick was reached in November 2022 with 21,159 crypto coins featured on the crypto data authority, according to CoinMarketCap.com. The growing popularity and adoption rate indicates that cryptocurrencies are in the mainstream of the payment sector. The advantages and disadvantages of it as payment and investment are continued to be debated but one of the most alarming concerns is its environmental sustainability.

Most of the researchers of the cryptocurrency are focused on the following areas: the carbon footprint of the cryptocurrencies mining, comparative energy consumption of cryptocurrencies with the traditional payment systems, and opportunities for reducing digital currencies energy consumption. The term ‘mining’ portraits an accurate picture of a cryptocurrency unit creation process due to uncertainty of its results, multiple competing participants, special equipment and vast amount of energy and time. One of the first detailed assessment of the bitcoin carbon footprint published by O’dwyer and Malone (2014) concluded that the power needed for profitable bitcoin mining is comparable with the energy consumption of the country of Ireland primary attributed to the mining process. Stoll et al. (2019) assessed the impact of specialized mining hardware, that required to make the mining profitable and found that the annual electricity consumption of Bitcoin in 2018 was 45.8 TWh, with annual carbon emissions ranging from 22.0 to 22.9 MtCO2, comparable to the emissions of Jordan and Sri Lanka.

The geographical distribution of miners has created significant discrepancies between the locations of Bitcoin holders and the locations of emissions. The China’s crackdown on cryptocurrencies in 2021 had a noticeable effect on Bitcoin's greenhouse gas emissions, which dropped from nearly 75 MtCO2e in May to 28 MtCO2e in July 2021. The percentage of coal in the global energy mix for Bitcoin mining also reduced by half during this period. By the end of 2022, the United States led in global hash power, followed by China and Kazakhstan. The share of renewable sources in Bitcoin's global electricity consumption decreased from 41.6% in 2020 to 25.1% in August 2021 1. The environmental impact of Bitcoin mining goes beyond carbon emissions, including water and land footprints, and electronic waste from short-lived mining devices. De Vries and Stoll (2021) estimated that Bitcoin e-waste added up to 30.7 metric kilotons per annum, comparable to the waste produced by a country like the Netherlands.

At the early stages of the pioneering Bitcoin launch, mining was a lucrative endeavour because the success was rewarded with the new ‘block’ of 50 BTC and transaction fees. Since 2012, Bitcoin organisation introduced the ‘halving’ as a fundamental aspect of its monetary policy, which the reduced the reward block size to half every 4 years, making it less and less attractive to the miners. By his alleged founder’s design, the Bitcoin supply was limited with the total cap of 21 million. According to the Blockchain Council prediction all bitcoins will be mined by the year 2140.

The amount of literature about the harmful impact of crypto mining may distort the view on the opportunities of the blockchain solutions. Firstly, there are alternatives to mining and there are existing crypto currencies like Ripple (XRP) that uses different consensus algorithms. Secondly, the mining does not cover the entire value chain of the cryptocurrency network operation, with the exchanges, the transactions validating nodes, wallet providers, payment processors, merchants, and the users, individual as well as entities. Considering the traditional financial sector infrastructure with the core ITC devices automated teller machines (ATMs), the bank branches, etc. the banking on blockchain represent a significant energy saving opportunity.

It was proven by many scholars that the mining process energy efficiency has improved significantly since 2008. The key drivers were the changes of consensus mechanisms, use of renewable energy, as well as the government’s fiscal policies. The very first consensus mechanisms, so called the Poof of Work (PoW) was introduced with the launch of the Bitcoin and was adopted by few other cryptocurrencies but new technological solutions being constantly developed. The specific of PoW algorithm dictate the type of devices with the various level of efficiency. The study of 20 minable crypto coin and tokens, including Bitcoin, established dependency between the consensus mechanism algorithm, devices hash rates and the energy consumption of the respective network and concluded that the Bitcoin accounts for 2/3 of global share, however “the understudied currencies add nearly 50% on top of Bitcoin’s energy hunger” (Gallersdörfer et al., 2020). In general, Decentralised Finance

(DeFi), the term used to describe decentralized applications or protocols running on a blockchain network. experienced a boost in 2022. 'Between July 2021 and June 2022, DeFi has accounted for 37% of all North American cryptocurrency transaction volume — more than any other region. Western Europe is second at 31%, while other regions like Sub-Saharan Africa have as little as 13% of activity coming from DeFi'

The international regulators and national Central Banks are actively exploring the opportunities of the regulated digital currencies. Central Bank Digital currency (CBDC) became a reality after the launch of the 'sand dollar' in the Bahamas in October 2020. By the end of 2022 three more retail CBDCs in Jamaica, Eastern Caribbean and Nigeria went into the circulation and about 25% of central banks had it in pilot phase. With over 90% of central banks actively exploring the wholesale and retail CBDC solution, BIS experts predict that there could be fifteen retail and nine wholesale CBDCs publicly circulating in 2030. The lesson learnt from the Bitcoin network statistic prompted the suggestions for alternative to Proof-of-Work (PoW) permissioned crypto asset that can "have an edge in terms of energy use over DLT-based Crypto asset and can reduce energy consumption relative to the existing payment system" (M. I. Agur et al., 2022). The optimal solution for each market is likely to be a technical trade-off between account or token-based access and a conventional or distributed infrastructure, which meets the requirements of user's privacy, accessibility, resilience, and convenience. Retail CBDC has a potential to provide a cash-like peer-to-peer payments or replace debit cards use cases.

3.2.2 Cash

Cash payments, in the form of the physical banknotes and coins, were in declined in the past decade, however it remains a widely used payment methods in all jurisdictions, despite the increasing popularity of the electronic and mobile payment methods accelerated by the global pandemic. According to Bank of International Settlement (BIS) brief by the end of 2022 currency in circulation exceeded its pre-pandemic levels nearly everywhere. For instance, in the UK cash remains the second most frequently used payment method behind debit cards. BIS and other financial authorities' prediction is the accelerating trend to the cashless societies, nevertheless the physical cash will continue to be in circulation during its unique utilities such as anonymity, a budgeting tool, useful social contrivance, historically trusted value holder in uncertain times.

With the cash remaining in the payments landscape its carbon footprint cannot be ignored. Banknotes and coins are the most used product in the world, but its production and composition vary significantly from one jurisdiction to another. The study of one selected country allows a more granular determination of the life cycle sub-processes and inventory inputs. Thus, the carbon footprint of the of one banknote, depends on the assumption about typical sources of the raw materials, such as cotton yarns, energy consumption and other environmental impacts at each stage of the production. The distribution process involves the transportation and the maintenance of the automated teller machines (ATMs). For instance, the major contribution factor at the operational phase of cash in the EU is the energy consumption of the about 400,000 automated teller machines (ATMs), which are switch on 24/7 to be available for the average 86 transactions per ATM per day (Pollani, 2021). Based on the ReCiPe Endpoint (H) method (Pollani, 2021) calculated the global warming potential (GWP) of the entire Eurozone cash payment system in 2020 as 0.014% of total CO2 emissions in the EU. The total environmental impact of the cash system also included human health, ecosystem quality and resources (Hanegraaf et al., 2018; Pollani, 2021).

In the last decade the banknotes carbon footprint was improving because many jurisdictions were replacing the cotton-paper with polymer bank notes, that have 2,5 times longer useful life and its end-of life recycling process does not produce carbon. The example, of the LCA assessment of the Swiss banknotes issued between 2016 and 2019 proved that it overall environmental impact of the ninth banknote series is just under 20% lower than that of the eighth dated 1999 (Swiss National Bank, 2022) with the highest environmental impact at "the manufacturing phase of 82%, with 50% arising from provision of raw materials", 16% at logistic and 2% at disposal phases. However, this analysis does not take into account the operational phase with the banknote circulation via bank branches, ATMs and retail networks. In 2020 the study, commissioned by the UK cash distribution network LINK, confirmed the Bank of England assessment that ATMs and cash centres contribute over 60% of the carbon footprint in the life of a banknote.

The cheques and bills of exchange, as a paper document that authorises transfer of funds between bank accounts, remains in circulations in many countries including the UK, USA and France. In the UK the attempts to withdraw cheques from the circulation, as costly and unsecure methods of payment, were unsuccessful due to its popularity among the older group for population. The cheque clearing process is very resource intensive which makes its administration costs disproportionally high for the payment service providers compared to the small segment of consumers. (John Vines et al., 2012) researched possible alternatives to replace cheques without compromising its social-economic properties and concluded that "digitising even small parts of cheque-based transactions might be detrimental to the models of collaboration, trust and security". Despite the steady declined of usage, the cheques will be part of the payment ecosystem for some time therefore the environmental impact of this payment methods requires further investigation.

Gold and silver seized to be a mean of payment as it used to be for centuries, however the precious metal coins and bullions are continuing to hold a status of legal tender in most jurisdictions. Status of gold as an investment asset rather than payment media prompted the parallel with the bitcoin as a digital gold. It had a raised a question of the comparative carbon footprint of the bitcoin mining and gold production. By applying LCA method the researchers Üçtuğ and Ünver (2021) confirmed that the bitcoin mining has much higher carbon footprint than gold production measured in CO2e kg of $1000,000 of asset. The conclusion of the assessment is that it is very unrealistic for Bitcoin to reach a value, where it would have a lower carbon footprint than gold, at least in the near future.

The launch of Bitcoin into circulation reignited the interest in the concept of private money as an alternative to the official state currencies. Historically, the local private currencies always existed in communities: during the Great Depression in Germany and USA many local currencies emerged; the variety of local currencies such as Brixton Pound are still in circulation in the United Kingdom today, with some transitioning to digital form. The modern experiments with local currencies (LC), as form of money complementary to the national currencies, were inspired by the ideals of the efficient exploitation of the communities' economic and environmental resources addressing the social-economic and environmental problems associated with globalization. In terms of design the local currency can have a form of paper money in the case of most scrip currencies, or electronic in the case of mutual credit systems. Thus, the environmental impact can be compared with cash or mobile payments.

3.2.3 Electronic payments

Mobile payments were made possible with the introduction and mass adoption of smart phones. The trend to the cashless society has accelerated by the recent pandemic due to the enforced restrictions. Mobile payments were adopted by the wider group of the population that were previously reluctant to use them. Governments and regulators are encouraging the transition to the 'cashless society', which is perceived to be more environmentally friendly. The numerous forms of mobile payments solution can be divided into two types: mobile credit cards and digital wallets.

There is a limited number of studies of the 'cashless transactions' energy consumption. Some observations related to the perception of money and spending behavior at the credit and debit cards payment are relevant to the mobile payments. (Khan & Craig-Lees, 2009) proved that the 'volume and value per transaction increases' when cashless payment is used. Further research is required to understand the patterns of behavior depending on the cultural norms, age and experience. However, it is safe to assume the mobile payments encourage more frequent payments, resulting in the high transactions traffics and therefore increased total energy consumption. Considering that communication with the payment gateway follows similar process as for credit and debit cards, the added energy use by the mobile payments' application remains an open research question.

And the winner is plastic. According to (Santoso et al., 2022) 'until 2021, it is undeniable that credit cards dominated by Visa and Mastercard rank first with the most efficient energy consumption' of 0.0008 and 0.0006 electricity consumption per transaction in kWh respectively. The statement is consistent with the assessment of other studies of the payment methods environmental impact by (Leopold and Englesson, 2017) and (Fiedler et al., 2019). According to the McKinsey Global Payments Report, 2022 debit and credit card transactions continued to grow at rates comparable to those before the pandemic (20 percent and 18 percent, respectively, between 2020 and 2021). Most recently, the technological innovation of contactless cards and the social-economic trend to the cashless society, accelerated the credit and debit cards adoption. By statistics, published at theglobaleconomy.com, in 2021 the average percent of people who had debit cards was 51.23, and those who had credit cards was 22.26. According to Visa factsheet, available at www.visa.couk, its payment network is enabling 3,3 billion cards worldwide and has a capacity of 65,000 transaction messages per second. In comparison to the consumers activities, such as driving and flying, the annual CO2 emission of Visa network is equal to emission from 1,934m miles driven or 12.34 trips around the world in Boeing 747 (Leopold and Englesson, 2017). In 2022 Visa reported in the Environmental, Social and Governance Report '89% reduction of scopes 1 & 2 GHG emissions since FY18 and 100% renewable electricity use maintained for operations. Considering that credit and debit card systems are complex financial mechanisms that involve multiple components such as issuing and acquiring financial institutions and banks, payment processors and payment networks such as Visa and Mastercard, merchants and cardholders. Lindgreen et al. (2017) evaluated the environmental impact of debit card payments in Netherland showed the absolute environmental impact of Dutch debit card transaction in 2015 of 470 µPt with 75% of total impact contributing by the payment terminals: 'terminal materials (37%) and terminal energy use (27%) are the largest contributors to this share, while the remaining impact comprises datacentre (11%) and debit card (15%) subsystems".

3.3 The comparative analysis of payments' carbon footprint

With the emergence of the cryptocurrencies the environmental impact of the payments attracted attention of the academic researchers as well as financial industry and sustainability practitioners. The analysis highlighted that the rapidly expanding payment sector contributes significantly to the global energy consumption. It poses the question of how to assess the environmental impact of money in the modern world. In the study 'How Eco friendly is our money and is there an alternative?' Leopold and Englesson (2017) including fiat and cryptocurrencies, with the aim to understand the economic and environmental benefits of choosing one currency over the other. The investigation opened a further discussion on what level of carbon footprint of different currencies is acceptable. The key conclusion was that the fundamental utilities of the currency, trade and payments, have to be in balance with its efficiency: 'it needs to be efficient in order to have a chance of being widely adopted and functional for us all and the planet Earth' (Leopold and Englesson, 2017).

The common theme in the literature on the sustainability assessment of the payment sector is the lack of consensus about the appropriate data sources and calculation methodologies. One of the approaches is estimating the carbon footprint based on the large-scale financial transaction data. (Trendl et al., 2023a) advocated this approach as a highly scalable and ultra-fast method of the carbon profiling. The study used 'the transaction data generated by more than 1000,000 customers of a large retail bank in the United Kingdom' (Trendl et al., 2023a) and quantitively compared the results of the carbon footprint with the carbon profiling, obtained via the largest household expenditure survey in the UK. The results proved that the large transaction data offered a valuable and reliable data source for calculating the carbon footprint.' However, due to the General Data Protection Regulations (GDPR) 'the restricted data availability of financial transactions remains a key challenge to realizing these benefits' despite the ease of access offered by introduction of the Open Banking technology. The authors suggest the way forward is the voluntary donation of data by the individuals and commercial organisation.

Review of the literature revealed that the most trusted method of research is the Life Cycle Assessment (LCA) method (Hanegraaf et al., 2018, 2020; Norgate and Haque, 2012; Pollani, 2021). LSA is the internationally recognised standards for assessment of the environmental impact of the product or service, which was adopted as an ISO 14044 in 2006. LCA has proven to be an efficient and practical method for the companies to track the GHG emissions because it embeds the cradle-to-grave thinking about any system and links it's to the final products or services.

The researchers of the comparative analysis of the Euro-cash payment system and bitcoin had chosen LSA approach allowed to define the scope in the less ambiguous terms than other studies and include all relevant factors in assessing the payment type value chain (Pollani, 2021). The author considered the sustainability in its interconnected dimensions of the environmental, social and economic impact. The entire Euro cash payment system, including the printing the banknotes, the coins manufacturing, transportation and distribution via ATMs, but excluding the disposal process, was assessed 478,406.09 tons CO2-eq. In comparison, the entire Bitcoins network estimated climate change impact was calculated as 19,900,000 tons CO2-eq, which represented the 0.058% of the total CO2 emissions worldwide in 2020 (Pollani, 2021). Considering the standardised energy mix assumptions and the geographical limitations of the scope, the researcher draws the conclusion that 'the possibility of replacing all cash in circulation with a mineable cryptocurrency like Bitcoin is inconceivable especially for the socially wasteful electricity use, but also for the lack of regulation' (Pollani, 2021). The author recommends the path to the cashless society via the introduction of 'a stable digital currency that provides security, efficiency, and does not require intensive power consumption', and suggest that a central bank digital currency (CBDC) could be an option.

The study 'Financial revolution of payment methods toward energy efficiency growth' published in 2022 analysed energy usage and the CO2 emissions of the paper money, plastic cards and cryptocurrency and predicted that cryptocurrency has a potential to be the most energy-efficient payment method in the future (Santoso et al., 2022). The brief history of the cryptocurrency's evolution proved that innovative technologies could transform the 'extremely energy-hungry process' of early bitcoin mining to more energy efficient method of payment. In 2022 International Monetary Fund (IMF) FinTech committee considered 'the prospect that digital currencies can come to play a prominent role in the payment system is material' despite the uncertainty of the regulatory environment and demand (M. I. Agur et al., 2022). The report reiterates the established perception that cash, credit cards payment and bank transfers systems energy consumption is 'nonnegligible' and investigates the difference in energy costs of various digital currencies depending on Distributed Ledger Technology (DLT) based design options. The approach to assessing the payment systems energy consumption is based on distinguishing two main components: core processing and user payment means. The key differentiator of the traditional payment systems from the digital currencies from the core processing perspective is need of the trusted actors, such as banks. In contrast, the digital currencies systems rely on the consensus mechanisms of DLT. By making a comparison in energy consumption of the cryptocurrencies with on the prove-of-work (PoW) mechanism, such as bitcoin, with the non-PoW mechanisms (M. I. Agur et al., 2022) proved that the permissioned Non-PoW design option of DLT system is the most energy efficient with the up to thousand times less energy consumption per transactions than the permissionless Non-PoW DLT and credit card systems. However, the researchers pointed out that 'the various factors complicate the comparison', mainly because the credit cards processing involves actors other than the credit card issues and its current scale in terms of volumes is much greater than any existing DLT system.

In comparison with other payment methods the cards are perceived as the most environmentally friendly with a potential of further optimising the energy consumption. It was estimated that the Visa card CO2 emission per transaction in 2017 was about 18,000 times less than of Bitcoin transaction: 0.00794 LBS compare to 144.2029 LBS (Leopold and Englesson, 2017). The card transactions are more energy efficient than cash and as 'De Nederlandsche Bank (DNB) reported that an average cash withdrawal in 2015 had a GWP of 4.6 g CO2e, whereas an average debit card transaction had a GWP of 3.8 g CO2e'. However, by factoring the average of 5 payments per cash withdrawal, it can be argued that cash is more environmentally friendly than cards (Delnevo and Smyth, 2020). In addition, the cards production and disposal have additional environmental impact due to the usage of the various metals, silicon, raisins and plastic. During the operational phase the payment terminals are the major contributors at 75% to the card's total environmental footprint due to the materials used in its manufacturing and the terminals energy use (Lindgreen et al., 2017). Consideration must be given to packaging, transportation, distribution, and the energy consumption of the bank's data centre. The suggested improvements include the use of renewable energy, 'reducing the standby time of payment terminals' and increasing the lifetime of cards (Lindgreen et al., 2017). Regarding another traditional payment system of the bank transfers, the comparison was drawn between the Euro system TARGET Instant Payment Settlement (TIPS) that was launched in November 2018 to enable real time and around the clock funds transfers to the business and retail customers. Its estimated energy consumption per transaction of 4x10-5 kWh (Tiberi, 2021) is closed to the permissioned non-PoW DLT.

The most scholars and industry researchers assess credit and debit cards as the most environmentally friendly payment method at present. However, the future of this leading position is not certain with some researchers predicting that the cards' energy efficiency will be surpassed by the digital currencies due to its exponential growth (Santoso et al., 2022). Laboure (2020) predicts: "while we believe cash will stay, the coming decade will see digital payments grow at light speed, leading to the extinction of the plastic card". In relation to the environmental impact of cash, as a legacy mean of payment has the merits that digital forms of money cannot easily replicate.

3.4 Impact of the Information and Communication Technology (ICT)

In the era of the digital evolution assessment of the financial systems cannot be completed without the analysing impact of its enabler – information and communication technology (ICT). The ICT solutions for the financial industries are experiencing the renewed growth with the Fintech sector being one of the most innovative industries worldwide. The attention to Fintech sometimes overshadows the impact of the existing ITC landscape of the payments industry. From the international credit cards companies and commercial banks to the central banks, clearing houses and various payment systems providers (PSPs), the ITC systems play a dual role of the enablers of the financial services innovation and the major contributors to its energy consumption and the overall environmental impact.

ICT professionals and academics were long investigating the relationships between the digitalization positive effect on the economic growth and the adverse effect on the environment. The dilemma of the green ITC versus ITC for green is a part of the wider 'decoupling debate' (Santarius et al., 2020) about the transforming the economic growth stimulus from the unsustainable mode of resources consumption towards greener alternatives. Regarding digitalization, the expectations of its being a factor of increased resource efficiency is proved to be offset by the ICT own resource consumption. At the widely cited study by (Lange et al., 2020) analysed effects of digitalization, combining theoretical and empirical findings, and concluded that 'overall, digitalization increases energy consumption'.

In the context of payment services, the core enabler of the business activities are the financial information systems. Consequently, the energy consumption and sustainability of their design directly impact the carbon footprint of the payment service providers. In November 2017 the UN Environmental Programme published the Roadmap for a Sustainable Financial System, that integrates sustainability considerations into its design and operations. The report states Digital Finance or *fintech'* has the potential to deliver environmental outcomes and support a transformation in financing for sustainable development,' but the impact depends on the carbon footprint disclosure methodologies and the regulatory incentives.

The common approach to assessing the payment systems energy consumption is based on distinguishing two main components: core processing and user payment means. For instance, the core component of the bank transfers is the data centres and Real Time Gross Settlement system (RTGS) of the national Central Bank; the user payment means includes bank branches, cheques, websites, mobile applications etc. The carbon footprint of the payment service provider depends on the regional location of its core financial systems, and it determines how the electricity usage is translated to the CO2 emission. To illustrate the point Leopold and Englesson (2017) state that Visa nodes are predominately located in the US and Europe, were the energy generated by coal is less than 53 % and the Bitcoin and Ethereum mining and Proof of Work activities are mainly based in China, where the energy production depends 70% on coal.

User devices, including the personal computers, mobile phones and wearables, make up the largest proportion of the ICT sector energy use Invention and mass adoption of the smartphones opened new horizons for the consumer services including the financial services. Many modern payments sectors solutions rely on the smartphone applications as prerequisite for consumer's onboarding. Therefore, the impact of the collective mobile phones' emission on the overall ICT energy consumption cannot be undermined. Addressing this issue, (Ercan et al., 2016) completed cradle-to-grave study of the selected smartphone device, a Sony Mobile Z5, including accessories, and calculated GWP as '57 kg CO2e for an assumed operating lifetime of 3 years, excluding the network usage'.

In case of the mobile payments the process of tokenization and authentication is determined by the mobile application solution. (Cano and Domenech-Asensi, 2011) investigated energy efficiency of the mobile applications and established that the design options such as message types, encryption algorithm and security protocol are the key factor that influence the energy consumptions, which can be reduced by more than 30% with the optimal application layer protocol.

In 2015 (Whitehead et al., 2015) studied the data centres in the UK using Life Cycle Assessment (LCA) methodology and identified the effects of the cooling and power delivery, energy mix as well as ratio of operational and embodied energy consumption. 'Embodied energy refers to the non-operational energy consumption such as the energy required for equipment manufacture, assembly, and disposal', which is measured in terms of carbon emission and contribute to 20-30% of the ICT sector emission (*Energy Consumption of ICT*, 2022). The International Energy Agency (IEA) report estimates the ICT will 1% of global electricity demand in 2020, excluding crypto mining.

Many scholars pointed out that there is 'little research to date that attempts to quantify ICT's resource demand, both regarding past and future demand' (Santarius et al., 2020). In 2022 the UK Government estimated that ICT sector used 4-6% of 'all electricity generated globally in 2020' (*Energy Consumption of ICT*, 2022). The forecasts of the future consumptions vary in deferent sources; however, the consensus is that it is most likely to increase to 2030.

4 Conclusion

Modern payment services are the one of the most technologically innovative and fast-growing industry. It offers continuously evolving variety of options from the well-established bank transfers, debit and credit cards to emerging crypto currencies and stablecoins. Each payment services provider represents a complex value chain enabled by information technology solutions. It is evident from the academic research, regulators and industry experts' analysis that the carbon footprint of the payment services is increasing significantly in comparison to other industries. From the perspective of any environmentally conscious organisation the indirect emissions generated by its incoming and outgoing payment activities should be accounted in the overall assessment of its carbon footprint. The challenges in the GHG Scope 3 emissions reporting remain, however there is growing awareness of the environmental impact of the payment services that stimulates the consistent efforts to optimise the balance between the business functionality and the energy efficiency.

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