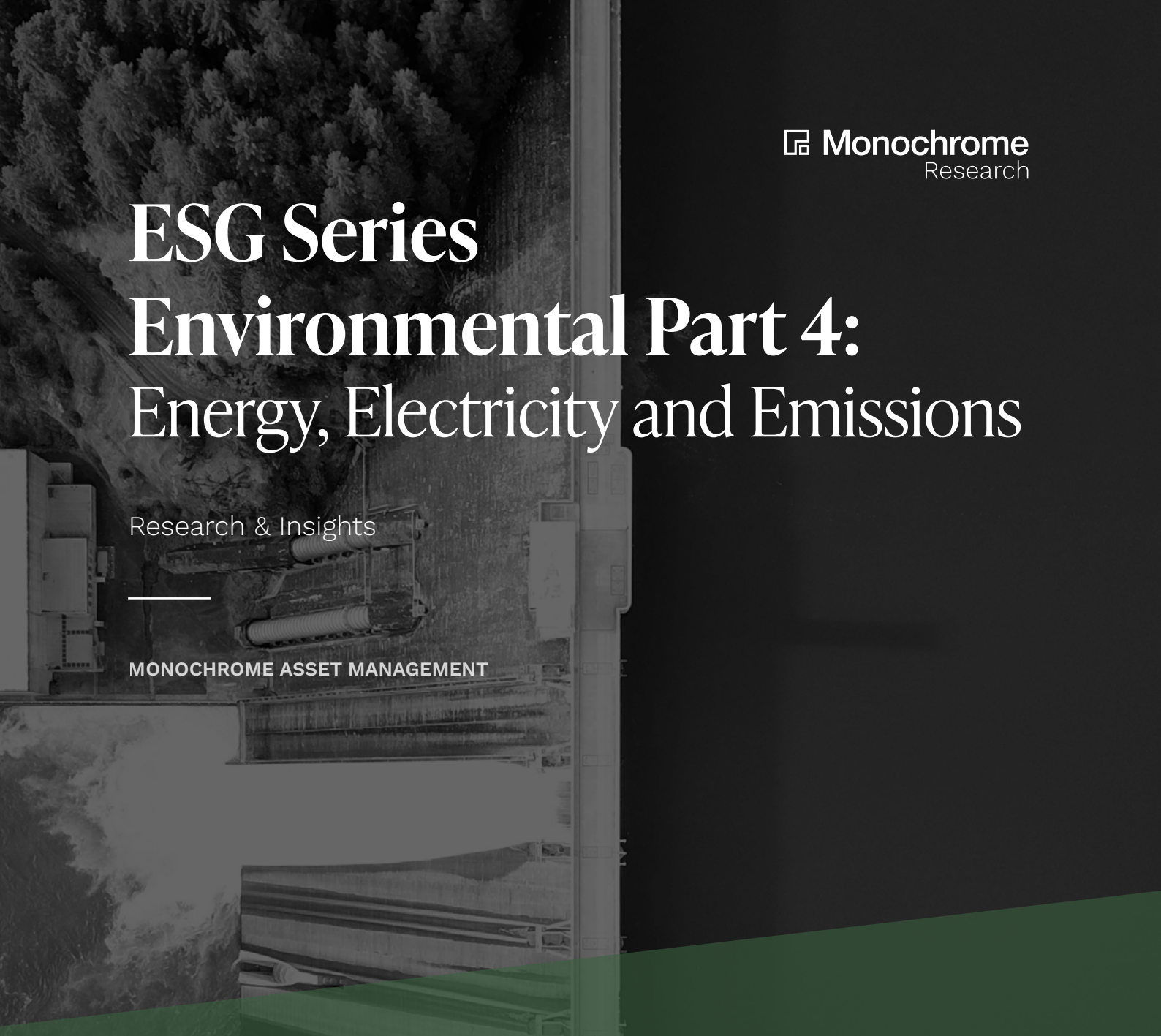

Monochrome Research

ESG Series Environmental Part 4: Energy, Electricity and Emissions

Research & Insights

MONOCHROME ASSET MANAGEMENT

Learning Outcomes

In this piece, we will discuss the relationship between energy, electricity and emissions, and why the distinction is necessary to make. We will show Bitcoin's current electricity mix, and what that means in regards to energy use and emissions in a global context. The key topics of this piece include:

- World energy, electricity and emissions statistics, and how Bitcoin compares
- The differences between energy, electricity and emissions
- Different electricity generation methods and their emissions
- Bitcoin's electricity mix pre-and-post China ban
- The difference between greenhouse gas and carbon dioxide emissions
- "Carbon Offsetting" with Bitcoin Mining

Introduction

As was highlighted in the introduction to this series, all electrical energy starts its life as "primary energy", i.e., a ray of sunlight, gust of wind, drop of oil, or lump of coal. Depending on the particular fuel source and generation method, greenhouse gas emissions (GHGs) such as carbon dioxide or methane, are released into the atmosphere as a byproduct. **The amount of GHGs** (measured in grams of Carbon-Dioxide Equivalents (g CO2eq)) **emitted per kilowatt-hour (kWh) of electricity generated is known as carbon intensity (CO2eq/kWh)**. The International Panel on Climate Change (IPCC)[1] has collected data on carbon intensity to demonstrate the difference between technologies, as is shown in Figure 1 below.

Of relevance to note in the Table is the 50th-%ile scores for all technologies, where there is a clear difference between green technologies and fossil fuels. Of interest to note is that best-in-class Carbon Capture & Storage (CCS) fossil fuel plants are comparable to worst-in-class solar Photovoltaic (PV). This is the level of carbon intensity variation found in generation methods around the world.

Table A.II.4 | Aggregated results of literature review of LCAs of GHG emissions from electricity generation technologies as displayed in Figure 9.8 (g CO_2eq/kWh).

Values	Bio-power	Solar		Geothermal Energy	Hydropower	Ocean Energy	Wind Energy	Nuclear Energy	Natural Gas	Oil	Coal
		PV	CSP								
Minimum	-633	5	7	6	0	2	2	1	290	510	675
25th percentile	360	29	14	20	3	6	8	8	422	722	877
50th percentile	18	46	22	45	4	8	12	16	469	840	1001
75th percentile	37	80	32	57	7	9	20	45	548	907	1130
Maximum	75	217	89	79	43	23	81	220	930	1170	1689
CCS min	-1368								65		98
CCS max	-594								245		396

Note: CCS = Carbon capture and storage, PV = Photovoltaic, CSP = Concentrating solar power.

Figure 1 - IPCC Data on Carbon Intensity of Various Generation Types

Bitcoin's Electricity Mix & Use

On energy mix, we look to Cambridge University's data which provides robust Pre-China information.[2] In the turmoil of the Chinese Ban, The Bitcoin Mining Council, which currently represents almost 50% of the network hash rate,[3] presented as a robust secondary source to fill data gaps post-migration.[4] Data on world energy and grids is obtained from Oxford University's Our World in Data.[5,6]

[1] International Panel on Climate Change, 'Special Report of the Intergovernmental Panel on Climate Change (ipcc.ch)', Cambridge University Press, 1 January 2012, accessed 7 January 2022.

[2] Cambridge Centre for Alternative Finance, '3rd Global Cryptoasset Benchmarking Study (jbs.cam.ac.uk)', University of Cambridge Judge Business School, September 2020, accessed 13 January 2022.

[3] Bitcoin Mining Council, 'Q2 Bitcoin Mining Council Survey Confirms Year on Year Improvements in Sustainable Power Mix and Technological Efficiency (mnchr.me/3aZliwk), Bitcoin Mining Council, 19 July 2022, accessed 20 July 2022.

[4] Bitcoin Mining Council, 'Q4 Bitcoin Mining Council Survey Confirms Improvements in Sustainable Power Mix and Technological Efficiency (mnchr.me/3ImE9fs), Bitcoin Mining Council, 18 January 2022, accessed 18 March 2022.

[5,6] H Ritchie & M Roser, 'Electricity mix (mnchr.me/3KZus8x)', Our World in Data, n.d., accessed 22 February 2022.

The figure below aggregates data from the two aforementioned sources, and presents them in a table. There you will see the world average primary energy and grid mixes by generation technology, as well as Bitcoin's energy mix pre-and-post China Migration. Data on the "% sustainable technologies" as well as carbon intensity are shown at the bottom. It is clear that Bitcoin outperforms the world average figures.

Electricity Generation Method	World Primary Energy Mix (2020)	World Grid Mix (2020)	Bitcoin Mix (Pre-China Ban)	Bitcoin Mix (Post-China Ban)
Coal	25.3%	33.8%	30.0%	10.0%
Oil	30.9%	4.4%	4.0%	3.0%
Gas	22.7%	22.8%	17.0%	29.3%
Nuclear	4%	10.1%	10.0%	15.0%
Hydroelectric	6%	16.8%	28.0%	30.0%
Solar	2%	3.3%	3.0%	3.0%
Wind	2%	6.1%	8.0%	9.7%
Other Renewables	7.1%	2.7%	0.0%	0.0%
Total % Sustainable**	21.1%	39.1%	49.0%	57.0%

Figure 2 - Bitcoin's Energy Mix Compared to the rest of The World.
** Sustainable includes all renewables + hydroelectric + nuclear

Bitcoin's Energy Use

Earlier in this series, we calculated how much electricity Bitcoin uses by multiplying the average miner efficiency with the network hashrate, resulting in **15.3GW of power draw**, the equivalent of **133.8 TWh per year** (about **0.5%** of the 26,290TWh of electricity produced by the world annually).[7] Now that we understand Bitcoin's electricity use and generation mix, we can calculate **total energy use.**

Every time primary energy is converted into electrical energy, some energy goes to waste. Using well established **conversion factors**, we can work backwards and calculate the primary energy required to produce electricity.[8,9] Conversion factors (CF) are defined as the proportions of primary energy that are converted to electrical energy.[10] Hydroelectricity is highly efficient and converts 90% of energy at the turbines into electricity at the wire. Coal and oil are less efficient at a 32% conversion factor. Conversion factors of other generation methods, as well as Bitcoin's overall conversion factor, are presented in Figure 3 below.

[7] H Ritchie & M Roser, 'Electricity mix (mnchr.me/3KZus8x)', Our World in Data, n.d., accessed 22 February 2022.

[8] U.S. Energy Information Administration, 'Table A6 Approximate Heat Rates for Electricity, and Heat Content of Electricity (eia.gov)', U.S. Energy Information Administration, 2021, accessed 27 January 2022.

[9] G Zeiss, 'Energy Efficiency of Fossil Fuel Power (geospatial.blogs.com)', Geospatial Blogs, 31 January 2010, accessed 27 January 2022.

[10] U.S. Energy Information Administration, 'Table A6 Approximate Heat Rates for Electricity, and Heat Content of Electricity (eia.gov)', loc. cit.

Energy Source	Bitcoin's Energy Mix Proportion	Conversion Factor	Energy Mix Proportion x Conversion Factor
Coal	10%	32%	3.2%
Oil	4%	32%	1.3%
Gas	30%	44%	13.2%
Nuclear	15%	33%	5.0%
Hydroelectric	30%	90%	27.0%
Solar	3%	39%	1.2%
Wind	8%	39%	3.1%
		Bitcoin's Conversion Factor	**53.9%**

Figure 3: Bitcoin's sustainable energy mix and corresponding energy to electricity conversion ratios

Bitcoin's energy mix implies an overall energy to electricity conversion ratio of approximately 53.9%. This means that the **133.8 TWh of electrical energy used by Bitcoin, divided by 53.9%, results in 252.5 TWh of primary energy**. This is equivalent to 0.15% of the world's primary energy supply of 173,430 TWh.[11]

Bitcoin's Emissions

Using the 50th-percentile figures shown in Figure 1 above, and Bitcoin's Energy mix from Figure 2, we can quickly find **Bitcoin's carbon intensity to be 269 grams of CO2e/kWh**.

Energy Source	Bitcoin's Energy Mix Proportion	Carbon Intensity (g CO2e/kWh)[12]
Coal	10%	1001
Oil	4%	840
Gas	30%	469
Nuclear	15%	16
Hydroelectric	30%	4
Solar	3%	40
Wind	8%	12
	Bitcoin's Carbon Intensity (g CO2e/kWh)	**269**

Figure 4: Bitcoin's sustainable energy mix and corresponding carbon intensity

[11] H Ritchie & M Roser, 'Energy mix (mnchr.me/3qhUSud)', Our World in Data, n.d., accessed 20 December 2021.
[12] International Panel on Climate Change, 'Special Report of the Intergovernmental Panel on Climate Change (ipcc.ch)', loc. cit.

From here, simply multiply Bitcoin's Carbon Intensity of 269g CO2e/kWh by Bitcoin's yearly electricity use (133.8 TWh) to get to an emissions figure of **36 megatons (MT) of Greenhouse Gases per year, or 0.07% of the world's 49,360 MT of GHG emissions.[13]**

In the next section of this piece, we will dig into what emissions are, the difference between them and the need to account for all of them, not just carbon dioxide.

Emissions - Greenhouse Gases vs Carbon Dioxide

By definition, greenhouse gases (GHGs) capture and reflect heat back to the Earth.[14] There are four categories of GHG, these being carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), and fluorinated gases.[15] Therefore, similar to how electricity is a subset of energy, carbon dioxide is a subset of greenhouse gases, as shown in the figure below.

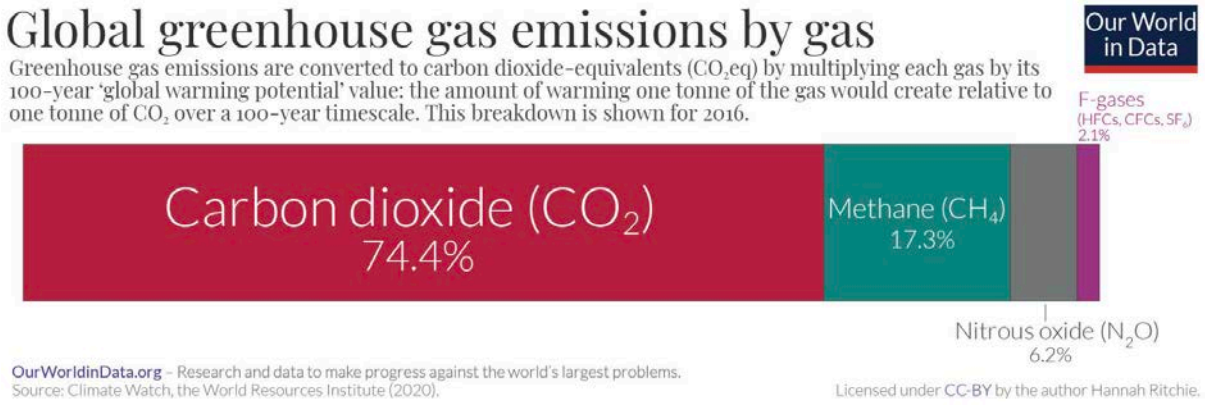

Figure 5 - GHG emissions by type[16]

An Introduction to Methane, and its Negative Environmental Impacts

Methane is most prevalently emitted into the atmosphere through the production, processing and storage of natural gas and petroleum, which comprises 30% of total methane emissions.[17] Methane is also emitted through landfill and coal mining, which comprise about 17% and 7% of methane emissions, respectively.[18] Methane is the second-most prevalent GHG in the world after CO2, but has 56-times more warming potential.[19,20] As such, methane emissions are an environmental issue that must be addressed.

[13] Bitcoin Mining Council, 'Q4 Bitcoin Mining Council Survey Confirms Improvements in Sustainable Power Mix and Technological Efficiency (mnchr.me/3ImE9fs), Bitcoin Mining Council, accessed 18 March 2022.

[14] Department of Environment and Science, 'Greenhouse gas (environment.des.qld.gov.au)', Queensland Government, n.d., accessed 13 January 2022.

[15] United States Environmental Protection Agency (EPA), 'Overview of Greenhouse Gases (epa.gov)', United States Government, n.d., accessed 13 January 2022.

[16] H Ritchie & M Roser, 'Greenhouse Gas Emissions (mnchr.me/3cBkzSx)', Our World in Data, n.d., accessed 20 July 2022.

[17] ibid.

[18] ibid.

[19] United States Environmental Protection Agency (EPA), 'Importance of Methane (epa.gov)', loc. cit.

[20] United Nations Framework Convention on Climate Change, 'Global Warming Potentials (IPCC Second Assessment Report (unfccc.int)', United Nations Framework Convention on Climate Change, n.d., accessed 10 January 2022.

In the oil and gas fields, methane is emitted into the environment through 2 methods; venting and flaring. Vented methane is methane immediately released straight into the atmosphere, which is suboptimal environmentally.[21] With flaring, this vented methane is combusted and converted into water vapour, heat, and the relatively more favourable carbon-dioxide.[22] Whilst flaring reduces environmental impact substantially, the practice is still susceptible to heavy winds leading to incomplete combustion of the methane, resulting in some methane still being released into the environment.

Thus, reducing the amount of vented and flared methane would be instrumental in helping reduce the impacts of climate change.[23]

How Bitcoin Currently Offsets Flared Methane

Bitcoin does not need an electric grid per se - only an energy source. Bitcoin can contribute to reducing the impacts of climate change as it can use flared methane, or any waste energy for that matter, to power the network. The most notable oil and gas corporations engaging in this scheme are ExxonMobil and ConocoPhillips, which have partnered with flared methane bitcoin mining specialist Crusoe Engineering to redirect their excess gas from being flared to being used to power bitcoin miners.[24]

[21] Earthworks, 'Flaring and Venting (earthworks.org)', Earthworks, n.d., accessed 13 January 2022.

[22] ibid.

[23] United States Environmental Protection Agency (EPA), 'Importance of Methane (epa.gov)', loc. cit.

[24] M Sigalos, 'Exxon is mining bitcoin in North Dakota as part of its plan to slash emissions (mnchr.me/3MJjlld)' , CNBC, 26 March 2022, accessed 15 May 2022.

Instead of flaring the gas, or worse, venting it, Bitcoin miners transport their equipment to an oil field with active flares, then divert the natural gas to generators that generate electricity to power the Bitcoin mining rigs.[25] This solution mitigates the negative environmental effects from just flaring gas by up to 63%,[26] and has significant environmental and economic benefits to oil and gas companies who can now both clean and monetize their waste through partnerships with Bitcoin miners.

Since Bitcoin can be powered by stranded energy sources across the globe, Bitcoin miners will modify their mining operations to take advantage of cheap energy of any kind or in any location given that the incentive exists.

Conclusion

Bitcoin has gradually shifted towards cleaner and more sustainable energy sources over time, and most importantly, shifted away from one of the dirtiest, least transparent power grids in the world in China, which has resulted in a dramatic improvement in carbon emissions. Bitcoin can continue to have a positive impact on the environment by feeding on lethal waste greenhouse gases, particularly flared methane, to reduce the amount of dangerous GHGs emitted into the atmosphere. Finally, we saw that **Bitcoin uses only 0.15% of The World's Primary Energy, 0.5% of its electricity, and contributes 0.07% of The World's GHG emissions.**

Ultimately however, the energy mix of international grids is what drives Bitcoin's emissions, and indeed, global industry and commerce's emissions. Therefore, the responsibility falls on world governments to take action through proper incentives and regulations so that global emissions targets are met. In the meantime, Bitcoin miners will remain on the lookout for the cheapest form of energy available to them, which is increasingly becoming green.

[25] ibid.

[26] Crusoe Energy, 'Understanding the Problem Crusoe Solves (crusoeenergy.com)', Crusoe Energy, 23 September 2021, accessed 6 June 2022.

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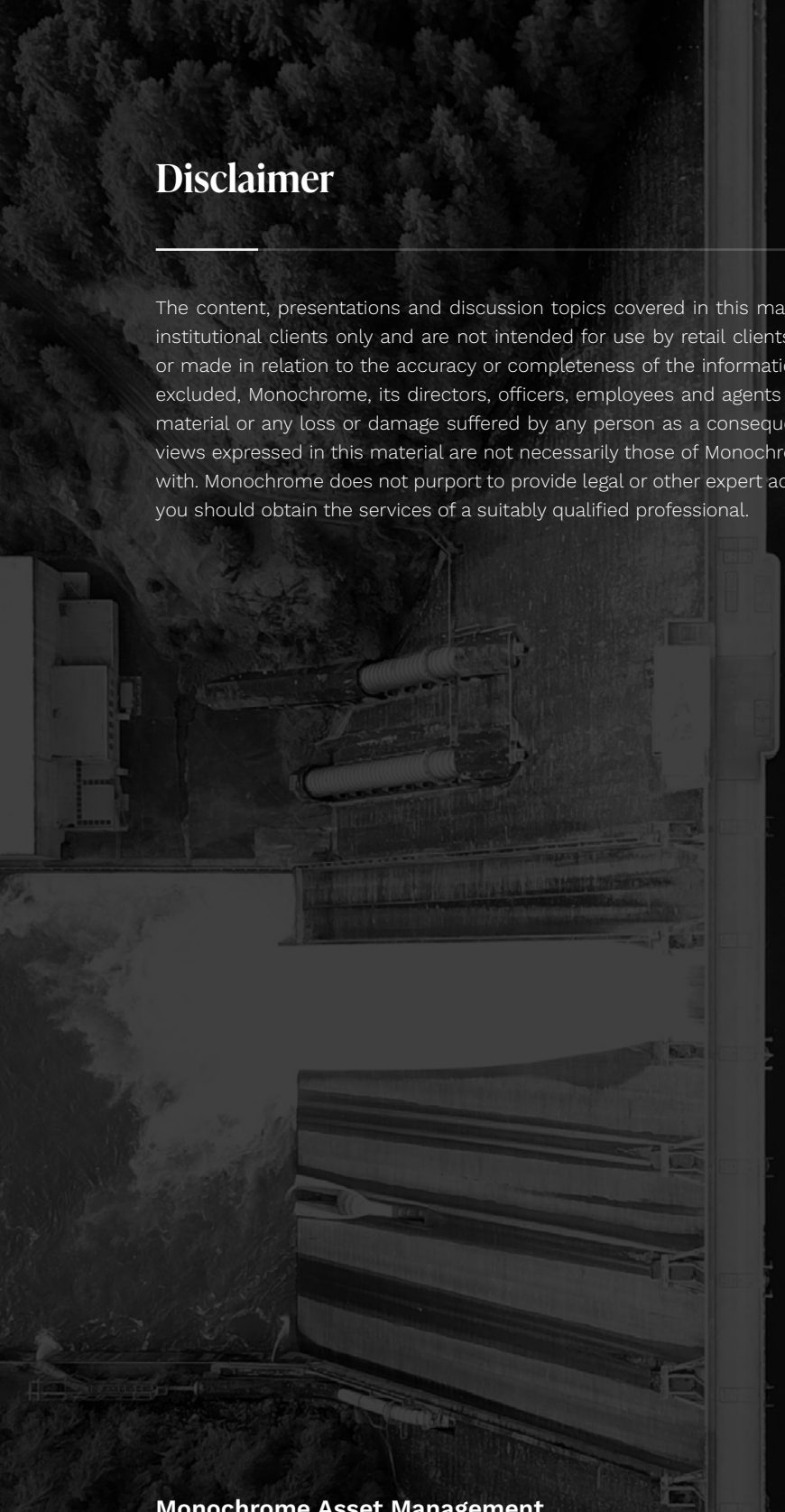

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Monochrome Asset Management offers investors regulated access to bitcoin via traditional investment vehicles without the administrative burden.

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