EU Blockchain
Observatory and Forum

PoW Energy Consumption in the EU

About this report

This is the thirteenth of a series of reports that will be published addressing selected topics in accordance with European Commission priorities. The aim is to reflect on the latest trends and developments and discuss the future of blockchain in Europe and globally.

This report has been produced by the EU Blockchain Observatory and Forum Experts Panel and team.

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Special thanks to the Cambridge Centre for Alternative Finance for their support and contribution.

Special thanks to **Scope** for the editorial review and language proofing.

Note

While we have done our best to incorporate the comments and suggestions of our contributors where appropriate and feasible, all mistakes and omissions are the sole responsibility of the authors of this report.

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PoW Energy Consumption in the EU

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Chapter 1: Bitcoin Mining and Energy Consumption of EU Member States

1.1 EU MEMBER STATES BITCOIN HASHRATE ANALYSIS

Proof-of-work (PoW), a technique for achieving consensus in blockchain networks, has attracted the interest of regulators, policymakers, and the public because of its energy intensity. The case of Bitcoin in particular, which consumes electricity comparable to a small country, has also raised environmental concerns. The EU has been perceived by the public as a minor contributor to PoW activity and energy consumption, yet no studies exist to support or reject this assumption.

In this report, we investigate the energy consumed by Bitcoin mining in the EU by looking at secondary resources. Utilising the Cambridge Bitcoin Electricity Consumption Index, we consolidate panel data on Bitcoin hashrate (which measures the 'intensity' of PoW) for EU Member States between periods of the years 2019 and 2022, as well as the years 2020 and 2021. Specifically, we examine the mining activities of each Member State for each month, as well as across each year, and we present various comparisons. At the same time, we utilise the energy consumption databases of the open knowledge repository datacommons.org to connect hashrate at national and EU level to the respective level of electricity consumption.

Hashrate and energy consumption data are not readily available and, even when data exists, it is difficult if not impossible to independently verify its credibility. A similar case is true for the hashrate figures, where data is only made available through the various private service providers. Lastly, and importantly, even if figures on energy consumption and hashrates were accurate, there is no way to verify the kind of energy resources utilised (renewable or otherwise) to assess PoW's environmental impact.

We should also note that the use of virtual private networks (VPNs) or proxy services by miners to hide their IP addresses and mask their location is common practice. This is especially true in countries where PoW mining and similar activities are banned or restricted, as in the case of the Chinese province of Zhejiang, and later, mainland China. As a result, hashrate data will contain distortions from miners proxying their location to other countries to bypass bans and prohibitions. When it comes to the EU, anecdotal evidence suggested that Germany and Ireland emerged as hotspots for miners masking their location. The data we present support this assumption.

However, despite the coarse and incomplete nature of available data, we observed trends supported by empirical evidence throughout our analysis. Overall, this report should not be read as conclusive evidence, let alone inform policy action. Instead, we hope that it serves as a conversation starter around PoW energy consumption in the EU and the need for access to higher-quality data.

1.1.1 Analysis of EU Member States' Hashrates the Year 2019

September 2019

Starting with September 2019, Germany already had the lion's share in Bitcoin mining across all EU Member States, with France following in second place. As we have pointed out in the introduction, data on Germany and Ireland in particular seem to be influenced by foreign miners masking their IP addresses. This issue becomes more apparent after 2020, when prohibitions on PoW came into effect. In many smaller Member States, such as Belgium, Croatia, Cyprus, and Luxembourg, mining activity amounted to practically zero (0.00%), whereas in most other countries it hovered around 0.04%.

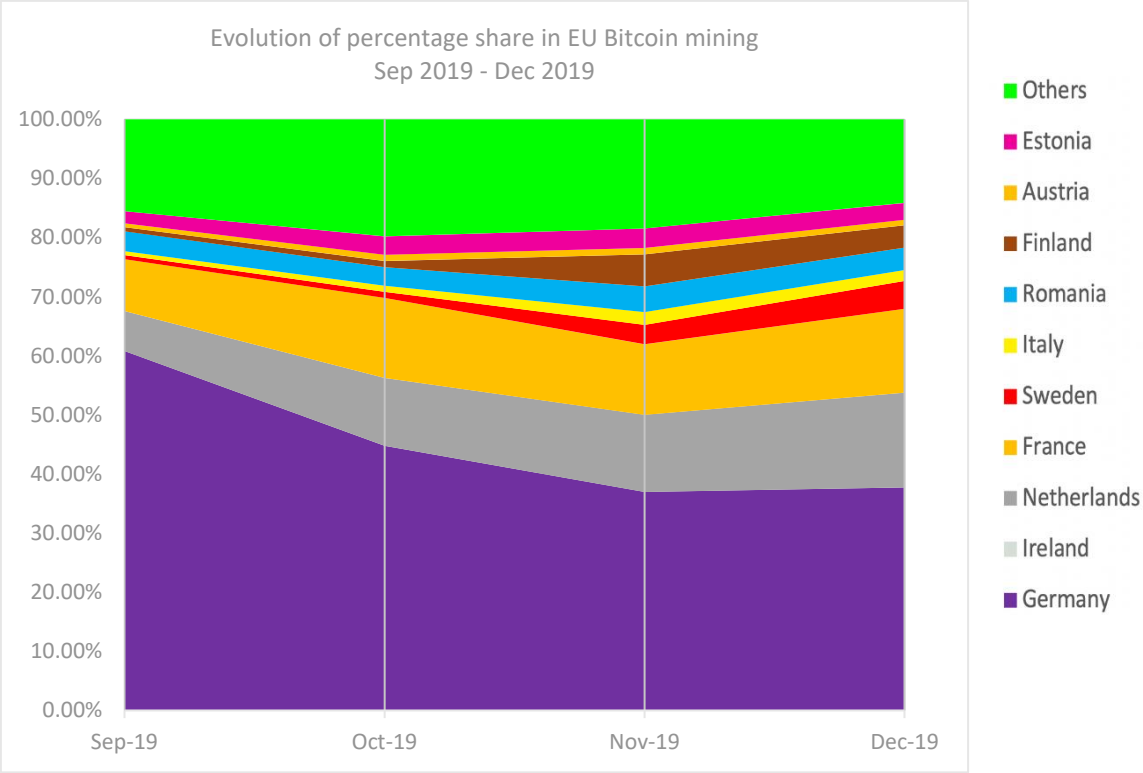


Figure 1: Evolution of percentage in EU Bitcoin mining, September-December 2019

October 2019

During October 2019, Germany and France remained the leading miners across EU Member States. More specifically, Germany's hashrate remained the highest at 0.43% and France's hash ate at 0.13%. Ireland's mining activity remained low.

November 2019

In November 2019, France moved into third place and was replaced by the Netherlands. The hashrate of the rest of the countries remained extremely low.

December 2019

Differences in the hashrate percentage were insignificant. Germany had the highest hashrate (0.17% for the Netherlands and 0.15% for France).

Member States for 2019

Figure 2: Volume of Bitcoin mining by hashrate for EU-member countries, September-December 2019

1.1.2 Analysis of EU Member States' Hashrates for the Year 2020

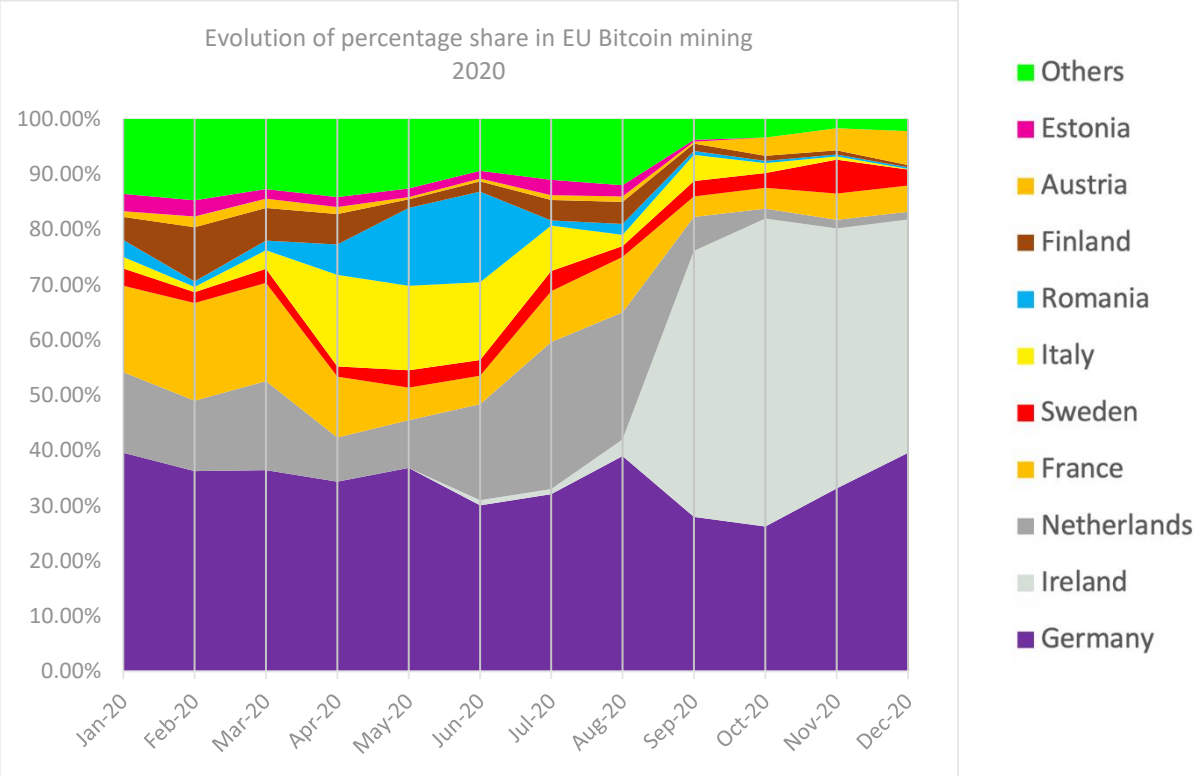


Figure 3:Evolution of percentage in EU Bitcoin mining 2020

January 2020

2020 started with France taking back second place from the Netherlands, albeit with a minor hashrate difference. Germany remained in first place, while Belgium, Croatia, Cyprus, Denmark, and Ireland, among other countries, had a zero (0.0%) hashrate.

February 2020

During February, although the key players in Bitcoin mining in the EU stayed the same, we observe a decrease in the hashrate of other countries.

March 2020

The state of Bitcoin mining in March 2020 was no different to February 2020. Nonetheless, Finland's hashrate rose from 0.03% to 0.07% and Italy suddenly rose to fifth place.

April 2020

In April 2020, the status of Italy changed, and its hashrate rose to second place. Also, Finland, Romania, and Spain slowly rose to 0.09%.

May 2020

During May 2020, Romania and Netherlands exchanged places and Romania climbed up to the third highest hashrate across EU Member States. Germany, Italy, Spain, and France still had the highest hashrates, and Sweden slowly started gaining momentum.

June 2020

In June 2020, the Netherlands rose to second place again, Germany remained in first place, while Romania, Italy, France, Spain, and Sweden still belonged in the top ten countries with the highest hashrates. However, countries like Latvia, Slovenia, and the Czech Republic still made no contribution.

July 2020

During July 2020, the Bitcoin mining status in the EU Member States remained almost as it was. A noteworthy change would be France moving back into the third place and Romania falling way back, from third to seventeenth place.

August 2020

In August 2020, we notice that Belgium rose to fifth place, with a low hashrate of 0.04%. Germany, Netherlands, and France still held the top three places, while the rest of the countries had significantly low hashrates.

September 2020

Starting in September 2020, we notice Ireland took over almost half of the EU Member States' hashrate. Nonetheless, it is worth mentioning that there is very little evidence of actual mining activities in the country, and it is strongly believed that these numbers are derived from proxy services and/or redirected IP addresses. The same is true for Germany.

October 2020

October 2020 found Ireland's hashrate expanding even more. Additionally, Austria rose from twelfth place to fourth. Germany and France were in second and third place respectively.

November 2020

In November 2020, we can see a jump in Sweden's hashrate before it returns to normal levels in December. This move could be explained by miners temporarily switching their VPN locations to Sweden from Ireland, which exhibited a drop in percentage hashrate. Of course, Ireland and Germany still had the lion's share.

December 2020

December's chart for 2020 followed familiar patterns.

Summary of the Annual Hash Rate for each EU Member State for 2020

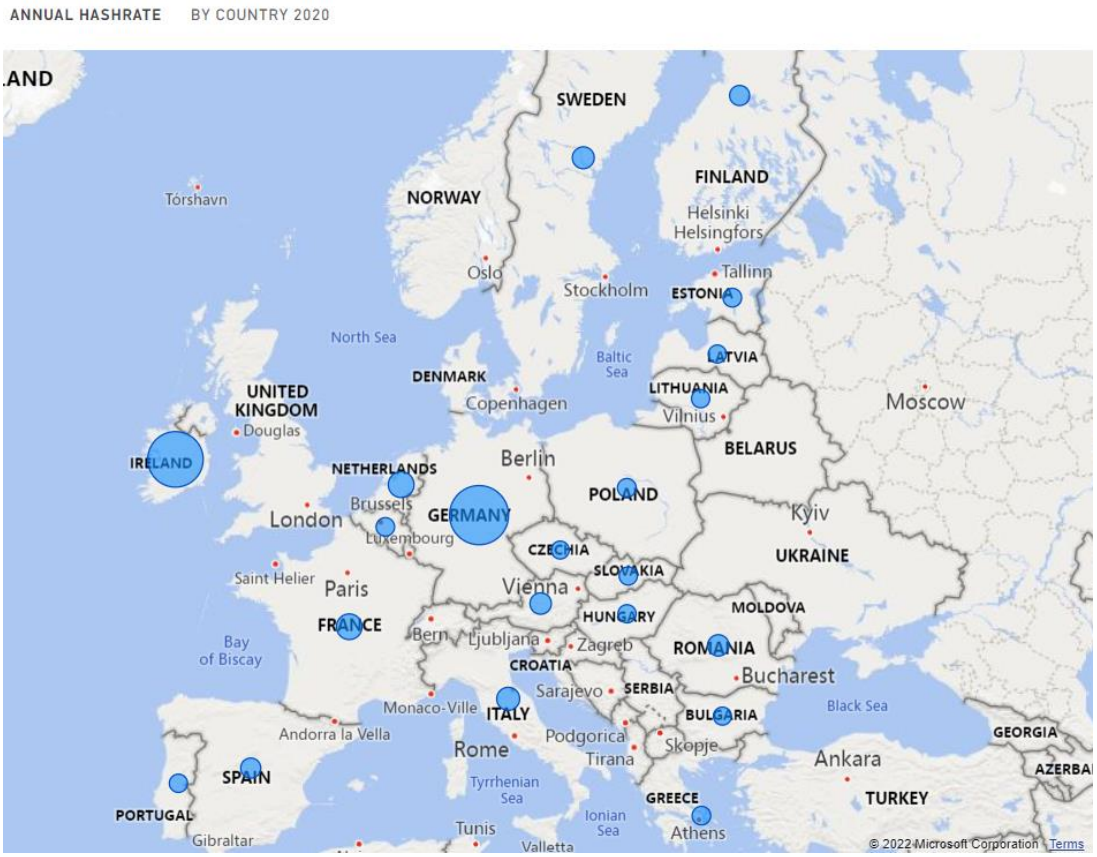


Figure 4: Volume of Bitcoin mining by hashrate for EU-member countries, 2019

1.1.3 Analysis of EU Member States' Hashrates for the Year 2021

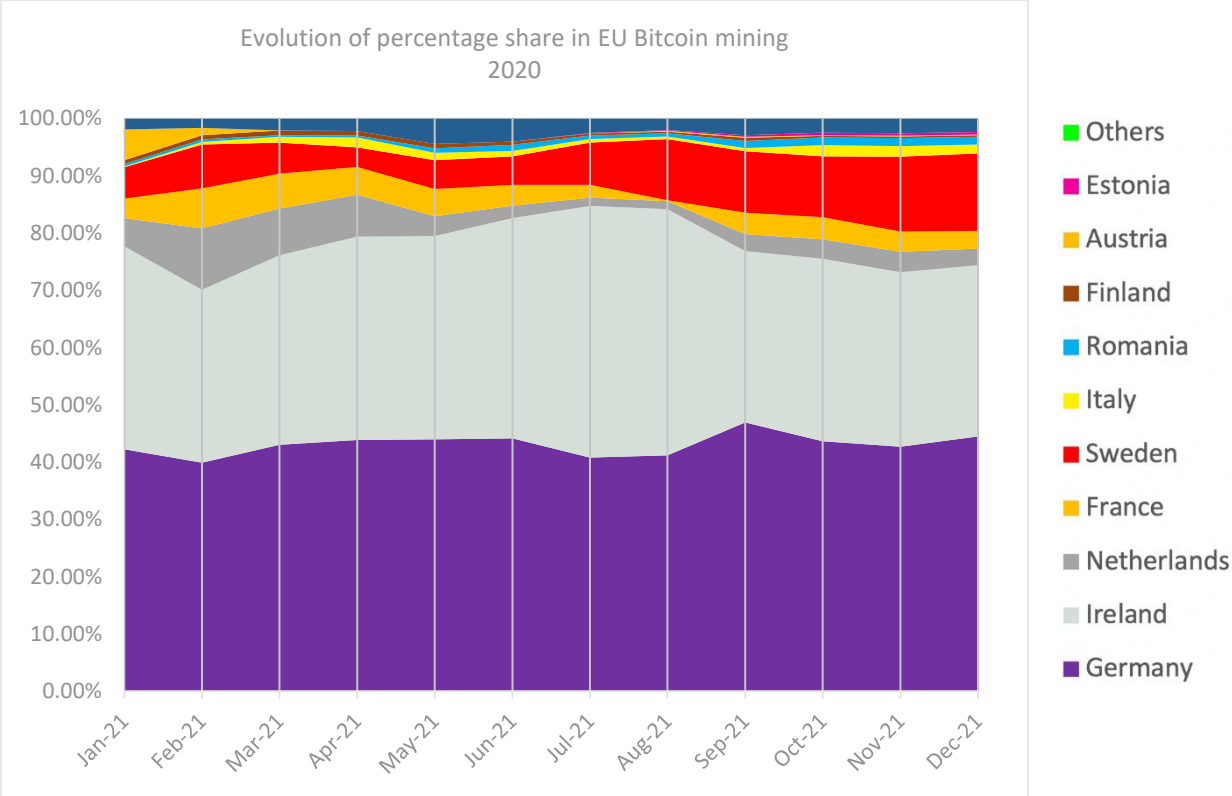


Figure 5: Evolution of percentage in EU Bitcoin mining 2021

January 2021

In January 2021, Germany and Ireland switched places, with Germany taking over first place. Sweden rose to third place, with Austria, the Netherlands, and France remaining in the top ten countries with the highest hashrate.

February 2021

In February 2021, the Netherlands climbed up to third place. Germany and Ireland still prevailed (inexplicably) with by far the highest hashrates, while countries like Slovenia, Slovakia, Croatia, Belgium, etc., still had no Bitcoin mining activity.

March 2021

During March 2022, the status quo remained almost as it was. However, Italy's hashrate almost doubled from 0.06% to 0.11%.

April 2021

In April 2021, not much changed from the previous month. Germany, Ireland, and the Netherlands were still the countries with the top three highest hashrates.

May 2021

During May 2021, Germany and Ireland's hashrates were still the highest. Furthermore, Sweden, France, the Netherlands, Spain, and Italy also had notable hashrates.

July 2021

We can observe a similar pattern over May, June, and July 2021.

August 2021

However, in August 2021 Sweden's hashrate rose significantly from 0.85% to 1.16%, while the Netherlands took France's place and France fell to the twelfth place.

September 2021

In September 2021, there were a few insignificant changes. The most notable was that Slovakia fell and returned to a 0.00% hashrate again.

October 2021

Although Germany and Ireland remained in first and second place respectively during October 2021, it looks like Germany's hashrate increased a little and Ireland's decreased. The hashrates of most of the countries remained as they were.

November 2021 and December 2021

Not much changed in November and December 2021.

Summary of the Annual Hash Rate for each EU Member State for 2021

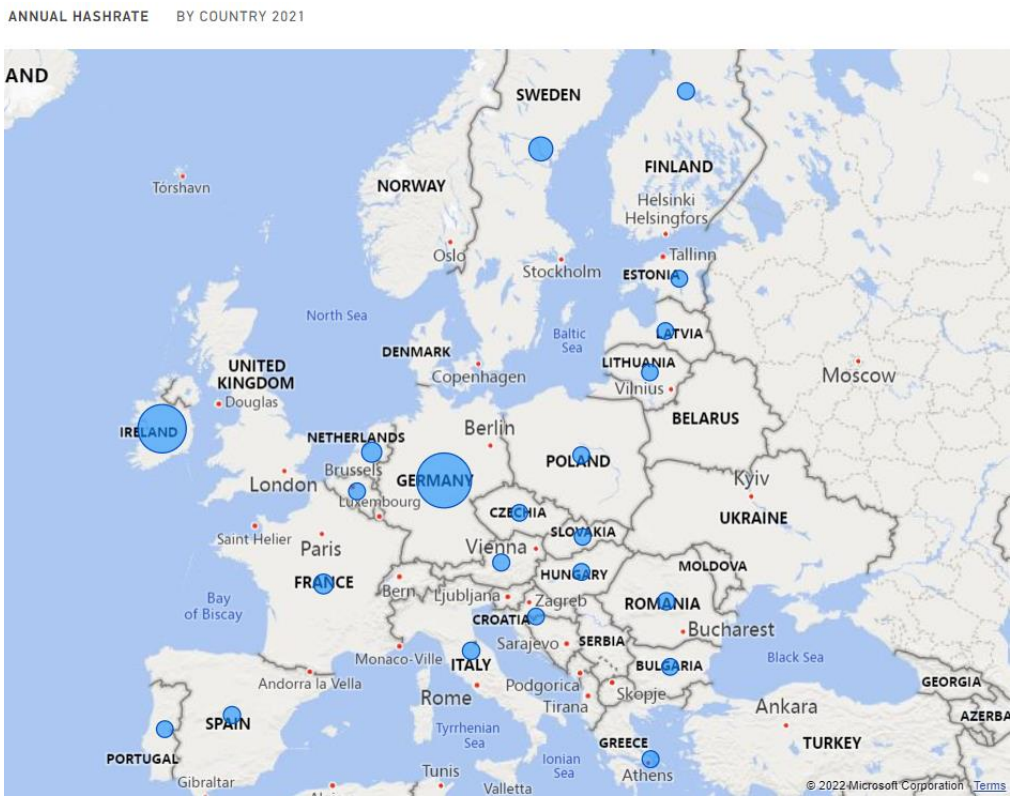


Figure 6: Annual hashrate for each EU Member State for 2021

1.1.4 Analysis of EU Member States' Hashrates for January 2022 and Overview

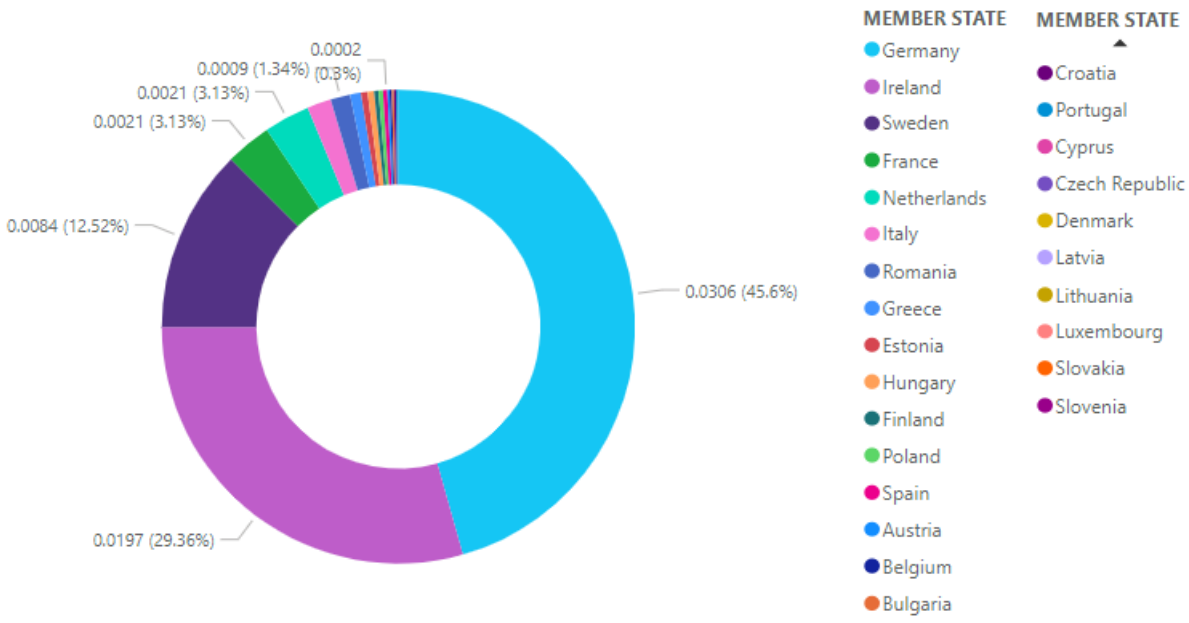


Figure 7: EU Member States hashrates for January 2022

January 2022

January 2022 is the most recent month that we examined. The latest data for the hashrate of EU Member States showed that Germany, Ireland, and Sweden had the top three highest hashrates with France, the Netherlands, Italy, and Romania following. However, after almost two and a half years, countries like Slovenia, Slovakia, and Luxembourg remained inactive in Bitcoin mining.

Overall, the hashrate evolution from September 2019 to January 2022 is shown in the figure below.

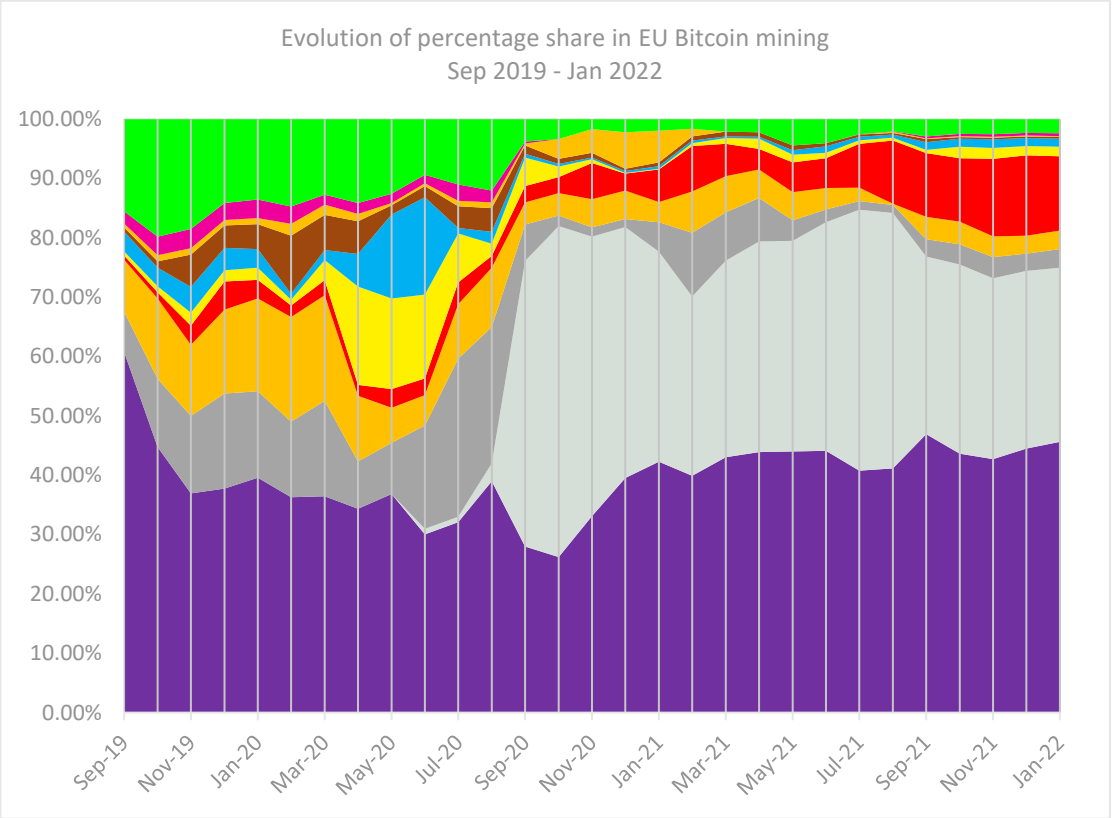


Figure 8: Evolution of percentage share of Bitcoin mining September 2019 – January 2022

1.1.5 Breakdown of the Total Monthly Hashrate for Each Year

Monthly total hashrate of 2019

Comparing September, October, November, and December of 2019, we observe that September had a significantly higher hashrate. More specifically, according to our data, September 2019 was the month when the EU Member States produced cumulatively the highest hashrate.

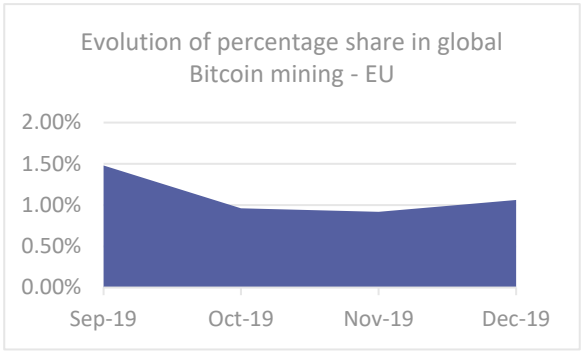


Figure 9: Evolution of percentage share in global Bitcoin mining (EU)

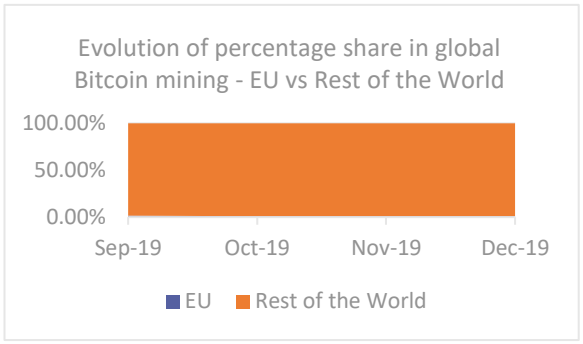
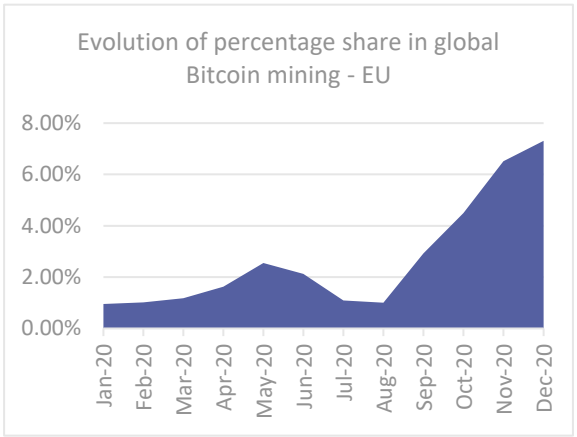


Figure 10: Evolution percentage share in global Bitcoin Mining (EU Vs rest of the world)

Monthly total hashrate for 2020

The hashrate for 2020 increased progressively, with January amounting to lowest hashrate and December the highest. With the exception of the last quarter of 2020, we can observe little mining activity but growing momentum in the EU.



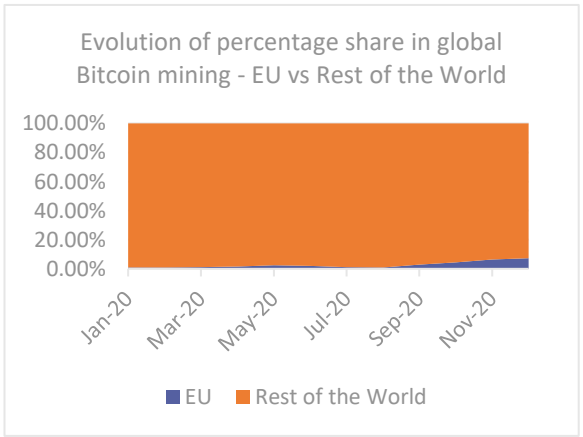


Figure 11: Total percentage per month of Bitcoin mining by hashrate for EU-member countries, 2020

Monthly total hashrate of 2021

The lowest hashrate in 2021, which was during March, is almost equal to the highest hashrate of 2020. July 2021 was the month with the highest hashrate in general. There are speculations that this increase can be possibly

attributed to China's ban on Bitcoin mining due to its energy intensity, which took place in May 2021 and forced many miners to migrate.

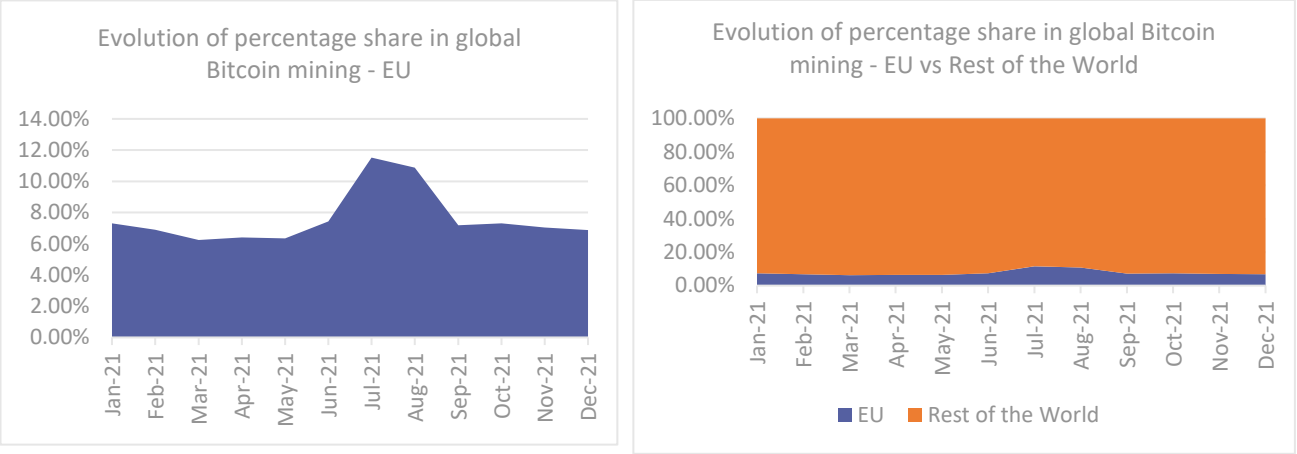


Figure 12: Total percentage per month of Bitcoin mining by hashrate for EU-member countries, 2021

Evolution of monthly hashrate between September 2019 and January 2022

The evolution of total hashrate is as follows:

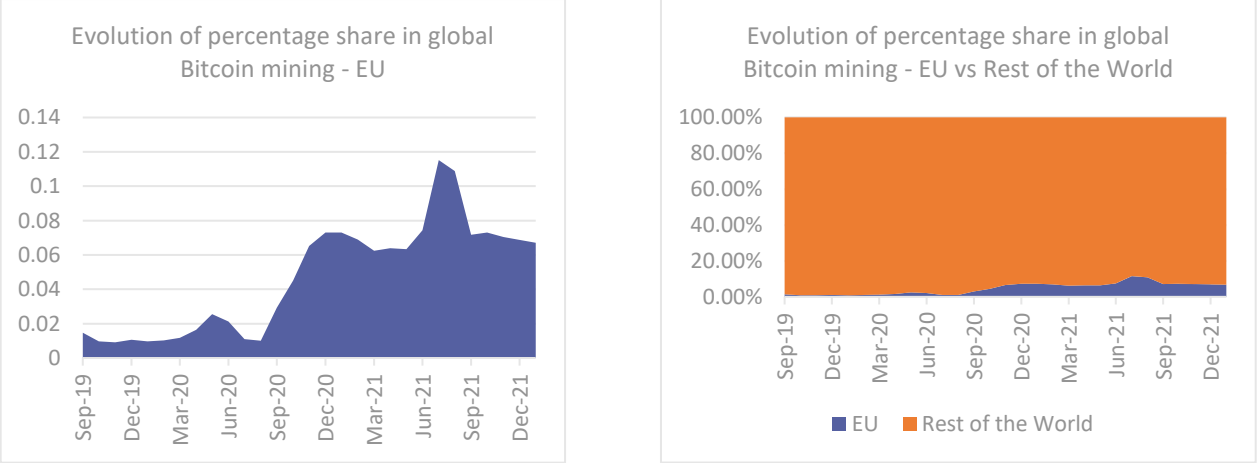


Figure 13: Evolution of percentage share in global Bitcoin mining in the EU and in the EU Vs the World, September 2019 – December 2021

Comparison of total EU Members' hashrate: 2020 Vs 2021

Overall, the hashrate in 2021 was almost 3 times higher compared to that of 2020. Some speculate that this increase resulted from the miners of China masking their IP addresses with the use of VPN through European countries or using proxy services, following the prohibition of mining. (source)

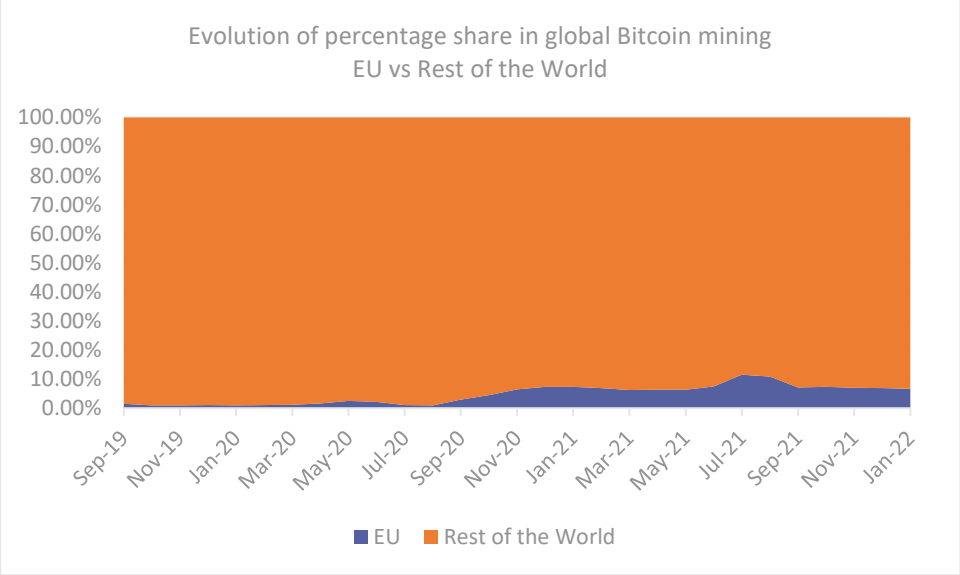


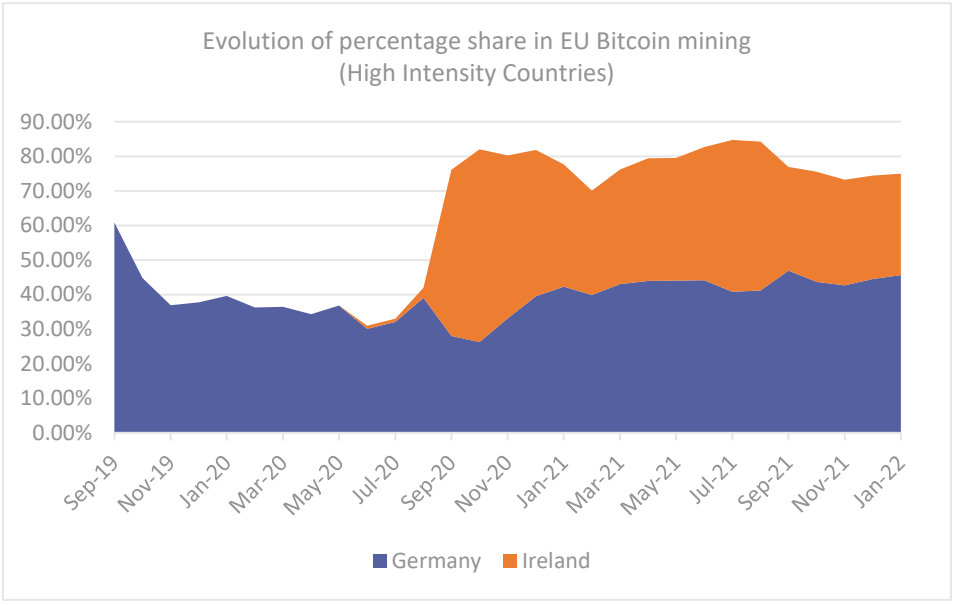
Figure 14: Comparison of the total percentage of Bitcoin mining by hashrate for EU Member states between 2020 and 2021

1.1.6 High-Intensity, Medium-Intensity, and Low-Intensity Mining Countries

High-intensity Bitcoin mining countries

In our analysis of hashrate share in the EU, we can observe a high-intensity group consisting of Germany and Ireland. As mentioned above, this can be at least partially attributed to foreign miners masking their IP location through VPNs and other tools.

Both Germany and Ireland had intensive mining activities in July 2021 and August 2021. For Germany, September 2021 was the month with the third-highest hashrate. However, in Ireland's case, September 2021 came with almost half the Bitcoin mining activity of August 2021. The month with the lowest hashrate for Germany was November 2019, while Ireland had several months with zero Bitcoin mining activity conducted. Additionally, it is worth mentioning that July 2021 coincides with the time that China banned Bitcoin mining (May 2021). Hence, it is speculated by many that this hyper-activity in Bitcoin mining in these countries is due to IP addresses redirected from China.



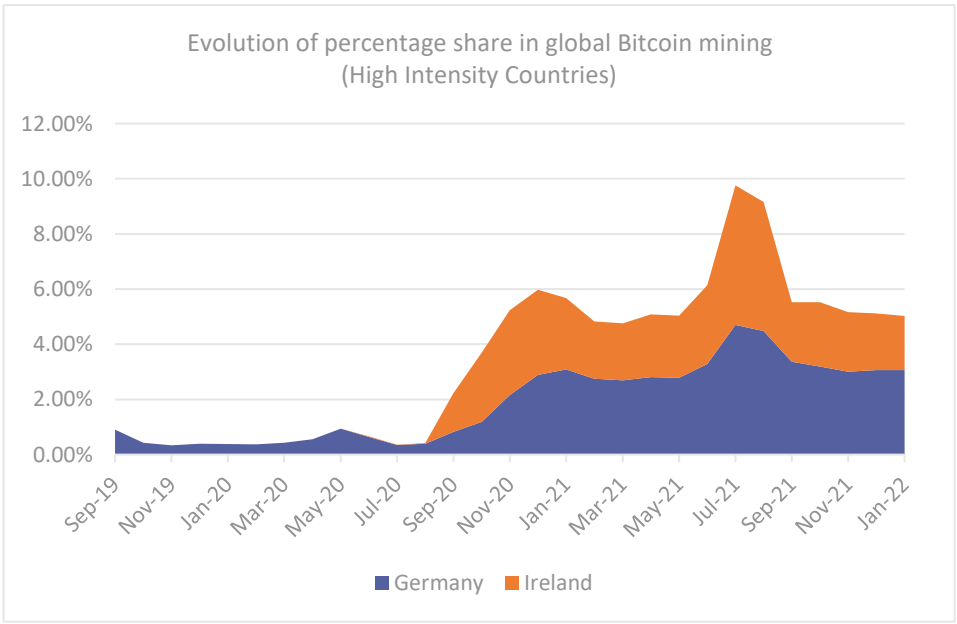
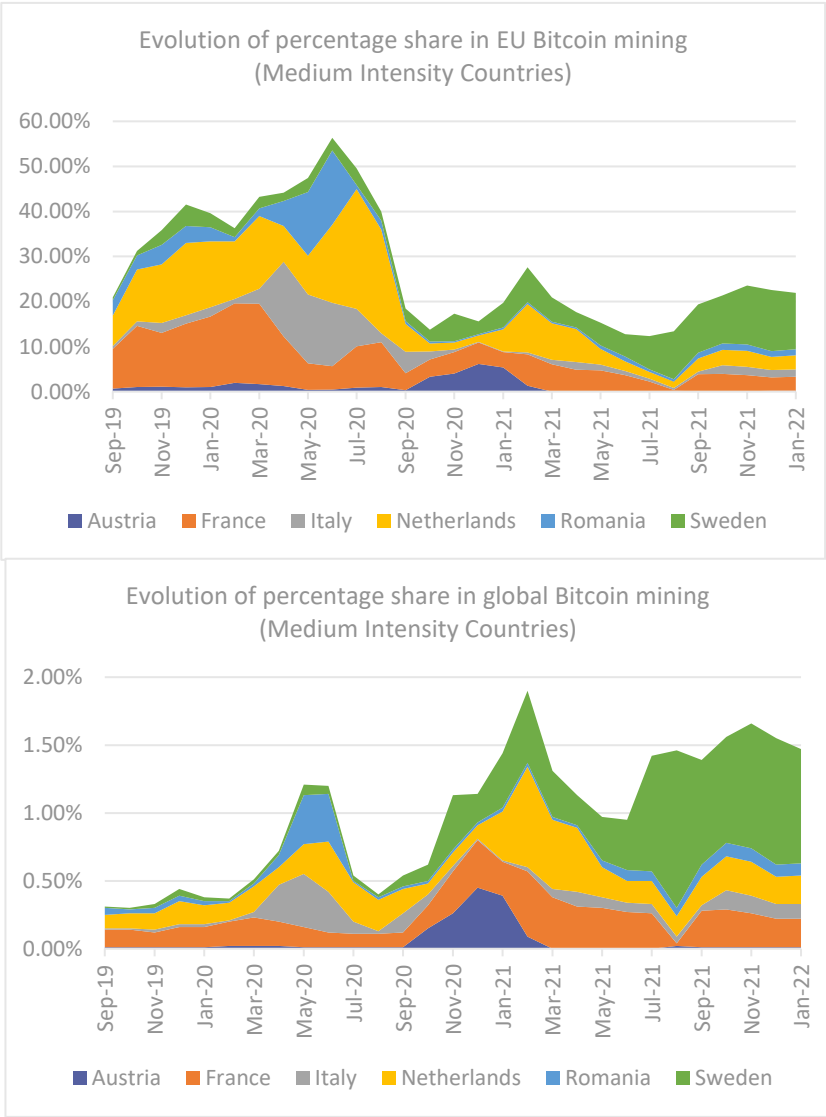


Figure 15: Hhigh-intensity Bitcoin mining countries throughout 2020 and 2021

Medium-intensity Bitcoin mining countries

The group of medium-intensity countries consists of Italy, France, the Netherlands, Finland, Romania, Sweden, and Austria. Undoubtedly, the most prominent of these countries is Sweden, which presented extreme highs and extreme lows, reaching its highest hashrate in August 2021. Both France and the Netherlands, although a bit 'late', reached their peak during February 2021. Italy, Romania, Finland, and Austria were the countries with the earliest Bitcoin mining activity, since the first three of them peaked in May 2020, and the rest of them in April 2020 and December 2020, respectively. Austria was the only country that recorded a hashrate as low as 0.00%, from March-July 2021, while the others kept their Bitcoin mining activity alive, even though to a very minor degree.

Figure 16: Medium-intensity Bitcoin mining countries throughout 2020 and 2021



Low-intensity Bitcoin mining countries

Spain leads the group of low-intensity countries. May 2020 and May 2021 were the months with the highest hashrate for this country. The period with the second highest hashrate for Spain (May 2021) coincided with the time China banned Bitcoin mining. Except for Finland and Spain, the rest of the countries had the lowest Bitcoin mining activity, at just 0.01%. March 2020 was also an important month for Finland and Greece as well.

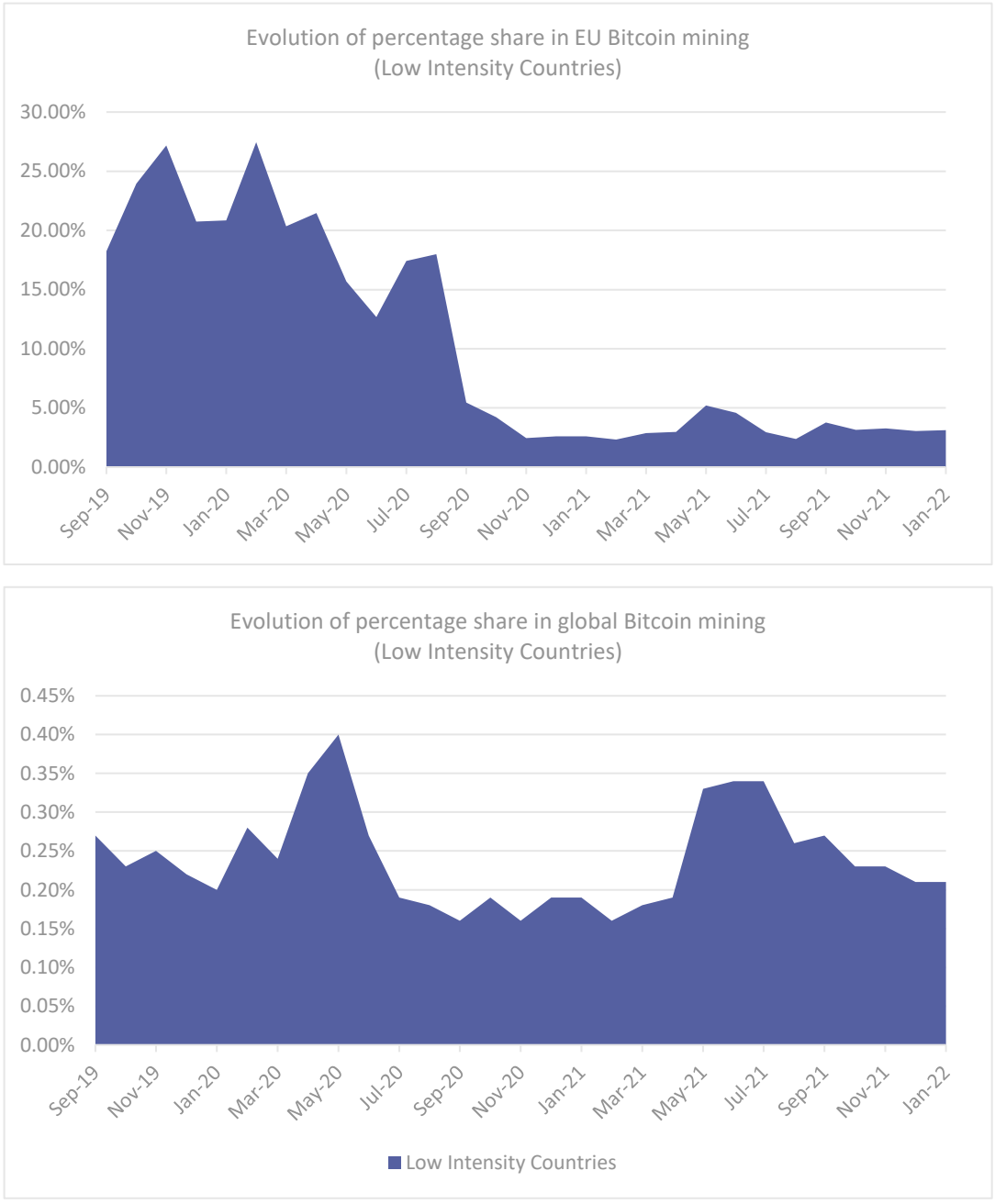


Figure 17: Low-intensity Bitcoin mining countries throughout 2020 and 2021

1.2 EU MEMBER STATES BITCOIN ENERGY CONSUMPTION ANALYSIS

In this section, we examine how much of the total energy consumption of each EU member state for 2020 and 2021 was due to Bitcoin mining. Examining the percentage of energy consumption dedicated to Bitcoin mining for each country, with data available from Data Commons, offers a better perspective on actual Bitcoin activity for each country. More specifically, we calculated the average growth rate for each year from 2009-2014 and used it to estimate the energy consumption of each EU member state for the years 2020 and 2021, before converting it to Terawatt hours. We then estimated the percentage of each country's electricity consumption dedicated to Bitcoin. In the analysis, we map the countries based on the above segmentation of high-intensity, medium intensity, and low-intensity countries.

We observe that, during 2020, Germany and Ireland's percentages of energy consumption dedicated to Bitcoin mining are relatively low. Then, in 2021, these percentages tripled, with 30% of Germany's and 35% of Ireland's energy being consumed by Bitcoin mining. However, there is little evidence of enough mining operations in either country to justify such big numbers. As we have noted before, this increase coincides with China's mining ban.

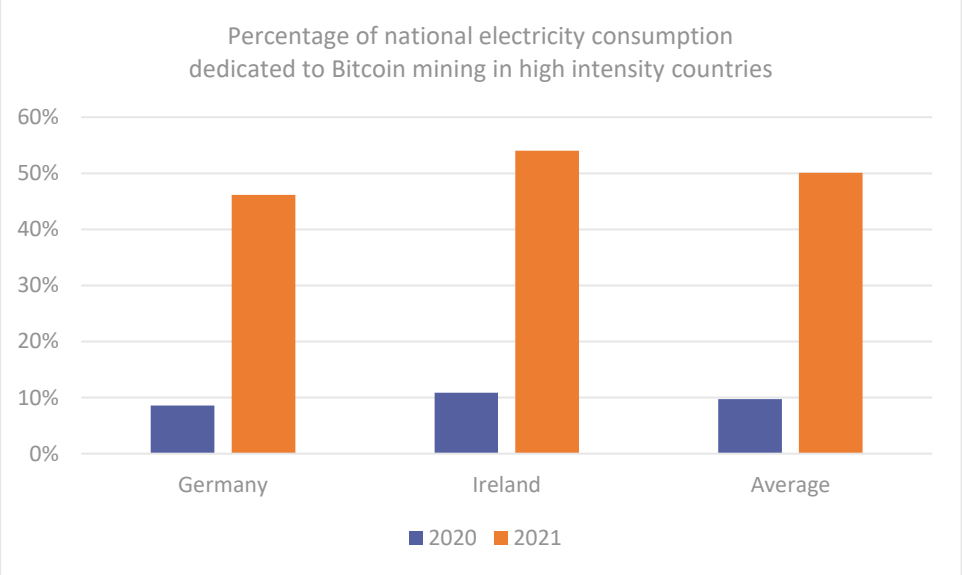


Figure 18: Percentage of High-Intensity Countries' Energy Consumption dedicated to Bitcoin mining for 2021 and 2021

In medium-intensity countries, Sweden's percentage of electricity consumption in 2021 was almost 7 times higher than that for 2020. On the contrary, Italy, Austria, and Romania had a higher percentage in 2020. We can also observe a number of low-intensity countries with extreme fluctuations (high highs low lows) in their Bitcoin mining activity. On the contrary, countries like Netherlands and France dedicated much more energy to Bitcoin mining in 2021 than in 2020.

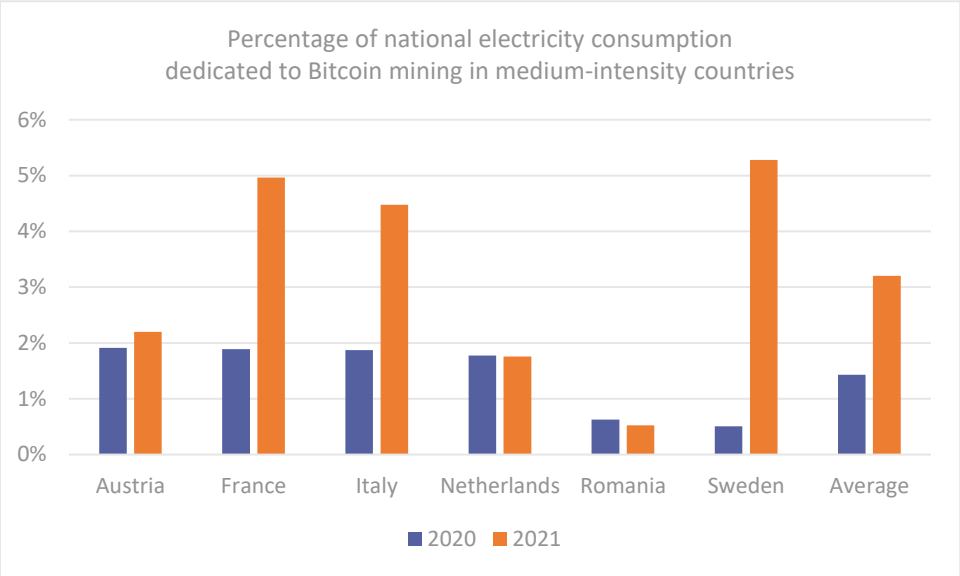


Figure 19: Percentage of medium-intensity countries' energy consumption dedicated to Bitcoin mining for 2021 and 2021

Finally, for the vast majority of low-intensity countries, the percentage of energy dedicated to Bitcoin mining is much higher in 2021 compared to 2020.

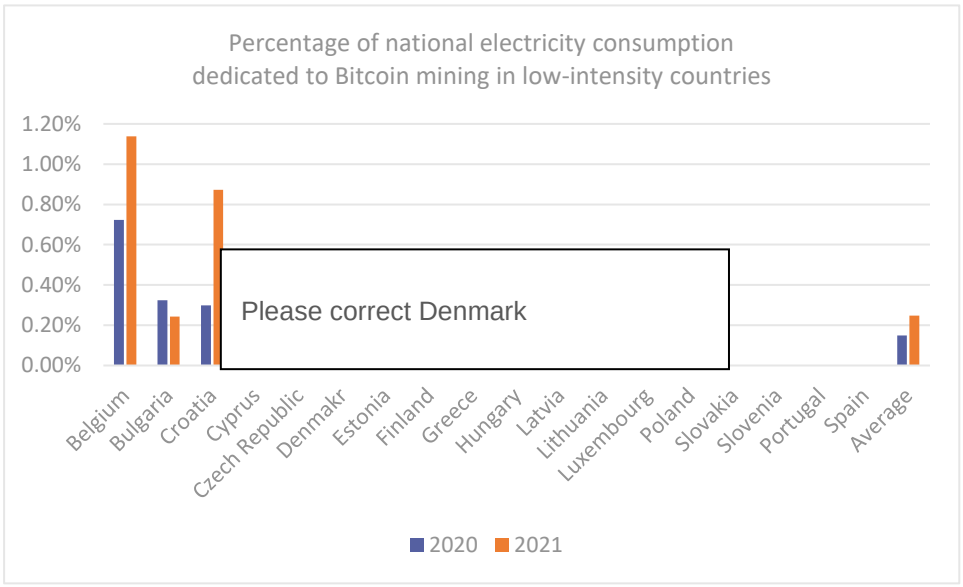


Figure 20: Percentage of low intensity countries' energy consumption dedicated to Bitcoin mining for 2021 and 2021

1.3 MAJOR MINING POOLS, OPERATORS, AND MINING FACILITIES

Mining started as a small-scale activity, where individuals using home computers were securing cryptocurrency networks and validating transactions. The increasing popularity of cryptocurrencies transformed mining activities into large-scale operations to benefit from and support the rise of crypto. The latter has created concerns regarding the power required to maintain operations in the context of a continuously growing mining industry, making the environmental cost of mining a key factor for those who look to source mining locations.

Additionally, the divergent national approaches to regulating and facilitating the adoption of cryptocurrencies and mining activities have a significant impact on the mining hubs, which seem to be in constant adaptation mode and in search of locations, preferably with cheap and renewable energy, confirming that the mining industry is location agnostic and moves to wherever the most affordable sustainable energy in vast quantities can be sourced.

With regard to the status of EU Member States in the mining industry, according to Bloomberg, in the European Union, Sweden has one of Europe's top three Bitcoin mining sectors, while Germany is active in mining, too. Furthermore, according to a Statista.com article on 'Countries that mine the most Bitcoin (BTC) 2019-2022':

> Due to the cryptocurrency's design focus on privacy, there is no indicator of how many new coins are created from which location – hence why the figures provided here look at PC processing power, and not Bitcoin themselves. There are figures for the current and maximum supply of Bitcoin, but these do not include the location where the currency was mined. The closest figure would be to look at the hashrate from so-called mining pools – places where miners can dig for Bitcoin – and how much they hashed in the last 24 hours.

There are several mining pool operators and mining facilities in EU Member States according to Sourceforge. Their market consists of miners, traders, and crypto users interested in using their idle computing power to mine cryptocurrency, or mining via a pool miner.

The list of EU mining pools on Sourceforge includes: CryptoLab Farm, Hiveon, 2Miners, Cruxpool, Zergpool, Prohashing, Cudo, Kryptex, unMineable, Mining-Dutch, MinerGate, CoinFly, BSOD Pool, CoinMinerz.com, P2Pool, BTC.com, CKPool.

However, we should note that mining pools differ substantially from mining facilities (although there is some overlap in some cases). Mining facilities can engage in proprietary or agent mining. In the first and most popular case, they use their own resources to generate PoW and benefit from the rewards of validating transactions. In the latter, they sell 'mining as a service' to customers in exchange for a fee. On the contrary, mining pools operate by bringing miners together to work on the same PoW. This means that they are not directly responsible for any energy consumption. As a result, the location of a mining pool operator does not provide any information on where the mining takes place, since pools can (and do) contain miners from all over the world.