Financial Industry Electricity Usage Balance

Amanda Fabiano
amanda.fabiano@galaxydigital.io

Rachel Rybarczyk
rachel.rybarczyk@galaxydigital.io

Drew Armstrong
drew.armstrong@galaxydigital.io

May 13, 2021

Contents

1 Annual Electricity Usage of the Bitcoin Network 3

1.0.1 Methodology 3

1.1 Bitcoin Miner Contribution 3

1.1.1 Assumptions 3

1.1.2 Methodology 4

1.2 Bitcoin Pool Contribution 4

1.2.1 Assumptions 4

1.2.2 Methodology 4

1.2.3 Slushpool Server Infrastructure Demand 5

1.3 Bitcoin Node Contribution 6

1.3.1 Assumptions 6

1.3.2 Methodology 6

2 Annual Electricity Usage of the Banking System 7

2.0.1 Methodology 8

2.1 Data Center Contribution 8

2.1.1 Assumptions 9

2.1.2 Methodology 9

2.2 Banking Branches Contribution 11

2.2.1 Assumptions 11

2.2.2 Methodology 12

2.2.3 Global Small Business Usage Estimate 12

2.3 ATM Contribution 15

2.3.1 Assumptions 15

2.3.2 Methodology 16

2.4 Card Networks Contribution 16

2.4.1 Assumptions 16

2.4.2 Methodology 17

2.4.3 The VISA Network Contribution 18

3 Annual GHG Emissions & Electricity Usage Equivalence of the Gold Mining Industry 19

3.0.1 Assumptions 19

3.0.2 Methodology 20

1 Annual Electricity Usage of the Bitcoin Network

Disclaimer: Information regarding the electricity usage required to operate Bitcoin mining machines *is* an estimate based on inherently public hashrate data, however some assumptions are made by in order to estimate the final electricity usage figures. The Galaxy Digital Mining Team encourages external thoughts and contributions that result in the most accurate figures possible.

1.0.1 Methodology

The estimated total annual electricity usage required to operate the Bitcoin network is calculated as follows:

$$E_{\text{BTC}} = E_{\text{Miners}} + E_{\text{Pools}} + E_{\text{Nodes}} \tag{1.1}$$

Where,

E_{BTC} = Estimated total annual electricity usage of the Bitcoin network, $\frac{\text{TWh}}{\text{yr}}$

E_{Miners} = Estimated total annual electricity usage of Bitcoin miners, $\frac{\text{TWh}}{\text{yr}}$

E_{Pools} = Estimated total annual eletricity usage of Bitcoin pools, $\frac{\text{TWh}}{\text{yr}}$

E_{Nodes} = Estimated total annual electricity usage of Bitcoin nodes, $\frac{\text{TWh}}{\text{yr}}$

Using the results described in Sections 1.1 - 1.3 below, Eq. (1.1) is solved as follows:

$$\begin{aligned} E_{\text{BTC}} &= E_{\text{Miners}} + E_{\text{Pools}} + E_{\text{Nodes}} \\ &= 113.8800 \tfrac{\text{TWh}}{\text{yr}} + 0.0086 \tfrac{\text{TWh}}{\text{yr}} + 0.0054 \tfrac{\text{TWh}}{\text{yr}} \\ &= 113.8940 \tfrac{\text{TWh}}{\text{yr}} \\ &= 113.89 \tfrac{\text{TWh}}{\text{yr}} \end{aligned} \tag{1.2}$$

Therefore, the estimated total annual electricity usage required to operate the Bitcoin network is 113.89 $\frac{\text{TWh}}{\text{yr}}$.

1.1 Bitcoin Miner Contribution

1.1.1 Assumptions

While hashrate data is public, the Cambridge Centre for Alternative Finance has made several assumptions in estimating the annual electricity usage of the Bitcoin network. A complete list and explanation of all assumptions made can be found here [1].

A brief overview of these assumptions are:

1. The global average electricity price is constant over time and corresponds to 0.05 USD/kWh.

2. During time periods where no mining equipment is profitable, the model uses the last known profitable equipment.

3. All miners use an equally-weighted basket of hardware types that are profitable in electricity terms.

4. All mining facilities have a PUE of 1.10.

1.1.2 Methodology

The Cambridge Centre for Alternative Finance has produced a continuously updating report on the electricity usage of the mining machines required to operate the Bitcoin network [2]. As of April 23, 2021, the reported annualized usage of the Bitcoin network is 113.88 $\frac{\text{TWh}}{\text{yr}}$, which is taken to be E_{Miners} in Eq. (1.1).

1.2 Bitcoin Pool Contribution

1.2.1 Assumptions

1. The operating hours of a Bitcoin pool is 24 hours per day, 7 days per week, 52 weeks per year, for a total of 8,760 hours per year.

2. Pools do not typically report data regarding their infrastructure, likely because this is not commonly requested information. Upon reaching out to Slushpool, a prominent Bitcoin mining pool, they readily provided the Galaxy Digital Mining Team with information on their infrastructure requirements. Slushpool's infrastructure is used to estimate their total annual electricity usage based on the demand of a typical server. To estimated the total annual electricity usage of all Bitcoin mining pools, a linear relationship between a pool's server demand and the number of mined blocks in a 4 day period is assumed.

3. The office space of the Bitcoin mining pools is not considered, but is a negligible amount as there are likely only a few offices globally.

4. 153 blocks mined in the considered 4-day period do not come from known pools, but are instead from unknown miners. In order to be conservative, these blocks are still included in this analysis because they still may be mined via a pool, not necessarily an individual miner.

1.2.2 Methodology

The estimated total annual electricity usage required to operate Bitcoin mining pools is calculated as follows:

$$E_{\text{Pools}} = blk_{\text{T}} \times \frac{D_{\text{SP}}}{blk_{\text{SP}}} \times H_{\text{yr}} \times C \tag{1.3}$$

Where,

Number of Mining Servers	Number of Proxy Servers	Number of Backend Servers	Number of Total Servers
25	25	15	65

Table 1.1: Slushpool Server Infrastructure as Reported by Slushpool

E_{Pools} = Annual eletricity usage of Bitcoin pools, $\frac{\text{TWh}}{\text{yr}}$

blk_{T} = Number of blocks mined in a 4 day period, 594 blocks [3]

blk_{SP} = Number of blocks mined by Slushpool in a 4 day period, 19 blocks [3]

D_{SP} = Demand of Slushpool's servers, 19.5 kW

C = Conversion factor, $\frac{1 \text{ TW}}{10^9 \text{ kW}}$

The operating hours of a Bitcoin pool is 24 hours per day, 7 days per week, 52 weeks per year, for a total of 8,760 hours per year. The infrastructure requirements to operate a pool are minimal and are not typically reported by a pool, likely due to lack of public interest and because the requirements are minimal. However, the Galaxy Digital Mining team reached out to Slushpool who provided details of their server infrastructure requirements, which is detailed in Table 1.1. A demand for a typical 1U server of 300 W is assumed [4] and is used to estimate Slushpool's server demand. In order to estimate the total annual electricity usage of all Bitcoin mining pools, a linear relationship between a pool's server demand and the number of mined blocks in a four day period is assumed. The four day period is from April 19, 2021 through April 22, 2021. During this period, 594 blocks were mined in total, 19 of which were mined by Slushpool [3]. The demand of Slushpool's servers is detailed in Section 1.2.3 below. Eq. (1.7) in Section 1.2.3 below finds Slushpool's server demand to be 19.50 kW.

Eq. (1.3) is solved as follows:

$$\begin{aligned} E_{\text{Pools}} &= B_{\text{Total}} \times \frac{D_{\text{SP}}}{B_{\text{SP}}} \times H_{\text{yr}} \times C \qquad (1.4) \\ &= 594 \text{ blocks} \times \frac{19.50 \text{ kW}}{19 \text{ blocks}} \times 8,760 \frac{\text{hr}}{\text{yr}} \times \frac{1 \text{ TW}}{10^9 \text{ kW}} \\ &= 8,609,328 \frac{\text{kWh}}{\text{yr}} \times \frac{1 \text{ TW}}{10^9 \text{ kW}} \\ &= 0.0086 \frac{\text{TWh}}{\text{yr}} \qquad (1.5) \end{aligned}$$

Therefore, the estimated total annual electricity usage required to operate the Bitcoin mining pools is 0.0086 $\frac{\text{TWh}}{\text{yr}}$.

1.2.3 Slushpool Server Infrastructure Demand

The estimated demand required to operate Slushpool's server infrastructure is calculated as follows:

$$D_{\text{SP}} = NS_{\text{SP}} \times D_{1\text{U}} \times C \qquad (1.6)$$

Where,

D_{SP} = Demand of Slushpool's servers, kW
NS_{SP} = Number of servers that Slushpool uses, 65 servers
D_{1U} = Demand of a common 1U server, 300 W [4]
C = Conversion factor, $\frac{1\ \mathrm{kW}}{10^3\ \mathrm{W}}$

Eq. (1.6) is solved as follows:

$$\begin{aligned} D_{\mathrm{SP}} &= 65 \times 300\ \mathrm{W} \times \tfrac{1\ \mathrm{kW}}{10^3\ \mathrm{W}} \\ &= 19.50\ \mathrm{kW} \end{aligned} \tag{1.7}$$

1.3 Bitcoin Node Contribution

1.3.1 Assumptions

1. The operating hours of a Bitcoin node is 24 hours per day, 7 days per week, 52 weeks per year, for a total of 8,760 hours per year.
2. The number of nodes on the Bitcoin network vary as participants come on and off line for a variety of reasons. The number of nodes used in this report is from a network snapshot taken on April 23rd, 2021.
3. The demand of a single node on the network is estimated to be the average of a standard laptop, a Raspberry Pi 4, and a 4-core CPU and disk space. This is a conservative estimate considering a Bitcoin node may not consume all of the hardware's resources.

1.3.2 Methodology

The estimated total annual electricity usage required to operate the nodes on the Bitcoin network is calculated as follows:

$$E_{\mathrm{Nodes}} = N_{\mathrm{Nodes}} \times D_{\mathrm{Node}} \times H_{\mathrm{yr}} \times C \tag{1.8}$$

Where,

E_{Nodes} = Estimated total annual electricity usage of Bitcoin nodes, $\frac{\mathrm{TWh}}{\mathrm{yr}}$
N_{Nodes} = Number of nodes on the Bitcoin network, 11,740 nodes [5]
D_{Node} = Estimated average demand of Bitcoin node hardware, 0.52 kW
H_{yr} = Operating hours of a Bitcoin node, 8,760 $\frac{\mathrm{hr}}{\mathrm{yr}}$
C = Conversion factor, $\frac{1\ \mathrm{TW}}{10^9\ \mathrm{kW}}$

The operating hours of a Bitcoin node is 24 hours per day, 7 days per week, 52 weeks per year, for a total of 8,760 hours per year. The number of nodes on the Bitcoin network on April 23rd, 2021 are 11,740 [5]. The system requirements to run a full node are minimal. Currently, most systems with around 500 GB of storage and a 4-core CPU are capable of running a node. Because of this, Bitcoin nodes are run on various types of hardware, including laptops, simple servers, and Raspberry Pi's. An average laptop consumes 60W, a Raspberry Pi 4 consumes a maximum of 15.3 W, and a typical 4-core CPU server and disk space consumes 81W [6, 7, 8, 9]. The demand of hardware running a Bitcoin node is estimated to be the average of these three pieces of hardware. This is a conservative estimate considering a Bitcoin node may not consume all of the hardware's resources.

Therefore, the estimated average demand required to operate a Bitcoin node is calculated as follows:

$$D_{\text{Node}} = \frac{D_{\text{4-core}} + D_{\text{laptop}} + D_{\text{RPi}}}{N_{\text{HW}}} \times C \tag{1.9}$$

Where,

D_{Node} = Estimated average demand of hardware running a Bitcoin node, kW
$D_{\text{4-core}}$ = Demand of a server with a 4-core CPU and disk space, 81W [8, 9]
D_{Laptop} = Demand of a typical laptop, 60W [6]
D_{RPi} = Demand of a Raspberry Pi 4, 15.3W [7]
N_{HW} = Number of hardware configurations considered, 3
C = Conversion factor, $\frac{1\ \text{kW}}{10^3\ \text{W}}$

Eq. (1.9) is solved as follows:

$$\begin{aligned} D_{\text{Node}} &= \tfrac{81\ \text{W}+60\ \text{W}+15.3\ \text{W}}{3} \times \tfrac{1\ \text{kW}}{10^3\ \text{W}} \\ &= 0.52\ \text{kW} \end{aligned} \tag{1.10}$$

Using the known number of nodes and the resulting estimated demand of a single node from Eq. (1.10), Eq. (1.8) is solved as follows:

$$\begin{aligned} E_{\text{Nodes}} &= N_{\text{Nodes}} \times D_{\text{Node}} \times H_{\text{yr}} \times C \\ &= 11,740 \times 0.52\tfrac{\text{kWh}}{\text{yr}} \times 8,760\tfrac{\text{hr}}{\text{yr}} \times \tfrac{1\ \text{TW}}{10^9\ \text{kW}} \\ &= 5,358,089.04\tfrac{\text{kWh}}{\text{yr}} \times \tfrac{1\ \text{TW}}{10^9\ \text{kW}} \\ &= 0.0054\tfrac{\text{TWh}}{\text{yr}} \end{aligned} \tag{1.11}$$

Therefore, the estimated total annual electricity usage of all Bitcoin nodes is 0.0054 $\frac{\text{TWh}}{\text{yr}}$.

2 Annual Electricity Usage of the Banking System

Disclaimer: Information regarding the electricity usage required to operate the traditional banking system is very difficult to find and

in most cases, completely unavailable to the public. Because of this, several assumptions are made in order to provide a best effort estimate. Electricity usage contributors not accounted for in this report, include but are not limited to, coins and paper currency, settlement layers (like the DTCC and central banks), and payment processors are not included in this analysis. The Galaxy Digital Mining Team encourages external thoughts and contributions that result in the most accurate figures possible.

2.0.1 Methodology

The estimated total annual electricity usage required to power the banking system's global infrastructure is calculated as follows:

$$E_{\text{Banks}} = E_{\text{DCs}} + E_{\text{Branches}} + E_{\text{ATMs}} + E_{\text{CNs}} \tag{2.1}$$

Where,

$$\begin{aligned}
E_{\text{Banks}} &= \text{Estimated total annual electricity usage required to operate} \\
&\quad \text{the banking system, } \tfrac{\text{TWh}}{\text{yr}} \\
E_{\text{DCs}} &= \text{Estimated total annual electricity usage of the top 100 world} \\
&\quad \text{bank's data centers, } \tfrac{\text{TWh}}{\text{yr}} \\
E_{\text{Branches}} &= \text{Estimated total annual electricity usage of bank branches} \\
&\quad \text{globally, } \tfrac{\text{TWh}}{\text{yr}} \\
E_{\text{CNs}} &= \text{Estimated total annual electricity usage of global card networks,} \\
&\quad \tfrac{\text{TWh}}{\text{yr}} \\
E_{\text{ATMs}} &= \text{Estimated total annual electricity usage of global ATMs, } \tfrac{\text{TWh}}{\text{yr}}
\end{aligned}$$

Using the results described in Sections 2.4 - 2.4 below, Eq. (2.1) is solved as follows:

$$\begin{aligned}
E_{\text{Banks}} &= E_{\text{DC}} + E_{\text{Branches}} + E_{\text{ATMs}} + E_{\text{CNs}} \\
&= 238.92\tfrac{\text{TWh}}{\text{yr}} + 19.71\tfrac{\text{TWh}}{\text{yr}} + 3.09\tfrac{\text{TWh}}{\text{yr}} + 2.02\tfrac{\text{TWh}}{\text{yr}} \\
&= 263.72\tfrac{\text{TWh}}{\text{yr}}
\end{aligned} \tag{2.2}$$

Therefore, the estimated total annual electricity usage of the banking system's data centers is 263.72 $\frac{\text{TWh}}{\text{yr}}$.

2.1 Data Center Contribution

The banking system does not publicly report the electricity usage data required to operate their data center infrastructure. Several assumptions are made in order to estimate this figure.

2.1.1 Assumptions

1. The operating hours of a banking data center is 24 hours per day, 7 days per week, 52 weeks per year, for a total of 8,760 hours per year.
2. Only the top 100 banks (by total deposits) were considered. Total deposit amounts for each bank are as of their latest annual report (per S&P Capital IQ).
3. The only major bank with public information regarding the number of data centers in use is Bank of America. For this reason, the electricity usage of all other considered banks are based on the available data from Bank of America.
4. A linear relationship between number of data centers and total annual deposits as reported by the latest S&P Capital IQ is assumed.
5. An area of 75,000 ft^2 is assumed for each data center.
6. A demand of 400 Watts per ft^2 for a data center is assumed [10].
7. Data center office space is not distinguished from server space.
8. Only electricity usage, not gas usage, is considered.

2.1.2 Methodology

The estimated total global annual electricity usage of the banking system's data centers is calculated as follows:

$$E_{\text{DCs}} = D_{\text{DCs}} \times H_{\text{yr}} \tag{2.3}$$

Where,

E_{DCs} = Estimated total annual electricity usage of the top 100 world bank's data centers, $\frac{\text{TWh}}{\text{yr}}$

D_{DCs} = Estimated demand of the top 100 world bank's data centers, 0.03 TW

H_{yr} = Operating hours of a banking data center, 8,760 $\frac{\text{hr}}{\text{yr}}$

The estimated total annual electricity usage of the top 100 banks is the product of the estimated data center demand for all considered banks and the hours of operation. The only bank that reports the number of data center it uses is Bank of America, which has 23 private data centers [11]. Therefore, Bank of America's data centers are used as a basis to estimate the total annual electricity usage of all considered banks. To estimate the data center demand for the top 100 banks, a linear relationship between number of data centers and total annual deposits is assumed.

The estimated demand of the considered banks is calculated as follows:

$$D_{\text{DCs}} = N_{\text{DCs}} \times A_{\text{DC}} \times D_{\frac{\text{W}}{\text{ft}^2}} \tag{2.4}$$

D_{DCs} = Estimated demand of the top 100 world bank's data centers, TW

N_{DCs} = Estimated number of the top 100 world bank's data centers, 909.15 data centers

A_{DC} = Estimated area of a bank's data center, 75,000 ft^2

$D_{\frac{\text{W}}{\text{ft}^2}}$ = Demand per area of a data center, $400\frac{\text{W}}{\text{ft}^2}$

None of the considered banks, including Bank of America, provide the data center demand or any other useful insights into their data center operations. The data center electricity demand is estimated by assuming a size of 75,000 ft^2, and a demand of 400 W per square foot [10].

The number of data centers for all banks considered is estimated to be the product of the total top 100 global banks annual deposits and the ratio of the number of Bank of America's data centers to Bank of America's total annual deposits and is calculated as follows:

$$N_{\text{DCs}} = \frac{N_{\text{DCs, BoA}}}{TD_{\text{BoA}}} \times \sum_{i=1}^{N_{\text{Banks}}} TD_i \tag{2.5}$$

N_{DCs} = Estimated number of the top 100 world bank's data centers, 909.15 data centers

TD_{BoA} = Total annual deposits of Bank of America, \$1,795.48-b

i = i^{th} bank of summation

N_{Banks} = Number of considered banks, 100 banks

TD_i = Total annual deposits of the i^{th} bank considered, \$-b

The summation of the total deposits for the top 100 global banks is \$70,972.10 billion, and the total deposits for Bank of America is \$1,795.48 billion. The estimated total annual electricity usage of the banking system's data centers is estimated to be the product of the total top 100 global banks annual deposits and the ratio of the estimated electricity demand of Bank of America's data centers to Bank of America's annual deposits.

Eq. (2.6) is solved as follows:

$$\begin{aligned} N_{\text{DCs}} &= \frac{N_{\text{DCs, BoA}}}{TD_{\text{BoA}}} \times \sum_{i=1}^{N_{\text{Banks}}} TD_i \\ &= \frac{23}{\$1,795.48\text{-b}} \times \$70,972.10\text{-b} \\ &= 909.15 \end{aligned} \tag{2.6}$$

Using the result in Eq. (2.6), Eq. (2.4) is solved as follows:

$$
\begin{aligned}
D_{\mathrm{DCs}} &= N_{\mathrm{DCs}} \times A_{\mathrm{DC}} \times D_{\frac{\mathrm{W}}{\mathrm{ft}^2}} \\
&= 909.15 \times 75,000\ \mathrm{ft}^2 \times 400\ \frac{\mathrm{W}}{\mathrm{ft}^2} \\
&= 0.03\ \mathrm{TW}
\end{aligned}
\tag{2.7}
$$

Using the result in Eq. (2.4), Eq. (2.3) is solved as follows:

$$
\begin{aligned}
E_{\mathrm{DCs}} &= D_{\mathrm{DCs}} \times H_{\mathrm{yr}} \\
&= 0.03\ \mathrm{TW} \times 8,760\ \frac{\mathrm{hr}}{\mathrm{yr}} \\
&= 238.92 \frac{\mathrm{TWh}}{\mathrm{yr}}
\end{aligned}
\tag{2.8}
$$

Therefore, the estimated total annual electricity usage of the top 100 banks (by total annual deposits) data center's is 238.92 $\frac{\mathrm{TWh}}{\mathrm{yr}}$.

2.2 Banking Branches Contribution

The banking system does not publicly report the electricity usage data required to operate their physical branch locations. Several assumptions are made in order to estimate this figure.

2.2.1 Assumptions

1. The operating hours of a bank branch is 9 hours per day, 5 days per week, 50 weeks per year, for a total of 2,250 hours per year.
2. The global adult population is considered to be 16 year old and above, and is taken in the year 2020, while the bank branches per 100,000 adults figure is from 2019.
3. A bank branch is considered to be a small business.
4. To obtain an estimation for the electricity usage of a small business, the estimated electricity usage of a small business for four regions is averaged together. The chose regions are the United States, the United Kingdom, Mexico, and China.
5. Small business electricity usage data is not readily available for Mexico or China, so a ratio of the small business usage to the residential usage of the known areas (the US and UK) is used to estimate the small business usage data for the regions with unknown data.
6. Only bank branch offices, not all financial offices, are considered.
7. Only electricity usage, not gas usage, is considered.

2.2.2 Methodology

The estimated total annual electricity usage required to power the banking system's physical branches is calculated as follows:

$$E_{\text{Branches}} = N_{\text{Branches}} \times E_{\text{Bus}} \times C \tag{2.9}$$

Where,

$$\begin{aligned}
E_{\text{Branches}} &= \text{Estimated total annual electricity usage of bank branches} \\
&\quad \text{globally,} \frac{\text{TWh}}{\text{yr}} \\
N_{\text{Branches}} &= \text{Number of bank branches globally, 654,502 branches} \\
E_{\text{Bus}} &= \text{Estimated average annual electricity usage of a small} \\
&\quad \text{business, } 30,116 \frac{\text{kWh}}{\text{yr}} \\
C &= \text{Conversion factor, } \frac{1 \text{ TW}}{10^9 \text{ kW}}
\end{aligned}$$

According to The World Bank, in 2019 there were 11.51 bank branches per 100,000 adults [12]. In 2020, the adult population (16 years old and above) was 5,686,376,363 [13]. Therefore, the estimated number of global bank branches is 654,502. In Section 2.2.3, Eq. (2.20) estimates the average annual electricity usage of a bank branch as 30,116 $\frac{\text{kWh}}{\text{yr}}$.

Eq. (2.9) is solved as follows:

$$\begin{aligned}
E_{\text{Branches}} &= N_{\text{Branches}} \times E_{\text{Bus}} \times C \\
&= 654,502 \times 30,116 \ \frac{\text{kWh}}{\text{yr}} \\
&= 19,710,756,180 \ \frac{\text{kWh}}{\text{yr}} \times \frac{1 \text{ TW}}{10^9 \text{ kW}} \\
&= 19.71 \text{ TWh/yr}
\end{aligned} \tag{2.10}$$

Therefore, the total annual electricity usage of the financial system is estimated to be 19.71 $\frac{\text{TWh}}{\text{yr}}$.

2.2.3 Global Small Business Usage Estimate

The average annual electricity usage of a small business in four countries in four different regions is used to determine a global small business electricity usage estimate. These four countries are the US, the UK, Mexico, and China.

The global estimated average annual electricity usage of a small business is calculated as follows:

$$E_{\text{Bus}} = \frac{\sum_{i=1}^{N_{\text{Reg}}} E_{\text{Bus},i}}{N_{\text{Reg}}} \tag{2.11}$$

Where,

E_{Bus} = Estimated average annual electricity usage of a small business, $\frac{\text{kWh}}{\text{yr}}$

$E_{\text{Bus},i}$ = Small business electricity usage for the i^{th} region in summation, $\frac{\text{kWh}}{\text{yr}}$

N_{Reg} = Number of considered regions, 4

Both the US and the UK have small business electricity usage data readily available, but it is difficult to locate data regarding a small business's electricity usage in many other geographical locations, including Mexico and China. Residential data, however, is available for all considered regions and is used in conjunction with the small business electricity usage data from the known regions in an attempt to make a fair estimate.

A ratio of a small business's annual electricity usage and a residential annual electricity usage for the countries with known data (the US and UK) is calculated as follows:

$$R_{\substack{\text{Bus,}\\\text{Reg}}} = \frac{E_{\substack{\text{Bus,}\\\text{Reg}}}}{E_{\substack{\text{Res,}\\\text{Reg}}}} \tag{2.12}$$

Where,

$R_{\substack{\text{Bus,}\\\text{Reg}}}$ = Regional small business to residential electricity usage ratio

$E_{\substack{\text{Bus,}\\\text{Reg}}}$ = Annual small business electricity usage for a specific region, $\frac{\text{kWh}}{\text{yr}}$

$E_{\substack{\text{Res,}\\\text{Reg}}}$ = Annual residential electricity usage for a specific region, $\frac{\text{kWh}}{\text{yr}}$

In 2019, the EIA reported that the monthly average electricity usage of a small business operating in the United States is 6,066 kWh/mo, or 72,792 kWh/yr [14]. Another report by the EIA last updated in 2019, reported that the annual average electricity usage of a residence in 2015 was 11,000 kWh/yr [15].

Eq. (2.12) for the US is solved as follows:

$$\begin{aligned} R_{\text{Bus, US}} &= \frac{72,792\ \frac{\text{kWh}}{\text{yr}}}{11,000\ \frac{\text{kWh}}{\text{yr}}} \\ &= 6.62 \end{aligned} \tag{2.13}$$

In the UK, a small business uses 25,000 [16]. The average UK household consumes about 10 kWh/day, for a total of 3,650 kWh/yr [17].

Eq. (2.12) for the UK is solved as follows:

$$\begin{aligned} R_{\text{Bus, UK}} &= \frac{25,000\ \frac{\text{kWh}}{\text{yr}}}{3,650\ \frac{\text{kWh}}{\text{yr}}} \\ &= 6.85 \end{aligned} \tag{2.14}$$

The final ratio used is an average of the two ratios in Eq. (2.13) and (2.14) and is defined as follows:

$$R_{\text{Bus}} = \frac{\sum_{i=1}^{N_{\substack{\text{Known}\\ \text{Reg}}}} R_{\substack{\text{Bus,}\\ \text{Known Reg}_i}}}{N_{\substack{\text{Known}\\ \text{Reg}}}} \tag{2.15}$$

Where,

R_{Bus} = Average ratio of the small business to residential electricity usage ratios for the known regions

i = Summation start index

$N_{\substack{\text{Known}\\ \text{Reg}}}$ = Number of known regions

$R_{\substack{\text{Bus}\\ \text{Known Reg}_i}}$ = Ratio i_{th} region with known annual small business electricity usage ratios for the known regions

The results of Eq. (2.13) and (2.14) are similar in number, lending credence to the accuracy of this method.

Using the results of Eq. (2.13) and (2.14), Eq. (2.15) is solved as follows:

$$\begin{aligned} R_{\text{Bus}} &= \frac{6.62 + 6.85}{2} \\ &= 6.73 \end{aligned} \tag{2.16}$$

Using the resulting ratio defined in Eq.(2.16), the annual electricity usage of a small business in regions with residential data only is defined as follows:

$$E_{\substack{\text{Bus,}\\ \text{Unknown Reg}}} = R_{\text{Bus}} \times E_{\substack{\text{Res,}\\ \text{Reg}}} \tag{2.17}$$

Where,

$E_{\substack{\text{Bus,}\\ \text{Unknown Reg}}}$ = Estimated total annual small business electricity usage for region with no data, $\frac{\text{kWh}}{\text{yr}}$

R_{Bus} = Ratio of the average small business to residential electricity usage ratios for the known regions, 6.73

$E_{\substack{\text{Res,}\\ \text{Reg}}}$ = Annual residential electricity usage for a specific region, $\frac{\text{kWh}}{\text{yr}}$

In 2018, the Department of Architecture at the Universidad de las Americas Puebla reported that the daily average electricity usage of a household in Mexico consumes 4.76 kWh/day, or 1,737 kWh/yr [18].

Eq. (2.17) for Mexico is solved as follows:

$$\begin{aligned} E_{\substack{\text{Bus,}\\\text{Mexico}}} &= R_{\text{Bus}} \times E_{\substack{\text{Res,}\\\text{Mexico}}} \\ &= 6.73 \times 1,737 \ \tfrac{\text{kWh}}{\text{yr}} \\ &= 11,699 \ \tfrac{\text{kWh}}{\text{yr}} \end{aligned} \tag{2.18}$$

In 2016, the American Council for an Energy-Efficient Economy estimates that in rural China the average residence uses 1,371 kWh/yr, and residences in more urban areas use 1,888 kWh/yr [19]. An average of these two numbers is used for the small business electricity usage of China, which is found to be 1,630 kWh/yr.

Eq. (2.17) for China is solved as follows:

$$\begin{aligned} E_{\substack{\text{Bus,}\\\text{China}}} &= R_{\text{Bus}} \times E_{\substack{\text{Res,}\\\text{China}}} \\ &= 6.73 \times 1,630 \ \tfrac{\text{kWh}}{\text{yr}} \\ &= 10,972 \ \tfrac{\text{kWh}}{\text{yr}} \end{aligned} \tag{2.19}$$

Using the known annual small business electricity usage for the U.S. and the U.K., as well as the results of Eq. (2.18) and (2.19), for Mexico and China, respectively, Eq. (2.11) is solved as follows:

$$\begin{aligned} E_{\text{Bus}} = \frac{\sum_{i=1}^{N_{\text{Reg}}} E_{\text{Bus},i}}{N_{\text{Reg}}} &= \frac{72,792 \ \frac{\text{kWh}}{\text{yr}} + 25,000 \ \frac{\text{kWh}}{\text{yr}} + 11,699 \ \frac{\text{kWh}}{\text{yr}} + 10,972 \ \frac{\text{kWh}}{\text{yr}}}{4} \\ &= 30,116 \ \tfrac{\text{kWh}}{\text{yr}} \end{aligned} \tag{2.20}$$

2.3 ATM Contribution

The banking system does not publicly report the electricity usage data required to operate ATMs. Several assumptions are made in order to estimate this figure.

2.3.1 Assumptions

1. The operating hours of an ATM is 24 hours per day, 7 days per week, 52 weeks per year, for a total of 8,760 hours per year.
2. The global adult population is considered to be 16+ and taken in the year 2020, while the ATM per 100,000 adults figure is from 2019.
3. The global adult population is considered to be 16 year old and above, and is taken in the year 2020, while the ATMs per 100,000 adults figure is from 2019.
4. The demand of a single ATM is assumed to be that of a Prineta ATM, which is 145 W [20].

2.3.2 Methodology

The estimated total annual electricity usage required to power the banking system's ATMs is calculated as follows:

$$E_{\text{ATMs}} = N_{\text{ATMs}} \times D_{\text{ATM}} \times H_{\text{yr}} \times C \tag{2.21}$$

Where,

$$\begin{aligned}
E_{\text{ATMs}} &= \text{Estimated total annual electricity usage of ATMs, } \tfrac{\text{TWh}}{\text{yr}} \\
N_{\text{ATMs}} &= \text{Number of ATMs globally, 2,432,632 ATMs} \\
D_{\text{DCs}} &= \text{Estimated demand of a single ATM, 145 W} \\
C &= \text{Conversion factor, } \tfrac{1\ \text{TW}}{10^{12}\ \text{W}}
\end{aligned}$$

According to The World Bank, in 2019 there were 42.78 ATMs per 100,000 adults [12]. In 2020, the adult population (16 years old and above) was 5,686,376,363 [13]. Therefore, the estimated number of ATMs is 2,432,632 globally.

Eq. (2.21) is solved as follows:

$$\begin{aligned}
E_{\text{ATMs}} &= N_{\text{ATMs}} \times D_{\text{ATM}} \times H_{\text{yr}} \times C \\
&= 2,432,632\ \text{ATMs} \times 145\ \text{W} \times 8,760 \times \tfrac{1\ \text{TW}}{10^{12}\ \text{W}} \\
&= 3,089,928,922,866\ \tfrac{\text{Wh}}{\text{yr}} \times \tfrac{1\ \text{TW}}{10^{12}\ \text{W}} \\
&= 3.09\ \tfrac{\text{TWh}}{\text{yr}}
\end{aligned} \tag{2.22}$$

Therefore, the estimated total annual electricity usage required to operate the banking system's ATMs is 3.09 $\frac{\text{TWh}}{\text{yr}}$.

2.4 Card Networks Contribution

Card networks do not publicly report the electricity usage data required to process transactions. Several assumptions are made in order to estimate this figure.

2.4.1 Assumptions

1. The operating hours of the card networks is 24 hours per day, 7 days per week, 52 weeks per year, for a total of 8,760 hours per year.

2. Data center electricity usage is assumed to be the only contribution.

3. The office space that the card network's use is not considered.

4. The only card network with public information regarding the number of their data centers is VISA. For this reason, the electricity usage of all other considered card networks are based on the available data from VISA.

5. A linear relationship between the estimated annual electricity usage of a card network's data centers and the number of transactions that each card network process is assumed.
6. A demand of 400 Watts per ft^2 for a data center is assumed [10].
7. Data center office space is not distinguished from server space.
8. Only electricity usage, not gas usage, is considered.

2.4.2 Methodology

The estimated total global annual electricity usage of the banking system's card networks is calculated as follows:

$$E_{\text{CNs}} = E_{\text{VISA}} \times \frac{N_{\text{tx, T}}}{N_{\text{tx, VISA}}} \tag{2.23}$$

Where,

E_{CNs} = Estimated total annual electricity usage of global card networks,
E_{VISA} = Estimated annual electricity usage of the VISA network, $\frac{\text{TWh}}{\text{yr}}$
$N_{\text{tx, T}}$ = Total number of billion transactions processed by all card networks in 2019, 441.0 billion transactions
$N_{\text{tx, VISA}}$ = Total number of billion transactions processed by VISA in 2019, 185.5 billion transactions

In 2019, 441.0 billion transactions were processed by the card networks globally, 185.5 billion of which were processed by VISA [21]. Public information on the electricity usage of the infrastructure required to power the card networks is not readily available, however, there is information available regarding the number and size of VISA's data centers (but not the data center demand). Therefore, VISA's data centers are used as a basis to estimate the total annual electricity usage of all card networks. To estimate the electricity usage of all card networks, a linear relationship between the estimated annual electricity usage of a card network's data centers and the number of transactions that each card network process is assumed.

The estimated annual electricity usage of the VISA network is detailed in Section 2.4.3 below, where Eq. (2.25) is solved to be 0.84 $\frac{\text{TWh}}{\text{yr}}$. Using this value and the number of billions of transactions processed globally in 2019, Eq. (2.23) is solved as follows:

$$\begin{aligned} E_{\text{CNs}} &= E_{\text{VISA}} \times \frac{N_{\text{tx, T}}}{N_{\text{tx, VISA}}} \\ &= 0.84\frac{\text{TWh}}{\text{yr}} \times \frac{441.0}{185.5} \\ &= 2.00\frac{\text{TWh}}{\text{yr}} \end{aligned} \tag{2.24}$$

Therefore, the estimated total annual electricity usage required to operate the card networks is 2.00 $\frac{\text{TWh}}{\text{yr}}$.

2.4.3 The VISA Network Contribution

The estimated total annual electricity usage of the VISA card network's data centers is calculated as follows:

$$E_{\text{VISA}} = \sum_{i=1}^{N_{\text{VISA, DC}}} E_{\text{VISA},i} \tag{2.25}$$

Where,

E_{VISA} = Estimated total annual electricity usage of VISA's data centers, $\frac{\text{TWh}}{\text{yr}}$

i = i^{th} VISA data center

$E_{\text{VISA},i}$ = Estimated total annual electricity usage of the i^{th} VISA data center data centers, $\frac{\text{TWh}}{\text{yr}}$

$N_{\text{VISA, DC}}$ = Number of VISA's data centers, 5 data centers

VISA reports to have five major data centers. These facilities and their reported square footage is listed in Table 2.1. The demand for these facilities is not publicly available, therefore a demand of 400 W per square foot is assumed [10].

The estimated total annual electricity usage for each facility is calculated as follows, where i refers to the specific data center in the summation:

$$E_{\text{VISA},i} = A_{\text{VISA},i} \times D_{\frac{\text{W}}{\text{ft}^2}} \times H_{\text{yr}} \times C \tag{2.26}$$

Where,

$E_{\text{VISA, }i}$ = Estimated total annual electricity usage of the i^{th} VISA data center

$A_{\text{VISA, }i}$ = Area of the i^{th} VISA data center, ft^2

$DS_{\text{DC, ft}^2}$ = Demand per area of a data center, 400 $\frac{\text{W}}{\text{ft}^2}$

H_{yr} = Operating hours of a VISA data center, 8,760 $\frac{\text{hr}}{\text{yr}}$

C = Conversion factor, $\frac{1\text{ TW}}{10^{12}\text{ W}}$

As an example, Eq. (2.26) is solved for VISA's Operations Center East (OCE) facility as follows:

$$\begin{aligned} E_{\text{OCE}} &= A_{\text{OCE}} \times DS_{\text{DC, ft}^2} \times H_{\text{yr}} \times \frac{1\text{ TW}}{10^{12}\text{ W}} \\ &= 140,000\text{ ft}^2 \times 400\frac{\text{W}}{\text{ft}^2} \times 8,760\frac{\text{hr}}{\text{yr}} \times \frac{1\text{ TW}}{10^{12}\text{ W}} \\ &= 490,560,000,000\frac{\text{Wh}}{\text{yr}} \times \frac{1\text{ TW}}{10^{12}\text{ W}} \\ &= 0.49\frac{\text{TWh}}{\text{yr}} \end{aligned} \tag{2.27}$$

Using the values in Table 2.1, Eq. (2.25) is solved and the estimated total annual electricity usage of VISA's data centers is 0.84 $\frac{\text{TWh}}{\text{yr}}$.

Facility	Data Center Area [ft^2]	Annual Electricity Consumption [TWh/yr]
Operations Center East (OCE)	140,000	0.49
Operations Center Center (OCC)	70,000	0.25
London 1	10,000	0.04
London 2	10,000	0.04
Singapore	10,000	0.04
Total	**240,000**	**0.84**

Table 2.1: Reported VISA Data Center Facilities [22, 23]

3 Annual GHG Emissions & Electricity Usage Equivalence of the Gold Mining Industry

Disclaimer: Information regarding the total annual green house gas (GHG) emissions and the electricity usage equivalence required to operate the gold mining industry is very difficult to find and in most cases, completely unavailable to the public. Because of this, several assumptions are made in order to provide a best effort estimate. The Galaxy Digital Mining Team encourages external thoughts and contributions that result in the most accurate figures possible.

3.0.1 Assumptions

The gold industry does not publicly report the electricity usage data required to operate their infrastructure. Several assumptions are made in order to estimate this figure.

1. The energy usage of the gold industry is not readily available, therefore this report relies on the robustness of The World Gold Council's *Gold and Climate Change: Current and Future Impacts* and assumes all energy usage from the gold industry is accounted for [24]. This may not be a strong assumption considering The World Gold Council is comprised of large industry gold companies.

2. In an attempt to make the most fair comparison between the Bitcoin network and gold, only Scope 1, Scope 2, and the refining and recycling of the upstream process are accounted for.

3. In an attempt to make the most fair comparison between the Bitcoin network's and gold, the GHG emissions are converted from pounds of CO_2 per kWh using a conversion metric from the EIA of 0.92 pounds of CO_2. This conversion factor is based on U.S. electricity generation data in 2019, but used to determine GHG emissions equivalent for the *global* gold mining industry. This implies a conservative assumption that gold mining industry is inline with the U.S. average of the carbon industry.

4. Another consideration with respect to the conversion factor of 0.92 pounds of CO_2 per kWh is that emissions from electricity generation and gold mining processes are variable. Some of the most notable variables include the type of energy sources, efficiency of power plants and gold processes, and location. Therefore, the conversion factor of 0.92 pounds of CO_2 per kWh is a ball park estimate that is used in lieu of robust public energy usage data reporting from the gold mining industry.

3.0.2 Methodology

A report by the World Gold Council titled *Gold and Climate Change: Current and Future Impacts* performed a detailed investigation on the GHG emissions various stages of the gold mining process, defined as *scopes* [24]. The sources of the GHG emissions due to gold mining is broken down into two buckets: upstream and downstream. The upstream processes encompass three scopes as well as the refining and recycling processes. These three scopes are: (1) direct GHG emissions, (2) indirect electricity emissions, and (3) other indirect emissions. In an effort to make the most fair comparison between the Bitcoin network and gold, this report only accounts for Scope 1, Scope 2, and the refining and recycling of the upstream process. The two scopes considered in this report are defined by The World Gold Council as follows:

1. **Scope 1: Direct GHG Emissions**
   GHG emissions occurring from sources owned or controlled by the organization, such as:
   (a) emissions from combustion in owned or controlled boilers, furnaces or vehicles,
   (b) emissions from chemical processes in owned or controlled equipment,
   (c) and emissions from land owned or controlled by the organization.
2. **Scope 2: Indirect Electricity Emissions**
   GHG emissions at power plants generating electricity purchased by the organization.

These scopes and the refining/recycling processes, their associated GHG emissions as reported by The World Gold Council, and the estimated electricity usage equivalences are detailed in Table 3.1 below. The total GHG emissions for the scopes and processes considered in this report is 100,408,504 tCO_2e. In an attempt to make the most fair comparison between the Bitcoin network's and gold, the GHG emissions are converted from pounds of CO_2 per kWh using a conversion metric from the EIA of 0.92 pounds of CO_2. This conversion factor is based on U.S. electricity generation data in 2019, but used to determine GHG emissions equivalent for the *global* gold mining industry. This implies a conservative assumption that gold mining industry is inline with the U.S. average of the carbon industry. Furthermore, it is important to note that emissions from electricity generation and gold mining processes are variable. Some of the most notable variables include the type of energy sources, efficiency of power plants and gold processes, and location. Therefore, the conversion factor of 0.92 pounds of CO_2 per kWh is a ball park estimate that is used in lieu of robust public energy usage data reporting from the gold mining industry.

Production	**Total GHG Emissions [t CO2e]**	**Total Equivalent Electricity Usage [TWh/yr]**
Scope 1	45,490,059	109.01
Scope 2	54,914,157	131.59
Refining/Recyling Gold	4,228	0.01
Total	100,408,504	240.61

Table 3.1: Gold Industry GHG Emissions and Electricity Usage Equivalence of the Considered Production (Upstream) Scopes and Refining/Recycling Processes [24].

The estimated total annual electricity usage GHG emissions equivalence of the global gold mining industry is calculated as follows:

$$E_{\text{Gold}} = GHG_{\text{Gold}} \times C_1 \times C_2 \times C_3 \tag{3.1}$$

Where,

E_{Gold} = Estimated total annual electricity usage GHG emissions equivalence of the gold mining industry, $\frac{\text{TWh}}{\text{yr}}$

GHG_{Gold} = Annual GHG emissions of the gold industy for considered scopes and processes, 100,408,504 $\frac{\text{tonne CO}_2\text{e}}{\text{yr}}$

C_1 = Conversion factor, 0.92 $\frac{\text{lb CO}_2\text{e}}{\text{1 kWh}}$

C_2 = Conversion factor, $\frac{\text{2,204.62 lb}}{\text{1 tonne}}$

C_3 = Conversion factor, $\frac{\text{1 TW}}{10^9\text{ kW}}$

Eq. (3.1) is solved as follows:

$$\begin{aligned}
E_{\text{Gold}} &= GHG_{\text{Gold}} \times C_1 \times C_2 \times C_3 \\
&= 100,408,504\ \frac{\text{tonne CO}_2\text{e}}{\text{yr}} \times 0.92\frac{\text{lb CO}_2\text{e}}{\text{1 kWh}} \times \frac{\text{2,204.62 lb}}{\text{1 tonne}} \times \frac{\text{1 TW}}{10^{12}\text{ W}} \\
&= 240,611,517,487\ \frac{\text{kWh}}{\text{yr}} \times \frac{\text{1 TW}}{10^9\text{ kW}} \\
&= 240.61\frac{\text{TWh}}{\text{yr}}
\end{aligned} \tag{3.2}$$

Therefore, the estimated total annual electricity usage GHG emissions equivalence of the gold mining industry for the considered scopes and refining/recycling processes is estimated to be 240.61 TWh/yr.

References

[1] Cambridge Centre for Alternative Finance. Cambridge Bitcoin Electricity Consumption Index Methodology. https://cbeci.org/cbeci/methodology, April 2021. Accessed May 13, 2021.

[2] Cambridge Centre for Alternative Finance. Cambridge Bitcoin Electricity Consumption Index. https://cbeci.org, April 2021. Accessed May 13, 2021.

[3] blockchain.com. Hashrate Distribution. https://www.blockchain.com/charts/pools, 2021. Accessed April 24, 2021.

[4] Vertatique. Average Power Use Per Server. https://www.vertatique.com/average-power-use-server, 2019. Accessed May 13, 2021.

[5] Clark Moody. Clark Moody Bitcoin Dashboard. https://bitcoin.clarkmoody.com/dashboard, April 2021. Accessed April 23, 2021.

[6] EnergyUseCalculator.com. Electricity usage of a Laptop, Notebook or Netbook. https://energyusecalculator.com/electricity_laptop.htm, 2021. Accessed May 13, 2021.

[7] Raspberry Pi Trading Ltd. Raspberry Pi 15.3W USB-C Power Supply. https://static.raspberrypi.org/files/product-briefs/USB-C-Product-Brief.pdf, June 2019. Accessed May 13, 2021.

[8] Intel. Intel Core i7-3770 Processor. https://ark.intel.com/content/www/us/en/ark/products/65719/intel-core-i7-3770-processor-8m-cache-up-to-3-90-ghz.html. Accessed May 13, 2021.

[9] Samsung. Samsung SSD 850 EVO. https://image-us.samsung.com/SamsungUS/pim/migration/doc/mz-75e1t0b-am_850EVO.pdf, 2014. Accessed May 13, 2021.

[10] Data Center Knowledge. New Workloads, Cost Pressures Drive Up Data Center Power Densities. https://www.datacenterknowledge.com/power-and-cooling/new-workloads-cost-pressures-drive-data-center-power-densities, April 2018. Accessed May 13, 2021.

[11] CIO Dive. Bank of America prioritized internal cloud. Now it's evaluating third-party providers. https://www.ciodive.com/news/bank-of-america-prioritized-internal-cloud-now-its-evaluating-third-party/565228, October 2019. Accessed May 13, 2021.

[12] The World Bank. Automated teller machines (ATMs) (per 100,000 adults). https://data.worldbank.org/indicator/FB.ATM.TOTL.P5?end=2019&start=2019&view=bar, 2021. Accessed May 13, 2021.

[13] Statista. Proportion of selected age groups of world population in 2020, by region. https://www.statista.com/statistics/265759/world-population-by-age-and-region, March 2021. Accessed May 13, 2021.

[14] U.S. Energy Information Administration. 2019 Average Monthly Bill- Commercial. https://www.eia.gov/electricity/sales_revenue_price/pdf/table5_b.pdf, 2019. Accessed May 13, 2021.

[15] U.S. Energy Information Administration. Use of energy explained. https://www.eia.gov/energyexplained/use-of-energy/electricity-use-in-homes.php, May 2019. Accessed May 13, 2021.

[16] Bionic. Bionic's guides to business essentials. https://bionic.co.uk/business-energy/guides/average-energy-usage-for-businesses/, 2021. Accessed May 13, 2021.

[17] Smarter Business. Average Gas & Electricity Usage in the UK - 2020. https://smarterbusiness.co.uk/blogs/average-gas-electricity-usage-uk, May 2021. Accessed May 13, 2021.

[18] Department of Architecture, Universidad de las Americas Puebla. Analysis of the Energy Use in the Mexican Residential Sector by Using Two Approaches Regarding the Behavior of the Occupants. https://www.mdpi.com/2076-3417/8/11/2136, November 2019. Accessed May 13, 2021.

[19] American Council for an Energy-Efficient Economy. Electricity Demand in Chinese Households: Findings from China Residential Energy Consumption Survey. https://www.aceee.org/files/proceedings/2016/data/papers/9_76.pdf, 2016. Accessed May 13, 2021.

[20] Prineta. How Much Electricity Does an ATM Use? https://prineta.com/atm-power-usage/, June 2020. Accessed May 13, 2021.

[21] Nilson Report. Global Cards - 2019. https://nilsonreport.com/research_featured_article.php, April 2021. Accessed May 13, 2021.

[22] Network Computing. Inside Visa's Data Center. https://www.networkcomputing.com/networking/inside-visas-data-center, May 2013. Accessed May 13, 2021.

[23] Network Computing. Inside Visa's Data Center. https://www.datacenterdynamics.com/en/news/visa-to-open-london-singapore-data-centers/, May 2013. Accessed May 13, 2021.

[24] World Gold Council. Gold and Climate Change: Current and Future Impacts. https://conferences.pionline.com/uploads/conference_admin/gold-and-climate-change-current-and-future-impacts-2.pdf, 2021. Accessed May 13, 2021.